THE ART OF MARIMBA ARTICULATION: A GUIDE FOR COMPOSERS, CONDUCTORS, AND PERFORMERS ON THE EXPRESSIVE CAPABILITIES OF THE MARIMBA

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Articulation is an element of musical performance that affects the attack, sustain, and the decay of each sound. Musical articulation facilitates the degree of clarity between successive notes and it is one of the most important elements of musical expression. Many believe that the expressive capabilities of percussion instruments, when it comes to musical articulation, are limited. Because the characteristic attack for most percussion instruments is sharp and clear, followed by a quick decay, the common misconception is that percussionists have little or no control over articulation. While the ability of percussionists to affect the sustain and decay of a sound is by all accounts limited, the ability of percussionists to change the attack of a sound with different implements is virtually limitless. In addition, where percussion articulation is limited, there are many techniques that allow performers to match articulation with other instruments. Still, percussion articulation is often a topic of little concern to many musicians.

The problem is not that this issue has been completely ignored, but rather that a vast number of contradictory and conflicting viewpoints still permeate pedagogical methods and literature. This is most certainly the case with the marimba, where a review of method books reveals a multitude of confusing statements about marimba articulation. It is clear that there is still widespread confusion about marimba articulation from composers, conductors, and most importantly percussionists themselves. This study attempts to advance percussion pedagogy in this area through a better understanding of the terminology of musical articulation, the acoustical principles of the marimba, and the techniques that affect sound production on this instrument. After a review of these three areas, this study examines 166 recordings, which look at the actual effect of specific techniques carried out on the marimba. Finally, the project offers a set of recommendations for composers, conductors, and percussionists on all aspects of marimba articulation, in the goal of increasing marimbists' potential for greater musical expression.

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CHAPTER 1

INTRODUCTION AND OVERVIEW

The percussion family contains some of the oldest instruments in the world, yet their serious study and acceptance into a classical music tradition has only occurred over the previous two centuries. Compared to members of the wind and string families, percussionists have a relatively short pedagogical history. A strong tradition of performance practice and pedagogy on many of these instruments is still evolving. While many areas of the percussion family deserve further study, perhaps the most misunderstood element of percussion performance is articulation.

Articulation is one of the most important elements of musical style, and musicians that have good control over the articulation of their instrument are able to express a wide variety of musical situations and contexts. For many teachers and performers, percussion articulation may be an afterthought, but others argue that "musical considerations such as articulation and dynamics are just as important for percussion as they are for wind and strings."[1] Articulation on percussion instruments is influenced by many factors outside of a performer's control, including the temperature, humidity, and acoustics of the performance space. However, there are many other factors that are more directly under a player's control. Percussionists that give little consideration to these issues are at a major disadvantage, especially when performing with other instrumentalists. In order to interact with other musicians in any meaningful way, percussionists must have a concept of articulation beyond just striking their instrument.

[1] Kevin Mixon, "Helping Percussionists Play Musically," *Music Educators Journal* 88, no. 4 (January, 2002): 55.

Many believe that the expressive capabilities of percussion instruments, when it comes to articulation, are limited.[2] Because the characteristic attack for most percussion instruments is sharp and clear, followed by a quick decay, the common misconception is that percussionists have little or no control over articulation. While the ability of percussionists to affect the sustain and decay of a sound is in many instances limited, the ability of percussionists to change the attack of a sound with different implements is virtually limitless! In addition, where percussion articulation seems limited, there are many techniques that allow performers to match articulation with other instruments. Still, percussion articulation is often a topic of little concern to many musicians.

The problem is not that this issue has been completely ignored, but rather that a vast number of contradictory and conflicting viewpoints still permeate pedagogical methods and literature. This is most certainly the case with the marimba, where a review of method books reveals a multitude of confusing statements about marimba articulation. According to one educator, leaving the mallet down after contact with a marimba bar traps the sound waves. This marimbist believes that, "The trapped sound waves are causing the note to sound fuller because they are bouncing between the end of the resonator column and the mallet head."[3] Other educators believe that the sound must be drawn out of the marimba, stating, "as soon as the note is struck the mallet must be lifted quickly to achieve clear articulation… this type of stroke allows the maximum amount of tone to be drawn out

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[2] Mary C. Broughton and Catherine J. Stevens, "Music, Movement and Marimba: an Investigation of the Role of Movement and Gesture in Communicating Musical Expression to an Audience," *Psychology of Music* 37, no. 2 (2009): 137-138.

[3] Nancy Zeltsman, *Four-Mallet Marimba Playing: A Musical Approach for All Levels*, (Milwaukee, WI: Hal Leonard, 2003), 10.

of the instrument."[4] Another prominent educator believes that the duration of a note is determined only by how much energy is applied to it.[5] In contrast to the opinions mentioned above, this educator believes the issues of grip tension and stroke direction after contact have nothing to do with the sound of the marimba.

The problem of marimba articulation is compounded by the use of misleading terminology. Thomas McMillan and Buster Bailey were among the first educators to use the terms staccato stroke and legato stroke in reference to the marimba.[6] These terms are still in wide use by many percussionists, without much consideration towards their meaning. The techniques implied by these terms often produce sounds that are incompatible with other instrumentalists' interpretation of legato and staccato. Some accept the notion that staccato and legato have different meanings for percussionists and marimbists, however, this leads to a great deal of confusion. Composers who write for percussion may or may not know how articulation marks will be interpreted by a performer. When notating a staccato dot for the marimba, should composers expect a short, damped sound or a sharp pointed attack? Conductors, in an effort to create a unified concept for their entire ensemble, must also know more about how marimba articulation is interpreted. When asking a performer to dry up the sound, is the traditional "staccato stroke" the best answer? It is clear that there is still widespread confusion about marimba articulation from composers, conductors, and most importantly percussionists themselves.

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[4] Thomas McMillan, *Percussion Keyboard Technique* (Miami, FL: Pro Art Publications, 1962) 4.

[5] Leigh Howard Stevens, *Method of Movement for Marimba* (Asbury Park, NJ: Keyboard Percussion Publications, 1979), 22.

[6] McMillan, *Percussion Keyboard Technique.* Elden Bailey, *Mental and Manual Calisthenics for the Modern Mallet Player*, (New York: Warner Bros, 1963).

In order to further advance percussion pedagogy in this area, composers, conductors, and performers need a better understanding of the terminology of musical articulation, the acoustical principles of the marimba, and the techniques that affect sound production and articulation on this instrument. This study will be the first step in increasing this understanding, although more work will need to be done. The following chapters will discuss terminology, acoustics, and technique. Several experiments carried out during the course of this project will also show the effect of different techniques on the articulation of the marimba. Although many of the conclusions made by this current study can be applied to the rest of the percussion family, further research will be needed to explore other instruments. It is my hope that this project will serve as a starting point for others wishing to research articulation beyond the marimba.

Chapter 2 examines the terminology of musical articulation. Before percussionists can learn the techniques of marimba articulation, they must understand what articulation is and what the various articulation markings specify. This chapter also discusses how other instrumentalists interpret various markings concerning articulation. As is seen in this chapter, the standardization of many of these terms is not possible. While notation of pitch and rhythm is objective and precise, the notation of articulation is always based on musical context. Understanding the subjectivity of articulation marks is an important part of their interpretation.

Chapter 3 gives a brief introduction to the history of the marimba and discuss important acoustical properties of the instrument. The vibrations produced by a marimba bar are more complex than those of a tensioned string. These vibrations must be tuned to a synthetic harmonic series and amplified by a resonator. This chapter also discusses the variables and techniques that affect sound production on the marimba. While the marimba is still evolving, the principles behind its sound are based on acoustics and physics. Percussionists will be more successful in creating articulation if they understand how their instrument functions.

Chapter 4 surveys some of the leading pedagogical methods on marimba articulation. Various method books and articles offer a multitude of different opinions on this topic, though many of these opinions would seem to be in direct contradiction to one another. This chapter addresses the misconceptions and misleading terminology surrounding these methods and discuss how each technique can actually affect marimba articulation.

Chapter 5 presents the findings of several important scientific studies on marimba articulation as well as the results from 166 recordings carried out during the course of this study. These recordings examine the effects of stroke velocity, stroke direction, playing area, and multiple aspects of mallet choice. The data from these recordings is shown through 3D spectrogram images in order to visualize the volume, duration and frequency components of each technique. By analyzing this data, conclusions can be made about the effectiveness of various techniques on the articulation of the marimba.

Chapter 6 is the culmination of the study. It presents the findings of the project in full and present ideas for future research. This final chapter gives recommendations for composers, conductors, and percussionists on how to better deal with the issue of marimba articulation.

CHAPTER 2

ARTICULATION TERMINOLOGY AND INTERPRETATION

The advent of standard musical notation has helped to preserve the work of countless musicians. As it evolved, notation became more precise, giving musicians a way to recreate works as they were originally conceived. In 1965, Hermann Keller referred to articulation as the stepchild of musical notation.[7] His work, *Phrasing and Articulation: A Contribution to a Rhetoric of Music*, is considered one of the leading sources on the history and practice of articulation. His attempt, along with other scholars, to clarify the subject of musical articulation and expression has proved to be a difficult task. To this day, articulation is still one of the least standardized elements of musical performance.

One of the reasons musical articulation seems to be so hard to standardize is because its application depends a great deal on its musical context. Notation of pitch and rhythm is exact and objective, however, the notation of articulation is subjective. Because performers have longer durations to consider, staccato articulation in a piece marked Adagio can have a totally different meaning than staccato in a piece marked Presto. In addition instrumentation, period of composition, tessitura, and performance space can all determine how articulation marks are interpreted. Differences in the contextual application of musical articulation lead to different opinions on the definitions of even the most common articulation markings. Various musicians have defined the staccato marking to mean detached, short, half the value of the note, quarter of the value of the note, or accented. Take into account less common types of articulation like portato, and the

[7] Hermann Keller, *Phrasing and Articulation: A Contribution to a Rhetoric of Music*, Translated by Leigh Gerdine (New York, NY: W.W. Norton and Company Inc., 1965), 4.

problem of a standard definition becomes even greater. Donald Martino comically explains this problem using the example of a dash or tenuto marking:

> The dash, to performer one (a string player) is a bowing indication whose attack characteristics might range from relatively incisive to barely audible; to performer two (a wind player) it means a soft attack. Performer three reads this sign as tenuto: a term which is variously interpreted as "hold the note its full value" or "hold the note a bit longer than its full value." Attack for this player has never been of great concern. To performer four, a dash means that the note is somehow invested with great expressive significance and, therefore, he is free to play in whatever manner seems most appropriate. And to performers five through infinity it means things the aural results of which are too horrible to contemplate.[8]

Another factor that makes articulation hard to discuss is the fact that each instrumental family has unique technical concerns when producing various articulations. The principles of musical articulation are derived from nuances of spoken language.[9] Due to this fact, articulation in vocal music is executed in much the same way as speech, however, for instrumental music the task is not so easy. Each instrumental family has unique properties of attack and decay, a characteristic articulation that is produced by default. In order to alter their sound beyond this characteristic articulation, performers have to use a variety of techniques. Many of these techniques were developed out of the need to alter an instrument's natural characteristics and to imitate the clarity of the voice. Often a musician's understanding of articulation terminology is based on their specific method of production, rather than the effect produced. To string players a curved line may indicate to play multiple pitches in one bow, while this same marking to a wind player indicates performing multiple notes in one breath. How each musician executes

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[8] Donald Martino, "Notation in General – Articulation in Particular," *Perspectives of New Music* 4, no. 2 (Spring-Summer 1966): 47.

[9] Keller, *Phrasing and Articulation*, 31.

articulation can lead to differences of opinion about articulation marks between instrumental families. String musicians execute articulation with the bow, wind musicians with the tongue, and keyboard musicians with touch.[10] Before we can address the specific problems of percussion and marimba articulation, we must first consider problems of musical articulation in general and attempt to clarify the terminology and interpretation of articulation markings for all musicians.

Articulation is one of the essential elements of musical style. Through changes of articulation a performer can make music sound lyrical, light, witty, heavy, humorous or any number of different styles. It is one of the most important expressive tools in a musician's set of skills. The first edition of the New Grove Dictionary of Music defines articulation as:

> The manner in which successive notes are joined to one another by a performer. In the simplest term, opposite kinds of articulation are staccato (detached, prominent articulation) and legato (smooth, invisible articulation). In reality articulation involves myriad aspects of the voice or instrument that determine how the beginning and end of each note are to sound.[11]

This entry goes on to say that articulation is one of the main components of phrasing. Articulation and phrasing are two terms that are often linked together and sometimes confused. Keller describes the difference between articulation and phrasing in terms of their function. The function of phrasing is, "to link together subdivisions of musical thought (phrases) and to set them off from one another."[12] The function of musical articulation is,

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[10] Bryan White, "Articulation," *The Oxford Companion to Music*, ed. Alison Latham, *Oxford Music Online,* Oxford University Press, accessed November 17, 2016, http://www.oxfordmusiconline.com/subscriber/article/opr/t114/e420

[11] David Fallows, Mark Lindley, and Maurice Wright, "Articulation," *The New Grove Dictionary of Music and Musicians*, eds. Stanley Sadie and Nigel Fortune (London: Macmillan, 1980), Vol. 1: 643.

[12] Keller, *Phrasing and Articulation*, 4.

"the binding together or the separation of the individual notes."[13] In this sense, one can understand phrasing as dealing with large-scale structures and articulation as dealing with small-scale structures or single notes. The purpose of phrasing and articulation is similar, but on macro and micro levels respectively.

Geoffrey Chew's entry in the New Grove defines articulation as, "The separation of successive notes from one another, singly or in groups, by a performer, and the manner in which this is done."[14] This definition accurately describes one of the most common articulation types, staccato, but it fails to mention other forms. Staccato belongs to a group of articulations that influence the decay or the end of a note. Other articulations deal with the attack of a note and still others deal with a note's sustain. According to Grant Fletcher, "the term articulation has often been used to express the manner of playing certain passages where it refers not only to the inceptions of the note, but also to its manner of continuation."[15] Mark McGrain also points this out in his text on music notation, stating, "Articulation refers to the way in which a sound is initiated and released. It implies a specific quality of attack, duration, and termination."[16] Articulation markings have an influence on the entirety of the sound envelope. A current definition takes these points into account:

> Articulation – An element of musical performance that facilitates the degree of clarity between successive notes by affecting the attack, sustain, and/or the decay of each sound.

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[13] Ibid.

[14] Geoffrey Chew, "Phrasing and Articulation," *The New Grove Dictionary of Music and Musicians*, eds. Stanley Sadie and J. Tyrell (London: Macmillan, 2001), Vol. 2.

[15] Grant Fletcher, "Effect of Other Musical Elements Upon Rhythmic Stress Perception," *Percussionist* 10, no. 4 (Summer 1973): 114.

[16] Mark McGrain, *Music Notation: Theory and Technique for Music Notation* (Boston, MA: Berklee Press, 1990), 155.

However, the discussion cannot end here, as each articulation and their markings have a multitude of interpretations and definitions. As music notation has developed, many articulations have gained new meaning and taken on a performance practice contrary to their historical definitions. Throughout music history articulation markings have been the focus of intense debate as their meanings often change according to time period and even from one composer to the next. Because the interpretation of articulation is a subjective art, this debate is bound to continue. However, all musicians should have an understanding of the most common articulation marks and how to interpret them on their instrument.

The list of common articulation types used by wind and percussion musicians is relatively smaller than the list in use by orchestral string players. The string family, especially the violin, has a long history in the methods and procedures of articulation through bowing. Phillip Coffman has written about the connection between percussion technique and string bowing. He believes that, "both percussion and string performers will find great advantage in learning how the other approaches the problem of articulation."[17] The same advantages can be gained through understanding wind articulations as well. A better understanding of how different instruments approach each type of articulation will allow marimbists to recreate these articulations on their own. Some of the most common musical articulation types, which deserve further study, are staccato, legato, portato, tenuto, marcato, and the accent.

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[17] Phillip Coffman, "Articulation in the Percussion and String Families: A Similitude," *Percussive Notes* 17, no. 2 (Winter 1979): 33.

Staccato

Staccato is indicated by a dot above or below the note head of each pitch. These dots were first used in music notation by the keyboard composers of the seventeenth century.[18] Coming from the original Italian, The Oxford Dictionary of Music defines staccato as "detached."[19]

> Staccato – Detached. Method of playing a note (shown by a dot over the note) so that it is shortened¾ and thus 'detached' from its successor¾ by being held for less than its full value. Superlative is *staccatissimo*.

Some musicians define staccato simply as short, but as Otto Ortmann argues, "a tone merely of short duration, but connected to some other tone is not a staccato tone."[20] The degree to which a note is detached from a successor depends a great deal on context. Many musicians contend that staccato markings shorten the note by half its written length, a view that may be informed by CPE Bach's essay on playing keyboard instruments, in which he writes that notes marked with a dot "are always held for a little less than half of their notated length."[21] However, due to certain contextual nuances, this mathematical shortening of a note may not always be the accepted interpretation. At slow tempos performers have more freedom in the interpretation of staccato, due to the increased amount of time between each note. As Keller points out, staccato has a much broader range of expression than other forms of articulation due to

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[18] Gardner Read, *Music Notation: A Manual of Modern Practice* (New York: Taplinger Publishing, 1979), 260.

[19] Tim Rutherford-Johnson, Michael Kennedy, and Joyce Kennedy, eds., *The Oxford Dictionary of Music*, (Oxford: Oxford University Press, 2012).

[20] Otto Ortmann, *The Physiological Mechanics of Piano Technique: an experimental study of the nature of muscular action as used in piano playing, and of the effects thereof upon the piano key and the piano tone* (New York: Da Capo Press, 1981), 196.

[21] Carl Phillip Emanuel Bach, *Essay on the True Art of Playing Keyboard Instruments*, Translated by William Mitchell (New York: W.W. Norton & Company, 1949), 154.

an almost limitless variation in the kinds of discontinuity between notes.[22] The degree of separation between two notes is a wide spectrum and not a constant value.

In order to produce a detached or staccato articulation, an instrument's natural vibration must be stopped by the performer. Wind players can cease vibration by using their tongue, as Daniel Bonade instructs, "Staccato is an interruption of the tone by touching the tip of the tongue to the reed."[23] When string players execute staccato the hair of the bow remains on the string, effectively ceasing extra vibration.[24] While many percussion instruments produce sounds that are too short to be altered in any meaningful way, the marimba's sound can be shortened through damping the vibration with the mallet or the hand after striking the bars. This technique mirrors the techniques used by wind and string musicians.

Legato

Legato, in theory, requires less interpretation than its relative, staccato. The Oxford Dictionary of Music defines legato as "bound together," which is consistent with a literal translation of the word from Italian to English.[25]

> Legato – Bound together. Performance of music so that there is no perceptible pause between notes, i.e. in a smooth manner, the opposite of staccato. Indicated by a slur or curved line. Superlative is *legatissimo*.

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[22] Keller, *Phrasing and Articulation*, 34.

[23] Daniel Bonade, *Clarinetist's Compendium* (Kenosha: Leblanc Publications, 1957), 3.

[24] Daniel Andai, "A Contemporary Approach to Orchestral Bowing for the Concertmaster" (DMA diss., University of Miami, 2011) 29.

[25] Tim Rutherford-Johnson, Michael Kennedy, and Joyce Kennedy, eds., *The Oxford Dictionary of Music*, (Oxford: Oxford University Press, 2012).

While musicians can and do discuss the degree to which two staccato notes are separated, it is illogical to discuss the degree of connection between two legato notes. It should also be noted that both legato and staccato articulation markings refer to the performance of multiple notes. It is not possible to connect a single note to silence, or to separate one note from nothing. In a sense, the definitions of legato and staccato are polar opposites, however, the execution of these articulations actually affects different parts of a musical sound. Staccato creates separation between two notes by shortening the end of a sound, otherwise known as the decay. Legato connects two sounds by both lengthening the duration of the first note and minimizing or eliminating the attack of the second note. Staccato shortens the decay of a primary note, while legato lengthens the duration of the primary note and eliminates the attack of a secondary note.

In a literal sense, legato articulation implies that each note should proceed smoothly into the next without attack. This is accomplished on most wind instruments by moving the fingers on the instrument without an attack from the tongue, and on string instruments by performing the passage without lifting the bow. However, this literal translation is not always adhered to in actual performance. Often times moving to a new pitch on wind or string instruments without an attack is technically impossible or may cause unwanted sounds including glissandi. In these cases performers can create the illusion of a true legato by giving each note a soft attack. In wind instruments this is given the somewhat oxymoronic name of legato tonguing; legato meaning without attack and tonguing referring to attack. This is usually accomplished by the use of different syllables to articulate the notes. This practice goes back to at least the Baroque period, specifically to Quantz, who differentiated between the syllables Ti and Di on the flute.[26] The main difference between articulating with 'T' or 'D' sounds on wind instruments is the speed of airflow they each produce; The 'T' sound creating a much faster stream of air than 'D'.

The variation of speed to create a different articulation is mirrored in marimba performance as well. Because every marimba bar needs to be individually struck to create sound, a true connected legato is not possible under normal circumstances. While there are several techniques on marimba, including rolling, that can approximate a true legato, most players attempt to give each note a softer attack, similar to legato tonguing on wind instruments. One of the main ways they accomplish this goal is through a slower stroke speed, equivalent to using the 'D' syllable to articulate on wind instruments.

The marking for legato articulation is a curved line, however, composers have also indicated for performers to connect the notes by simply writing the word *Legato* above the staff. The curved line, or slur, is problematic in itself, as composers have often used it to signify something other than legato. Due to this fact, musicians have a variety of opinions on its meaning. While slurs today often connect many consecutive notes, this was not always the case. Up until the middle of the eighteenth century, the slur was hardly ever carried across the bar line.[27] During this time slurs rarely connected more than two notes at a time. As the use of the slur became more free, entire phrases might be connected under one curved line.

In Elizabeth Green's method for orchestral bowing, the slur is a particular type of

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[26] Johann Joachim Quantz, *On Playing the Flute*, Translated by Edward R. Reilly (London: Faber, 1966) 71-72.

[27] Hugo Cole, *Sounds and Signs: Aspects of Musical Notation* (London: Oxford University Press, 1974) 85.

legato bowing of which there are several others.[28] String players most often perform the notes contained within a slur using a single bow direction. This view goes back to at least the 18th century when Leopold Mozart stated that, "The notes that are over or under [a slur]… must all be taken together in one-bow stroke."[29] Other musicians consider the curved line to be unrelated to legato. In Mark McGrain's book on musical notation legato and tenuto markings are one in the same, a horizontal line. McGrain goes on to discuss slurs in another section altogether, which for him have no connection to legato.[30]

The curved line is also interpreted by some musicians as a phrase mark, which tells the performer how many notes to group into one phrase, but has little or nothing to do with articulation. Kurt Stone asserts that slurs indicate bowing for string instruments, breathing for wind instruments, notes sung on a single syllable for vocalists, and phrasing for keyboard instruments and pitched percussion.[31] While these interpretations may seem to be at odds with one another, in every case the slur signifies notes that are to be connected in some manner. Whether the notes under a curved line are performed as a true legato is another question that must be left to musical context.

Portato

Notes that are marked with a curved line and a dot have been given a host of

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[28] Elizabeth A.H. Green, *Orchestral Bowings and Routines*, (Fairfax, VA: American String Teachers Association, 1990), 58.

[29] Leopold Mozart, *A Treatise on the Fundamental Principles of Violin Playing*, Translated by Editha Knocker (London: Oxford University Press, 1951) 45.

[30]McGrain, *Music Notation*, 156 – 158.

[31] Kurt Stone, *Music Notation in the Twentieth Century: A Practical Guidebook* (New York: W.W. Norton & Company, 1980) 35.

different names ranging from portato, louré, slurred-staccato or legato-staccato. While the latter two names are self-explanatory, the former two require some discussion. Portato comes from the Italian "to carry" and is a reference to the bowing technique used to execute passages marked with a slur and a dot. Green explains this "carried" technique by stating, "the bow continues its motion as in any slur, but releases pressure slightly between notes so that the notes become somewhat articulated."[32] The term louré comes from a slow French Baroque dance of the same name, which is often performed with this bow stroke. While the terminology may not be common to wind and percussion performers, the term portato (to carry) offers the most precise definition of this articulation. For the remainder of this document, the combination of a slur and a dot will be referred to as portato.

Portato, through its name and marking, has caused great confusion among musicians. In fact, the interpretation of articulation marks underneath a slur has been a problem since at least the middle of the 18th century. Clive Brown states, "The main difficulty is to decide whether the notation indicates sharply separated notes, more gently emphasized and slightly separated, sometimes almost legato notes, or some intermediate degree of articulation."[33] Portato has also been confused, because of shared linguistic roots, with the term portamento. Portamento is a separate technique mainly used by vocalists and string players to connect two pitches by passing through every pitch in between, which creates the effect of a glissando. The Harvard Dictionary of music defines portato as the following:

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32 Green, *Orchestral Bowings and Routines*, 58.

33 Clive Brown, "Dots and Strokes in Late 18th and 19th Century Music," *Early Music* 21, no. 4 (Nov. 1993): 602.

> Portato – A stroke in which each of several notes is separated slightly within a slur, without a change in the direction of the bow.[34]

The New Grove Dictionary of Music and Muscians goes on to say that "this expressive re-articulation or pulsing of notes joined in a single bowstroke was described by Galeazzi as 'neither separate nor slurred, but almost dragged'."[35] As explained by Green and other string pedagogues, portato creates a pulsing effect by releasing pressure between each note in a passage. Each note is given a soft attack and separated just slightly. This marking affects not only the front of each note, but also the decay. In this way, portato is most closely related to the wind technique of legato tonguing. String portato is also closely related to using a slow velocity stroke on marimba, which while still creating a clear attack minimizes the impact of each note. Even though terminology may be different, there are many ensemble benefits to realizing the similarities found between wind, string, and percussion articulation.

Tenuto

Tenuto articulation is indicated by placing a horizontal line above or below each note head. From Italian, tenuto translates simply as "held" and in the Oxford Dictionary it is defined as follows:

> Tenuto – Held. Direction to hold note to its full value, sometimes even longer.[36]

While this definition seems clear, the tenuto marking can be interpreted to mean a variety of options. Hugo Cole points out that the horizontal line, or tenuto mark, can be performed

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[34] Don Michael Randel, ed., *The Harvard Dictionary of Music*, (London: Harvard University Press, 2003).

[35] Stanley Sadie, ed., *The New Grove Dictionary of Music and Musicians* (London: Macmillan, 2001).

[36] Oxford Dictionary

as, "1. Held out & ritenuto, 2. Held out & no ritenuto, 3. Slight accent, 4. Slight separation, 5. Vibrato."[37] Gardner Read asserts that this notation "implies a kind of leaning on the note, giving it special stress without noticeably attacking it."[38] As with the other articulations we have discussed, there is a clear difference between the accepted definition and its application. The tenuto marking maintained its standard interpretation throughout the eighteenth century, but by the nineteenth century the horizontal line acquired the implication of adding stress to the note.[39]

In percussion notation tenuto is almost always interpreted as a slight accent or stress on the note. Because most percussion instruments have a quick decay, holding a note for its full written value may not always be possible. Instead of sustaining the note through some other technique, percussionists will add a slight stress to notes marked with a horizontal line. This not only makes the specific note louder, but also, as more energy is transferred to the instrument, causes the vibrations last for a longer duration. By adding volume or stress to a note marked tenuto, percussionists actually do create a longer sound.

Accent Marks

The addition of stress or volume implied by a percussive tenuto mark has led some to classify the horizontal line as an accent mark. Accent marks are symbols that signify an exaggerated stress on the attack of a particular note, giving the music a distinctive rhythmic pattern. Under normal playing conditions, percussionists have the most control over the

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[37] Cole, *Sounds and Signs*, 84.

[38] Read, *Music Notation*, 261.

[39] Richard Rastall, *The Notation of Western Music: an Introduction* (London: Dent, 1983) 198.

attack of each note; Because of this fact, they have a great amount of control over the production of accents. Two of the most common accent marks, besides tenuto, are the horizontal wedge and the vertical wedge. As seen with other articulations, accents marks suffer from several misunderstandings about their terminology. Today many musicians know the vertical wedge as marcato. Italian for marked, marcato is defined in the Oxford Dictionary as follows:

> Marcato – Marking; marked, i.e. each note emphasized. *Marcatissimo* is the superlative.

This general description is problematic because all types of accent marks bring emphasis to their respective notes. The vertical wedge, horizontal wedge, and horizontal line all fit the definition of marcato. While many musicians reserve this term specifically for the vertical wedge, others use marcato in a more general sense and refer to all accent marks as "marked".

The horizontal wedge is most commonly known today simply as an accent. This term again carries a broad definition that could be applied to several other marks. Despite the confusion implied by their naming, it is generally accepted that the vertical wedge indicates a stronger, more forceful attack than the horizontal wedge. In addition, the vertical wedge usually implies a slight shortening of each marked note. The horizontal wedge signifies a moderately sharp attack, usually accompanied by a slight diminuendo after the attack. While these interpretations are used the majority of the time, Cole points out that, "it is often hard to decide whether a composer meant anything at all by a variation of sign."[40] He points to several examples in Stravinsky's carefully notated *Rite of Spring* in

[40] Hugo Cole, *Sounds and Signs*, 83.

which half the winds have the vertical wedge, while the other half has the horizontal wedge. As with all articulation marks, accent marks are bound to the context of the music and may have different implications from one piece to the next.

The problems concerning musical articulation and their markings are an extensive topic that many musicians have tried to tackle over the years. Many of the issues stem from the specificity of musical notation and its limitations. In an effort to alleviate some of these problems, Donald Martino has suggested 24 new articulation markings that signify various types of attack and decay.[41] However, critics of this system assert that "the 24 symbols are already both too many and still too few. Too many, because the increase in the number of signs to be recognized and responded to strains the already heavily-engaged attention of the performer; too few because such a range cannot begin to cover the countless subtle shades of inflection to be discovered in performance according to context and the particular circumstances prevailing."[42]

The issues discussed in this chapter point to the main differences between the standard notation of pitch and rhythm and the standard notation of dynamics and articulation. In the former, the information conveyed is absolute, precise, and objective. In the notation of dynamics and articulation, performers must take into account much more than the individual markings. It is not possible to standardize the interpretation of articulation marks, just as it is impossible to standardize the exact volume intended by a dynamic marking. Articulation markings are simply a way to notate a subjective musical

[41] Martino, "Notation in General – Articulation in Particular," 47-58.

[42] Hugo Cole, *Sounds and Signs*, 90.

expression. The consideration of musical context and style must always be the basis for interpreting these signs.

Table 2.1: Articulation Marks and their Interpretation

Legato		Connected. Performance of music so that there is no perceptible pause between notes.
Staccato		Detached. Method of playing a note so that it is shortened and separated from its successor
Portato		Carried. A method of playing in which each of several notes is separated slightly within a slur, performed on one bow or one breath.
Tenuto		Held. Direction to hold a note to its full value, sometimes even longer.
Marcato		Marked. Each note emphasized and slightly shortened.
Accent		Emphasized. Played with stress and held for full value.

CHAPTER 3

THE MARIMBA

A Brief History of the Modern Marimba

While the focus of this study is not the history of the marimba, a brief outline is necessary to understanding some of the acoustical issues of the instrument. Readers who want to know more about the history of the marimba will find more relevant discussions in the sources mentioned below. The modern marimba is a wooden idiophone, whose sound is produced by the striking of the bars with a mallet. Pitched idiophones, like the marimba, have a long history that goes back as far as the Paleolithic era. Some of the oldest instruments in existence are carved rocks and bones made specifically for striking. Still, the modern marimba is hardly a century old and is still undergoing improvements from the manufacturing community. Some of the marimba's oldest ancestors can be traced back to Indonesia and the gamelan orchestras of Java and Bali.[43] There is evidence to suggest these instruments, and the people who played them, migrated to Africa approximately fifteen hundred years ago.[44] The marimba's name is of African origin, specifically Bantu, and refers to an instrument with wooden bars and gourd resonators.[45] Instruments of this type were brought to North America through the slave trade. These early marimbas had a limited range and were often tuned to the pitches of the pentatonic scale. It wasn't until 1894 that Sebastián Hurtado of Guatemala created the first chromatic marimba with keys arranged in

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[43] David P. Eyler, "The History and Development of the Marimba Ensemble in the United States and its Current Status in College and University Percussion Programs" (DMA Diss., The Louisiana State University, 1985) 10.

[44] Ibid.

[45] Vida Chenoweth, *The Marimbas of Guatemala* (Lexington, KY: The University of Kentucky Press, 1964) 54.

two manuals like the piano.[46] The marimba occupies an important place in the culture of Guatemala and it is, to this day, the country's national instrument. The Hurtado family introduced the chromatic marimba, the so-called *marimba doble*, to the United States and Europe through various performances during the early 20th century. By 1910 the instrument was gaining in popularity, which led John C. Deagan and Ulysses G. Leedy to manufacture the first commercially available marimbas.[47]

Not much can be said about the evolution of the modern marimba without mentioning Clair Omar Musser. As a performer, conductor, arranger, instrument designer, and educator, Musser is one of the leading figures in the development of the marimba. He joined the Deagan Company in 1930 and helped to design several models of marimbas and various other instruments.[48] The first marimba Musser helped to design was the *Century of Progress* marimba. 100 of these marimbas were made for Musser's Century of Progress Marimba Orchestra that performed at the 1933 Chicago World's Fair. Besides designing the instruments for this performance, Musser also arranged the music, taught the performers, and served as conductor. Another 102 marimbas, specifically named the *King George* model, were made for a similar venture and performance at the Brussels World's Fair in 1935. Musser left the Deagan Company in 1948 and formed his own company, Musser Marimbas, Inc. This company still manufactures instruments and is now a division of the Ludwig Drum Company. Musser was one of the first people to recognize the potential of the marimba as a solo instrument. He wrote numerous arrangements and compositions for

[46] David P. Eyler, "The Hurtado Brothers' Royal Marimba Band of Guatemala," *Percussive Notes*, vol. 31 no. 3 (February 1993): 48.
[47] Frank K. MacCallum, *The Book of the Marimba* (New York: Carlton Press, 1969), 16.
[48] David P. Eyler, "Clair Omar Musser and His Contributions to the Marimba," *Percussive Notes* 28, no. 2 (Winter 1990): 63.

solo marimba and marimba ensemble, many of which are still performed today. As an educator at Northwestern University from 1942 to 1952, Musser had a great impact on his students, many of whom went on to have fulfilling careers as professional marimbists.

The range of the modern marimba is five octaves stretching from C_2 to C_7, but this is only a recent convenience. For much of its history, the range of the concert marimba only extended down to C_3 or A_2, for reasons to be discussed later. Credit for the extension of the range goes to the Yamaha Corporation, who at the request of marimbist Keiko Abe created a fully functional 5-Octave Marimba in 1984. The 5-Octave marimba, due to the influence of Abe and other marimbists, has now become the standard range for manufacturers, composers, and performers. Abe is widely considered one of the most influential marimbists of the 20th century. Through a series of commissioning projects, she oversaw the premiere of 54 original works for the marimba from 1964 to 1986.[49] Due to the work of Abe and other innovators, the marimba has achieved a large degree of popularity around the world.

Acoustical Properties of the Marimba

The acoustics of a vibrating bar differ greatly from the simple vibrations of a tensioned string or a column of air. Every vibrating body has several different modes of vibration that produce multiple high frequencies in addition to the lowest perceived pitch. For a string or air column the frequencies produced by these modes of vibration are found by multiplying the fundamental frequency by each whole-number integer (1*f*, 2*f*, 3*f*, 4*f*…).

[49] Rebecca Kite, *Keiko Abe: A Virtuosic Life*. (Leesburg, VA: GP Percussion, 2007) 245.

These modes then comprise what is called a harmonic series. The first six vibrations contained within the harmonic series of a string are shown in figure 3.1 below.

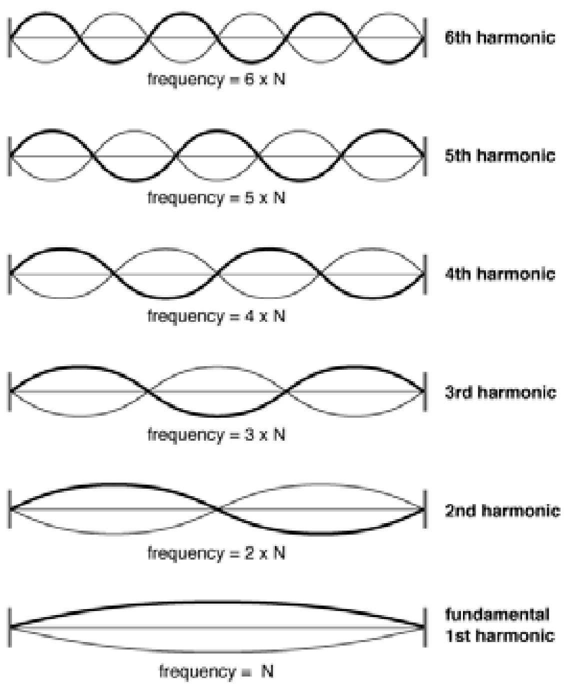

Figure 3.1: Vibrations Found in the Harmonic Series

For bars and other more complex shapes, the modes of vibration are not multiples of each integer and are not related harmonically. These complex modes of vibration are referred to as inharmonic overtones and are what give percussion instruments their distinctive, often unpitched, sound. Bars with a uniform cross-section have modes of vibration above the fundamental frequency at a ratio of 1:2.76, 1:5.4, 1:8.93, etc.[50] Because these vibrations can influence the perception of pitch, marimba bars are tuned in order to create synthetic harmonic relationships above the fundamental pitch.

[50] Thomas D. Rossing, "Acoustics of Percussion Instruments – Part 1," *The Physics Teacher* 14, no. 9 (1976): 548.

The pitch of a marimba bar is determined by its length and thickness, and is independent of its width. By changing the length and carefully cutting material away from the underside of each marimba bar, the modes of vibration can be tuned to resemble the harmonic relationships found in strings and columns of air. As marimba designer and innovator Doug Demorrow states, "The tuning of each bar is not automatic, it's intentional."[51] When material is removed from the underside of the bar, the pitch of all the modes of vibration are lowered. An expert tuner can extract material from specific points underneath the bar in order to tune individual modes of vibration. If the overall pitch of the bar gets too low, material can be removed from the length in order to raise the pitch.

Most marimba manufacturers focus on tuning at least the first three modes of vibration, the first being the fundamental pitch. Once the fundamental is lowered, the second mode of vibration is tuned to approximately at a ratio of 4:1 or two octaves above the fundamental pitch.[52] The third mode of vibration is tuned three octaves and major third above the fundamental or approximately at a ratio of 10.1:1.[53] A study conducted by Ingolf Bork and Jürgen Meyer concluded that these ratios help influence pitch perception and create an aesthetically pleasing tone that is characteristic of the marimba.[54] These ideal ratios are what set the marimba apart from its close relative, the xylophone. For a marimba bar the first three modes of vibration are tuned to the ratios 1:1, 4:1, and 10.1:1 as opposed

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[51] Doug Demorrow (President and Owner, Demorrow Instruments LTD.) interviewed by Adam Davis, March 2018.

[52] James Moore, "Acoustics of Bar Percussion Instruments" (PhD diss., The Ohio State University, 1970) 8.

[53] Ibid., 8.

[54] Ingolf Bork and Jürgen Meyer, "On The Tonal Evaluation of Xylophones," Translated by Thomas D. Rossing, *Percussive Notes* 23, no. 6 (September 1985): 103-104.

to a xylophone bar where they are tuned to ratios of 1:1, 3:1, and 6:1.[55] The tuned pitches of the first three modes of vibration for a marimba bar and xylophone bar with fundamental pitches of A_2 are shown below in figure 3.2. While the xylophone's range does not extend this low, this hypothetical bar is for the purpose of comparison.

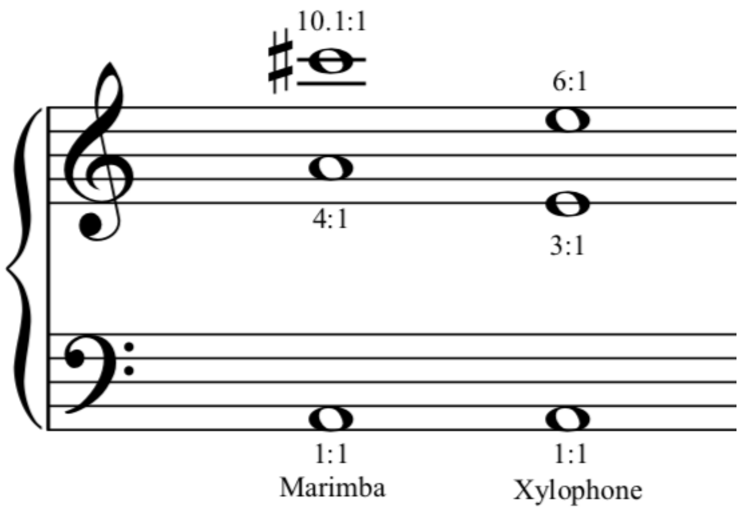

Figure 3.2: Tuned Modes of Vibration for a Marimba Bar and Xylophone Bar

It should be noted that the highest two octaves of marimba bars, C_5 to C_7, do not contain enough wood to tune these specific relationships. Cutting too much material from the underside of one of these bars would lower the fundamental pitch out of the desired range. Because of this fact, many manufactures tune the upper octaves of the marimba similar to a xylophone.[56] The modes of vibration in the upper octaves of a Malletech brand marimba, used during the course of this study, were tuned in ratios of approximately 1:1, 3:1, and 5:1.

[55]Moore, "Acoustics of Bar Percussion Instruments,"10.

[56] Ibid., 103.

Regardless of the method of tuning, each mode of vibration has multiple nodal points where vibration is at minimum amplitude, as well as points of maximum amplitude, called anti-nodes. For the first mode of vibration the nodal points occur at approximately 0.224 of the length of the bar.[57] Manufacturers use these points to drill holes through the bar. String or cord is strung through these holes to mount the bars onto the instrument's frame. The anti-node, or point of maximum amplitude, for the fundamental occurs in the exact center of the bar. For the second mode of vibration there are three nodal points, one of them occurring in the center of the bar. The anti-nodes for the second mode of vibration occur at approximately ¼ or ¾ of the length of the bar. For the third mode of vibration there are four nodal points and three anti-nodes. The modes of vibration continue in this manner infinitely, increasing the number of nodal points and anti-nodal points for each new vibration. Every odd number mode of vibration will have an anti-nodal point in the center of the bar, whereas every even number mode of vibration will contain a nodal point in this same spot. Figures 3.3-3.6 show illustrations of the first four modes of vibration.

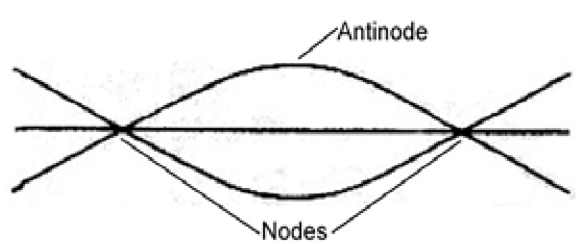

Figure 3.3: First Mode of Vibration for a Marimba Bar

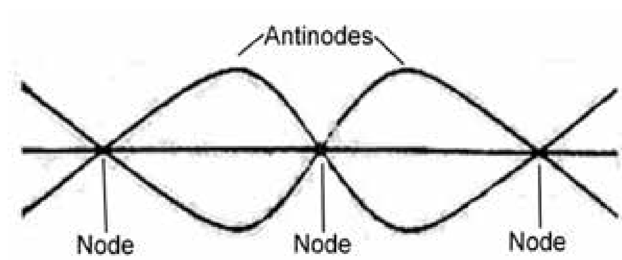

Figure 3.4: Second Mode of Vibration for a Marimba Bar

[57] Ibid., 67.

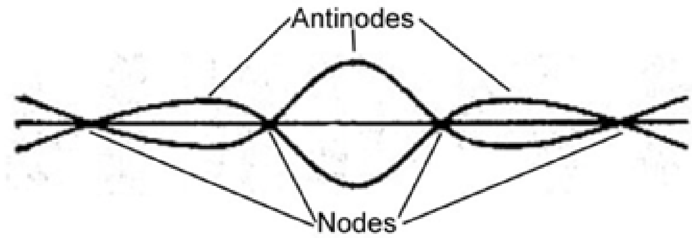

Figure 3.5: Third Mode of Vibration for a Marimba Bar

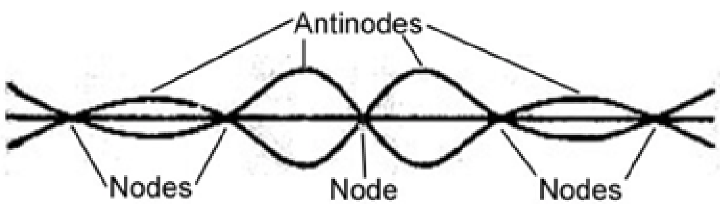

Figure 3.6: Fourth Mode of Vibration for a Marimba Bar

Performers can emphasize each overtone frequency by striking the bar at the anti-nodal point for each mode of vibration. The effect of this can be enhanced by muting the other modes of vibration at their anti-nodal points with a second mallet or with the performer's hand. Moore found in his research that "rather small changes in the striking location on a percussion instrument bar will produce important differences in tone quality."[58] He goes on to state that, "if the point of contact between the mallet and the vibrator is at the anti-nodal point of the fundamental the tone produced will emphasize this component and the partial tones will be less prominent. By moving the point of contact away from this anti-node point of the fundamental, the higher partials will become increasingly prominent."[59]

[58] Ibid., 94.

[59] Ibid.

The majority of marimba bars are made from Honduran rosewood, however, padauk wood and various synthetic materials are sometimes used as substitutes. Manufacturers have found that rosewood is the ideal material for musical instruments because of its resonant qualities. However, there can be significant differences in quality from one rosewood bar to the next. It goes without saying that performers who do not have access to high quality instruments have less control over the tone and articulation of the marimba. Doug Demorrow comments, "There is no way you can take a bad piece of wood and make it sound like a good piece of wood."[60]

The sound of the marimba is amplified by the use of resonators underneath each bar. Contrary to their name, resonators do not increase the length of bar's sound. Instead resonators increase the volume of the bar's vibrations and in the process use up the energy faster than if there were no resonator at all. This effect is most notable in the instrument's lowest register. Thomas Rossing found that "the decay time of a typical rosewood marimba bar in the low register (E_3) is about 1.5 seconds with the resonator and 3.2 seconds without it."[61] Decay times for an upper register bar (E_6) were found to be 0.4 seconds with a resonator and 0.5 seconds without one.[62]

There are two main types of resonators that are used in musical instruments: tubes with two open ends, and tubes with one closed end. Tubes that are open at both ends amplify vibrations when their length is equal to ½ the wavelength of a given frequency. Open-ended tubes enhance every integer multiple, or the complete harmonic series, of a

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[60] Doug Demorrow, interview March 2018.

[61] Thomas D. Rossing, *Science of Percussion Instruments* (Singapore: World Scientific Publishing, 2000) 60.

[62] Ibid.

given frequency.[63] Tubes with a cap at one end, need only be ¼ of the wavelength for a given frequency. Because closed-end, or quarter-length, resonators allow manufacturers to use less material to construct, while also keeping the instrument low enough to the ground to be playable, they are the standard in modern marimbas. Closed-end resonators only enhance odd numbered modes of vibration (ƒ, 3ƒ, 5ƒ, etc.), because these modes contain an anti-nodal point at the open end of the tube. Even numbered modes of vibration contain a nodal point at the opening of the tube and are not amplified. Figure 3.7 shows how quarter-length resonators function on odd numbered modes of vibration (l = the wavelength of a given frequency). Because the modes of vibration for a marimba bar are tuned to ratios of 1:1, 4:1, and 10.1:1, the only mode enhanced by the resonators is the fundamental. In the xylophone, resonators are able to enhance the second mode of vibration, tuned to a 3:1 ratio with the fundamental. This fact is one of the reasons why the timbre of the xylophone sounds much brighter than that of the marimba.[64]

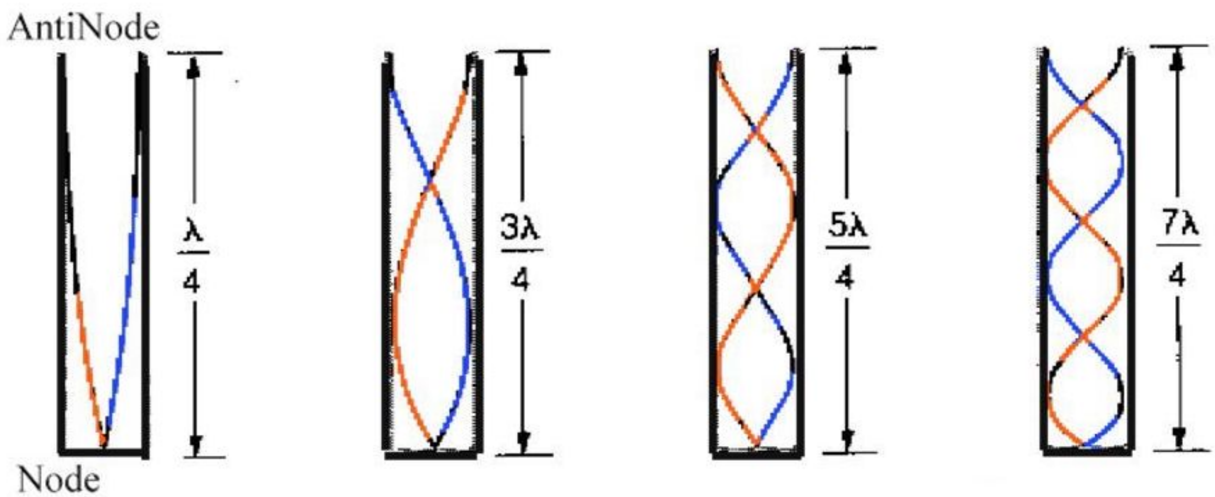

Figure 3.7: Closed-End Resonators and Odd Numbered Modes of Vibration

[63] Ibid., 50.

[64] Rossing, "Acoustics of Percussion Instruments – Part 1," 551.

Resonators work best when they are tuned specifically to the wavelength of the bar overhead. Because temperature can affect the speed of sound, resonators and bars can go out of tune with one another. Some manufacturers have adjustable end caps that allow the resonator to be shortened or lengthened in accordance with the wavelength of the bar. Tuning of the resonators cannot be altered within the course of a piece; however, a performer could adjust tuning before or between pieces. This can greatly affect the sound of each bar by changing the overall amplitude and decay time. Resonators that are tuned just above the fundamental pitch of the bar will create more initial volume in the contact sound of the mallet, while resonators that are tuned slightly low to the fundamental will create more length.[65] It should be stressed that these adjustments are only slight variations, as resonators that are more than a few cents sharp or flat to the bar will not amplify the note at all, creating what seems to be a dead sound. In fact, what many marimbists assume to be problems with the quality of the bar are actually problems with the tuning of the resonator. Experiments have also shown that adjacent resonators can have an effect on the decay time of a marimba bar, especially if they are tuned a semitone apart, as in the case of C and B.[66]

The material that the resonator is made of can also have an effect on the sound of the marimba. The two most common resonator materials in use today are brass and aluminum. Many players opt for aluminum resonators to facilitate easier transportation of the instrument, as brass is approximately three times heavier than aluminum. Besides this difference in weight, Doug Demorrow also hears a clear difference between the

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[65] Leigh Howard Stevens, "Resonator Acoustics." *Percussive Notes* 32, no. 5 (October, 1994): 23.

[66] Bork , "On The Tonal Evaluation of Xylophones," 121-122.

amplification of the marimba produced by these two materials. Demorrow believes "the ability of brass resonators to fill a space is vastly different compared to aluminum… with brass tubes it's like you lift a blanket off the sound."[67] The reasoning for this, as Demorrow states, is because of the way the sound wave moves in and out of the resonator. Because the inner surface of an aluminum tube has a rough texture compared to the smoothness of brass, Demorrow says, "the brass tube allows the air to move freer in and out than an aluminum tube, and it's just a matter of friction."[68]

For a marimba bar with a fundamental frequency of A_2 (110Hz), the accompanying resonator must be approximately 78.41 cm, based on a wavelength of 313.64 cm for that pitch. For much of the marimba's history, this was the longest resonator that manufacturers could produce without having to significantly raise the height of the instrument. As the modern marimba's range extended below A_2 to its full 5-octave range, manufacturers created various solutions to this problem. Trough resonators, box resonators, and curved resonators are just a few of the solutions currently in use, but new innovations are still being sought. Still, because of the way sound waves move, the most effective shape for resonators is cylindrical. Some manufacturers have created bent or curved cylindrical resonators in order to keep the height of the marimba low enough to the ground, without sacrificing sound quality.

Sound Production on the Marimba

Once the bars and resonators are tuned, the sound of the marimba can be reduced to

[67] Doug Demorrow, interview March 2018.

[68] Ibid.

a relatively small number of variables that are under the player's control. These variables can have a large impact on the tone and articulation of the instrument. In an early article in *Percussionist*, Donald Stauffer listed six principle factors that affect the resultant intensity and timbre of the sound produced through a percussive stroke:

> (1) The weight of the striking agent. (2) The speed with which the striking agent comes in contact with the vibrator. (3) The point of contact of the striking agent with the vibrator. (4) The angle at which the striking agent comes in contact with the vibrator. (5) The flexibility or elasticity of the striking agent. (6) The total area of the striking agent that comes in contact with the vibrator during the stroke.[69]

Stauffer's list of variables, while somewhat dated, are based on fundamental principles of physics and acoustics. The list can be updated to clarify meaning and organize the variables into two separate groups. The current study has identified two extra factors in addition to Stauffer's list that directly affect the sound of the marimba. These eight factors can apply not only to the marimba, but to other percussion instruments as well.

Variables of Mallet Choice

1. The weight of the mallet
2. The total area of contact of the mallet
3. The flexibility or elasticity of the mallet core
4. The mallet wrap

Variables of Technique

5. The velocity of the mallet at the moment of contact
6. The weight of the mallet at the moment of contact
7. The point of contact on the bar
8. The angle of contact with the bar

[69] Donald W. Stauffer, "A Motion and Muscle Study of Percussion Technique." *Percussionist* 5, no. 3 (March 1968): 293.

The first group deals exclusively with factors of mallet choice. Unless given ample time by a composer, marimbists do not usually have an opportunity to change mallets within the course of a piece. Therefore, marimbists must take these variables into account before performance, as they can only be altered with a change in implements. The second group of variables, however, can be changed at any point during performance and can even change from one note to the next.

Mallet choice is the most important factor in the sound of the marimba. This fact, while plainly obvious to most performers, is rarely discussed in method books. Each marimba mallet can create a unique articulation at the front of each note. With the large variety of mallets available today, the ability of percussionist to affect the attack of each note has few limitations. When choosing the right mallets for a piece of music, percussionists should consider the variables from the first group, above.

The weight of the mallet directly affects how far the bar is displaced when struck and therefore how loud and how long it will vibrate.[70] Displacing the bar further will create a higher amplitude sound but will also increase the time takes for the bar to return to rest, creating a longer sounding vibration. Displacement of the bar is dependent on the amount of energy applied. The amount of energy applied to a marimba bar can be calculated by the formula $E = \frac{1}{2}MV^2$ (one half the mass of the mallet times the velocity of the mallet squared)[71]. The more energy transferred to a bar the louder and longer it will vibrate. While mass and weight are not the same, they act on the marimba bar in the same manner.

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[70] Ibid., 293.

[71] Leigh Howard Stevens, *Method of Movement for Marimba* (Asbury Park, NJ: Keyboard Percussion Publications, 1979) 22.

Weight, or the amount of force exerted on an object by gravity, is proportional to mass, the amount of matter contained within an object; an increase in mass means an increase in weight. By selecting a heavy mallet, a performer is able to displace the marimba bar further than if struck with a light mallet, resulting in a louder and longer vibration.

The total area of contact created by a mallet can also affect the sound of the marimba. Several studies have shown that a larger contact area can reduce the activation of the higher modes of vibration, resulting in a sound that has a strong fundamental pitch and few overtones. Moore found that "a mallet head of soft material and relatively large contact area with the bar will produce a tone with a strong fundamental and less prominent partial tones. A mallet head with this large surface contact area tends to damp out partials whose anti-nodes occur in the striking area."[72] On the other hand, Moore also found that "a mallet head of hard material and a smaller contact area with the bar will produce a tone with more and stronger partial tones. Fewer higher partials will be damped since the area of contact is smaller on the surface of the bar."[73] The area of contact is in direct relation with the size of the marimba bar. If the width of each marimba bar is graduated, the effect of a larger mallet will have less impact in the lower register of the instrument.

The flexibility of the mallet core is a property of the mallet's hardness or the elasticity of the material. There are a number of different materials, including rubber, latex, acrylic, and various synthetic plastics, which are used in the core of a marimba mallet. Softer materials are more prone to temporary deformation during impact and are therefore more flexible. Harder materials are, by definition, less flexible and are not prone to

[72] Moore, "Acoustics of Bar Percussion Instruments," 28.

[73] Ibid.

deformation through impact. It is a common misconception that mallet hardness mainly affects volume. In actuality, hardness or flexibility affects the amount of contact time with the bar and therefore, along with the amount of contact area, it is one of the main factors influencing timbre. As Ortmann notes in his study of the piano, “The tendency of any body which rests against a vibrating body is to ‘damp’, that is, to destroy the vibrations.”[74] A soft mallet will stay in contact with the bar for a longer amount of time than a less flexible hard mallet. This longer contact time produced by a soft flexible material, will affect the sound of the marimba by damping the higher modes of vibration. A less flexible mallet will stay in contact with the bar for a shorter amount of time and allow higher modes of vibration to fully activate. Moore’s study of mallets with varying degrees of hardness yielded results that proved this point. He writes, “In comparisons of the wave form produced by hard and soft mallets heads, the relations between the fundamental and second partial were the same. The differences came with the higher frequency elements. The harder mallet displayed many quickly decaying, high frequency elements of a very complex nature and high amplitude.”[75]

The final factor in mallet choice is the type of wrap used around the core material and the relative tightness of that wrap. Percussionists have a wide variety of different options in this category. Many marimba mallets are wrapped with yarn, but variations exist between natural and synthetic fibers. The most common natural fiber found in marimba mallets is sheep’s wool, but manufacturers often blend this with other synthetic material.

[74] Otto Ortmann, *The Physical Basis of Piano Touch and Tone* (London: Kegan Paul, Trench, Tubner & Co., 1925) 101.

[75] Moore, “Acoustics of Bar Percussion Instruments,” 131.

The wrap of each mallet influences the impact sound or the contact noise created by the mallet. Marimba mallets made with a soft yarn and a relatively loose wrap create a less prominent impact on each bar. These mallets can come in handy when marimbists want to minimize the articulation of each successive pitch, however, if a clear attack is the goal, a tighter wrap is the solution.

While mallet choice is a very important factor in the articulation and tone quality of the marimba, the second group of variables is just as important and can be utilized during performance without a change of implement. As Linda Pimentel points out, "most marimbists give little thought to the way they strike a note," and are at disadvantage because of it.[76] If percussionists would like to have more control over the tone quality and articulation of the marimba, the variables found in the second group are the main factors to achieve that goal, without a change of mallet.

The velocity of the mallet when making contact with the instrument affects the amount of energy put into the bar exponentially. Energy is calculated through the formula $E = ½MV^2$. While the effect of mass is halved, the effect of velocity is squared. The amount of energy applied to the bar amounts to further displacement and therefore a longer and louder sound. According to Stauffer, velocity can also affect timbre. He points out that, "when any object is given a certain momentum in a given direction, some other body or bodies will get an equal and opposing momentum."[77] This rewording of Newton's third law of motion, which states that every action has an equal and opposing reaction, means that a faster velocity stroke also decreases the amount of contact time with the bar. Ortmann

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[76] Linda Pimentel, "Evolving Solo Technics for the Marimba," *Percussionist* 10, no. 4 (Summer 1973): 110.

[77] Stauffer, "A Motion and Muscle Study of Percussion Technique," 292.

noted this same fact on the piano as early as 1925 stating that, “The duration of contact between hammer and string decreases as we increase hammer-speed.”[78] Because a fast velocity stroke stays in contact with the bar for a shorter amount of time, it does not cancel out the upper modes of vibration and results in a much brighter sound than that of a slow velocity stroke. Thus, strokes with a high velocity produce sounds that are not only louder with longer duration, but also have more high frequency partials. In most marimba performance the production of louder notes results in a brighter timbre as well. Because of this fact marimbist and educator Tom Burritt notes that playing loud, dark tones on the marimba is very difficult to achieve[79]. This coupling of volume and timbre on marimba has led to the following cynical comment from Leigh Howard Stevens, writing that, “If one craves long mellow struck tones, use a large, soft mallet to cancel the overtones, and strike the bar with great velocity. If this won’t do, switch to cello…”[80]

All jokes aside, the manipulation of stroke velocity is one of the percussionist’s most useful tools. John Raush agrees, stating, “The speed of the stroke is the most significant variable that the marimbist can control. For example, although the player may, in some situations, have time to change mallets or may slightly vary the beating spot or striking angle, it is often impractical or even undesirable to do so.”[81] In many ways stroke velocity resembles the various syllables used by wind players to articulate. While discussing the syllables ‘Di’ and ‘Ti’ Quantz writes, “just as there are various shades between black and

[78] Otto Ortmann, *The Physical Basis of Piano Touch and Tone*, 84.

[79] Tom Burritt (Professor of Percussion, University of Texas) interviewed by Adam Davis, February 2018.

[80] Stevens, *Method of Movement for Marimba*, 22.

[81] John Richard Raush, “Four-Mallet Technique and Its Use in Selected Examples of Training and Performance Literature for Solo Marimba” (DMA diss., The University of Texas at Austin, 1977) 159.

white, there is more than one intermediate degree between a firm and a gentle tongue-stroke."[82] In much the same way, there are many degrees between a fast percussive stroke and a slow percussive stroke.

Stroke weight works in conjunction with stroke velocity to create the marimba tone. The two factors, while not equal, do influence the amount of energy applied to the bar, which in turn influences the volume and duration of vibration. Weight is an important factor in the choice of a mallet, however, performers may be able to increase the amount of weight applied to the bar using their stroke alone. Since the effect of an increase in mass is halved, while an increase in the effect of velocity is squared ($E = \frac{1}{2}MV^2$), changes of stroke weight will not be as apparent as changes in stroke velocity. However, many percussionists still cite this variable as an important part of their technique. Tom Burritt uses stroke weight to increase the volume of the marimba without an increase in brightness.[83] Because higher stroke velocity decreases the amount of contact time with the bar, less high frequency components are damped, resulting in a brighter tone. In order to achieve a loud sound with a dark timbre, Burritt increases the amount of energy applied to bar mainly through stroke weight rather than stroke velocity. This method and others like it will be discussed further in the next chapter.

The point of contact with a marimba bar is another useful tool for changing the sound of the instrument. Because of the way in which a marimba bar vibrates, changes in the striking location are fairly significant in determining the timbre of the instrument. If the performer strikes the bar at the anti-nodal point for the fundamental frequency (center of

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[82] Johann Joachim Quantz, *On Playing the Flute*, Translated by Edward R. Reilly (London: Faber, 1966.) 75.
[83] Burritt, interview February 2018.

the bar), the resulting sound will have a strong fundamental and no response from the second mode of vibration. This is because the second mode of vibration has a nodal point in the center of the bar. If the performer strikes at the anti-nodal point for the second mode of vibration, the resulting sound will emphasize the frequency two octaves above the fundamental. Moore's study found that moving just one-half inch in any direction on a marimba showed significant difference in the timbre of the instrument.[84] His results, which have been confirmed by the current study, are as follows:

> Striking the bar at its center produced an initial response of a strong fundamental and extremely complex high frequency components. One-half inch from the center on the fourteen-inch bar, in addition to the fundamental, a very strong second partial occurred. Higher frequency components were of greater amplitude, and the total response had more intensity. Response intensity was greatest, as well as high frequency response, midway between the supports and the center. Moving the striking point further toward the supports, caused the fundamental response to be less apparent, the second partial relatively large in amplitude, and the other higher frequency components less apparent. At the supports, where the nodes of the fundamental are located, a strike caused an almost pure response of the second partial. Moving out from the supports toward the end, the above effects reversed themselves until, at the end, the response was almost identical to that of the strike between the center and the supports, as described above.[85]

Changes in the angle of contact are often neglected in percussion performance. While the ideal angle of contact transfers the total amount of energy to the bar, by changing angle performers can adjust the mass of the mallet, the contact area, and flexibility in just one motion, essentially giving them a second mallet for the price of one. As Stauffer points out these changes have the "greatest effect in the glancing blow technique."[86] Changes of

[84] Moore, "Acoustics of Bar Percussion Instruments," 130.

[85] Ibid.

[86] Stauffer, "A Motion and Muscle Study of Percussion Technique," 295.

mallet angle are most significant with a non-uniform shaped mallet head and should be used more frequently by performers.

As will be seen in the next chapter, many percussion and marimba method books point to additional variables in the production of sound quality and articulation. Some well-known examples include discussions of grip tension, as well as the motion of the mallet after making contact with the bar, referred to as stroke direction. While some of these variables need further examination, many of them are secondary to the change they create in the variables listed above. Several studies, examined further in chapter 5, have concluded that when all other variables remain unchanged, factors of grip tension, and stroke direction have no discernable effect on the sound of the marimba. This is not to say that performers cannot use these techniques to change the articulation or tone quality of the marimba, but that their use does not directly affect the sound. Instead, these additional variables can help the performer make a change in the primary variables discussed above.

CHAPTER 4

THE STATE OF MARIMBA PEDAGOGY

"Legato" and "Staccato" Strokes

Method books provide considerable insight into the understanding or, at times, the misunderstanding of percussion articulation. While many books fail to mention articulation at all, the books that do raise the issue often contradict one another or are too vague to gain any insight on the matter. For some books, the best advice offered for marimbists is to "try to imitate wind and brass articulation sounds."[87] Hardly any methods go to the length of defining various articulations, but instead skip to teaching various stroke types that are meant to produce different sounds. The most widely known stroke types in percussion performance are commonly referred to as the legato stroke and the staccato stroke. Gary Cook believes these terms have "misled [percussionists] to think of playing as 'black and white'... This is unfortunate because there is a lot of 'gray' and other colors in between."[88] The use of the terms legato and staccato stroke have led to other problems as well.

Mainly through tradition, percussionists have adopted this terminology without considerable debate about the meaning behind it. Some have accepted this terminology with the caveat that in percussion "legato and staccato have slightly different meanings from those they have for wind and string players."[89] While this may be traditionally so, it leads to the confusion and misunderstanding that surrounds the current state of percussion articulation and there is no reason why this disconnect in terminology should

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[87] Tom C. Rhodes, Donald Bierschenk, Tim Lautzenheiser, *Essential Technique: Keyboard Percussion* (Milwaukee, WI: Hal Leonard Publishing Corporation, 1993) 2.

[88] Gary Cook, *Teaching Percussion* (Belmont, CA: Schirmer, 2006) 188.

[89] Mitchell Peters, *Fundamental Method for Timpani* (Van Nuys, CA: Alfred Publishing Co., 1993) 30.

continue to be the case. Also, as will be seen in the literature, percussion educators frequently disagree about the execution of the legato and staccato strokes. With various teachers referring to stroke direction, arm weight, grip tension, or velocity, it is hard to come across a universal definition of these two strokes. For percussion pedagogy and performance to advance, a common understanding of how these techniques affect articulation is paramount.

One of the earliest methods to address marimba articulation is Thomas McMillan's *Percussion Keyboard Technique*. Perhaps the first to use the terms staccato stroke and legato stroke in regard to the marimba, McMillan lays out various techniques for the execution of these two strokes. When performing a staccato stroke, McMillan instructs the student to use "a firmer than normal grip […] This, in addition to extremely quick wrist snap, will produce a staccato stroke."[90] For legato strokes he insists, "The grip is very relaxed, almost as if the sticks were feather-light."[91] For McMillan these strokes are executed through a change in grip tension and speed of stroke.

Buster Bailey's *Mental and Manual Calisthenics for the Modern Mallet Player* was written around the same time as McMillan's text and the two seem to mostly agree on the approach to articulation. Bailey describes staccato and legato playing through changes of grip tension and stroke velocity:

> If the mallets are held tight and short, sharp wrist motions are used, the only possible results can be sounds of a staccato nature. However, if the stick is allowed a little more freedom within the handgrip and smoother, relaxed wrist motions are

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[90] Thomas McMillan, *Percussion Keyboard Technique*, (Miami, FL: Pro Art Publications, 1962), 4.

[91] Ibid.

used, the player will then be able to feel and project a smoother, more legato-like style.[92]

As discussed in the previous chapter, stroke velocity does have a measurable impact on the amount of energy applied to the bar and therefore the loudness and length of vibration. Stroke velocity also changes the amount of contact time between the mallet and the bar; shorter contact time produced from a fast velocity stroke will in fact cancel less high frequency vibrations and produce a brighter timbre. However, as observed in experiments carried out by Erick Saoud, grip tension alone has no effect on articulation.[93] This may be a controversial revelation to many percussionists who have witnessed a change in sound when they grip the stick tighter. The reason for their disbelief is due to the fact that greater tension creates the necessary conditions for a faster velocity stroke. Ortmann found this true of piano playing, stating, "Rigidity tends to produce greater key-speed (hence louder tone) than relaxation."[94] In this sense grip tension is the means to creating a faster velocity stroke, while not having a distinct effect on articulation itself.

Consider the process of hammering a nail into a piece of wood. A certain degree of tension is needed to transfer energy from the arm and wrist through the hammer to the head of the nail. If you attempt to hammer the same nail with a looser than normal grip, less velocity will be created throughout the motion, and you will be stuck hammering for quite a long time. Raush relates this concept to the marimba, "As the marimbist tenses the

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[92] Elden Bailey, *Mental and Manual Calisthenics for the Modern Mallet Player*, (New York: Warner Bros, 1963), V.

[93] Erick Saoud, "The Effect of Stroke Type on the Tone Production of the Marimba," *Percussive Notes* 41, no. 3 (June 2003): 40-46.

[94] Otto Ortmann, *The Physical Basis of Piano Touch and Tone* (London: Kegan Paul, Trench, Tubner & Co., 1925) 34.

muscles of his forearm to increase finger pressure on the mallet handle, the mallet can no longer travel under its own momentum at the instant of impact; rather, it will be hurled at the bar with more speed, and hence, result in a louder attack."[95] A greater grip tension allows performers to move the mallet in a faster velocity, creating a louder and longer sound. A more relaxed grip allows the performer to let the stick move more freely and at a slower velocity, creating what will be a softer and shorter sound. However, by increasing or decreasing grip tension without a similar increase or decrease in velocity the sound of the marimba will remain unchanged! In fact, it is possible, although unnatural, to grip the mallet with an extreme amount of tension and still achieve a soft volume, short duration note with few high frequency components simply by moving through the stroke at a slow velocity.

Neither Bailey nor McMillan specifically define what staccato (detached) and legato (connected) mean in a musical context. Instead they focus only on changes in technique meant to achieve these articulations. While some of their methodology is flawed, the 'legato' and 'staccato' strokes they describe will ultimately produce different articulations through a variation of stroke velocity. Alterations in stroke velocity are measured in the amplitude, duration, and timbre of the note. As has been discussed, velocity affects the amount of energy applied to the bar and the amount of contact time with that bar. By playing with a faster stroke, performers transfer more energy to the bar, and because every action has an equal and opposite reaction, the faster moving mallet will stay in contact with the bar for less amount time. The resulting sound of a fast stroke, or Bailey and McMillan's

[95] John Richard Raush, "Four-Mallet Technique and Its Use in Selected Examples of Training and Performance Literature for Solo Marimba" (DMA diss., The University of Texas at Austin, 1977) 161.

staccato stroke, on the marimba is one that vibrates louder, longer, and has more upper partials present. The slow velocity stroke, or legato stroke, transfers less energy to the bar, but stays in contact for longer, creating a darker yet ultimately shorter sound. This stroke creates a note with less pointed articulation, which mirrors the technique of legato tonguing on wind instruments or portato playing on string instruments, however, it does not create a true legato.

True legato refers to the connection of a group of notes smoothly and without attack, whereas staccato refers to the separation or detachment of a group of notes. In wind and string performance, legato and staccato affect the space in-between notes or the decay of each sound. The strokes mentioned by Bailey and McMillan will have the greatest effect not on the end of each note, but on the front of the note or the attack. Also, as the so-called staccato stroke does create a more pointed attack, it actually creates a longer lasting note than the legato stroke. If the goal is to create shorter sounds, the use of the staccato stroke as described by Bailey, McMillan, and others, accomplishes the exact opposite.

Rebbeca Kite has argued that because "legato notes sound connected to each other and staccato notes sound separated from each other, a single note cannot be staccato or legato."[96] Kite's book, *Reading Mallet Percussion Music*, defines legato playing as having no "perceptible interruption between notes."[97] She goes on to correctly assert that because each note must be struck to create vibration, "a true legato is not possible on the marimba."[98] In this method book, Kite attempts to avoid confusion by giving new names to

[96] Rebecca Kite, "Marimba Articulation and Phrasing," *Percussive Notes* 52, no. 6 (November 2014): 52.
[97] Rebecca Kite, *Reading Mallet Percussion Music* (Leesburg, VA: TakiMusic. 2010) 115.
[98] Ibid.

stroke types. Instead of the traditional 'legato' and 'staccato' stroke, she offers the following three stroke types:

Normal

- Normal grip on the mallet handle
- Relaxed full stroke on the marimba bar

Connecting

- Loose grip on the mallet handle
- Down stroke into the marimba bar

Separating

- Firm grip on the mallet handle
- Quick, snappy stroke up and off the marimba bar[99]

While Kite's attempt to rebrand these strokes with new names was more than warranted, a 2014 article written by her has abandoned this terminology and returned to using the misleading labels of legato and staccato stroke.[100]

Another percussionist who has discussed articulation at length is Leigh Howard Stevens, in his book *Method of Movement for Marimba* and later in *The Marimbist's Guide to Performing Bach*. He points out that the natural or default articulation of most wind and string instruments is quasi-legato.[101] The dragging of the bow or the release of a breath lends itself to connection between pitches. On the marimba, Stevens likens our method of tone production to striking a pool ball or swinging a golf club. The harder one hits a golf ball the further it will travel, and once in motion the distance that the ball travels is out of our control. This is similar to the marimba, where the length of a note is determined by

[99] Ibid.

[100] Kite, "Marimba Articulation and Phrasing," 52.

[101] Leigh Howard Stevens, *Marimbist Guide to Performing Bach* (Asbury Park, NJ: Keyboard Percussion Publications, 2012) 17.

how hard or how fast the bar is struck. This lends marimbists an incredible amount of control over the initiation of a sound but makes control of the connection between notes much harder.

Stevens strongly agrees with Kite that one cannot have a single legato tone.[102] Because legato refers to the connection of two or more notes together, it is impossible to have a single legato note or for that matter a single legato stroke. The decay of the marimba bar makes connecting notes through a true legato impossible. Stevens laments percussionists who advise to play with "smooth and even strokes" to achieve legato. He offers this rebuttal to proponents of this idea:

> On percussion instruments such as the marimba and piano, immediately after the note is "poked or stroked," it decays. By the time the next note is poked ¾ no matter how fast the passage is ¾ whether the next note is one second later or one nano-second later ¾ the previous note is *always* already *softer*. The first note has had a certain amount of time to decrescendo from the high point of its attack. If the new note is *stronger than the volume level that the previous note is ringing*, the listener hears clear articulation. That is the opposite of "legato."[103]

However, Stevens also offers an alternative approach to create the illusion of connecting notes together. This is achieved by "matching the attack of a second note to the ring of the previous note."[104] If the attack of the secondary note is softer than the decay of the first note, the notes seem to be connected in a legato style. This illusion, when performed well, can mask the attack of notes underneath a slur marking, however, this means that every legato passage would have to be played with a diminuendo. Because of this fact, this technique does not work for passages longer than a few notes.

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[102] Leigh Howard Stevens, *Method of Movement for Marimba* (Asbury Park, NJ: Keyboard Percussion Publications, 1979) 23.

[103] Stevens, *Marimbist Guide to Performing Bach*, 17.

[104] Stevens, *Method of Movement for Marimba*, 23.

While true legato is not possible on the marimba, true staccato can be achieved quite easily. When executing staccato articulation wind and string players stop vibration using the tongue or the bow, which creates a detached sound. Marimbists can cease vibration by pressing the mallet head into the bar after contact. Linda Pimental describes Celso Hurtado making use of this technique quite early in the history of the instrument, "Mr. Hurtado made frequent use of a simple, dry staccato, attained by forcing the mallet head to remain on the note long enough to dampen the after-ring. He used this technic for long, completely staccato passages."[105] Stevens also uses this technique to stop the bar from vibrating in the same manner as stopping the reed with the tongue or stopping the bow on the string. Presumably because the term staccato stroke was already in wide use, Stevens and others have named this technique the 'dead stroke'.[106] Allen Otte creates another distinction in his playing between the 'dead stroke', in which one should "not allow the stick to rebound, but hold it firmly into the bar," and the 'drop stick', in which one should "neither lift off the bar, nor press into it."[107] By creating this distinction, Otte allows for more than one degree of detachment, or staccato, between notes. Marimbists' use of the term staccato stroke is usually reserved for a stroke that comes off the bar quickly, but in reality, the 'dead stroke' and 'drop stick' create a true staccato by leaving the mallet in contact and damping the vibrations of the bar. The fact that these damped strokes are referred to as anything other than staccato strokes is yet another example of what is wrong with many marimbists' use of articulation terminology.

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[105] Linda Pimentel, "Evolving Solo Technics for the Marimba," *Percussionist* 10, no. 4 (Summer 1973): 107.

[106] Stevens, *Method of Movement for Marimba*, 22.

[107] Allen Otte, "Considerations for Compositions for Marimba" *Percussionist* 11, no. 4 (Summer 1974): 131.

The two strokes mentioned by Bailey and McMillan do create a difference in the articulation of the marimba; however, the actual effects produced by these strokes do not match the interpretations of legato and staccato found on other instruments. The "legato stroke", as taught by many percussionists, is more closely aligned with portato than any other articulation. The sound produced by the "staccato stroke" is actually more closely aligned with marcato articulation, because it creates a loud, pointed attack. The marimba, under normal playing conditions, cannot perform a true legato, but can create the illusion of this articulation through careful dynamic contouring. If marimbists wish to play staccato, they should use damping after striking the note. In addition, marimbists and percussionists should use their ears to confirm whether the techniques they use in performance truly match the articulation of other instruments.

Stroke Direction

Another main focus of many marimba method books is the movement of the mallet after making contact with the bar. In addition to the staccato and legato strokes, Thomas McMillan's *Percussion Keyboard Technique* makes mention of a third stroke, which he labels the "up-stroke":

> The up-stroke is started from a position approximately two inches above the note. The note is struck by "snapping" the wrist. As soon as the note is struck the mallet must be lifted quickly to achieve clear articulation. Moreover, this type of stroke allows the maximum amount of tone to be drawn out of the instrument.[108]

McMillan's comments on the up-stroke are contrasted with comments made by Nancy Zeltsman, professor of percussion at the Boston Conservatory. She describes her method for a

[108] McMillan, *Percussion Keyboard Technique*, 4.

basic marimba stroke in the following passage:

> After making contact, I purposefully stop the mallet about a half-inch above the surface of the bar. After the momentum of the downstroke, stopping the mallet requires some tensing of your wrist muscles. In doing so […] I have the image that I am actively trapping the resonance of that bar with the mallet head. Acoustically, I believe there may actually be something to this. […] This basic stroke achieves a full sound; it could also be described as a "tenuto" stroke. In contrast, if, after the point of contact, you lift your mallet head very quickly off the bar, you will hear a thinner, more airy sound.[109]

In both of these examples, the authors focus on stroke direction (up-stroke and down-stroke) to produce different sounds, however, the effect achieved by these two strokes is at odds. McMillan uses a quick up-stroke to draw more sound out of the instrument, where the same stroke used by Zeltsman produces a thinner, more airy sound. Zeltsman, in contrast with McMillan, believes that the down-stroke is what achieves a fuller tone. How can these two methods assert opposite hypotheses?

To be certain, stroke direction is an important aspect of performing on any percussion instrument. Stevens correctly asserts, "Any percussion stroke has a minimum of two parts."[110] These two parts happen (1) before contact with the instrument and (2) after contact with the instrument. When discussing stroke direction, percussionists are referring to the second part of the stroke, or what happens after contact with the bar. Sofia Dahl explains this concept well, stating that stroke direction "describes the desired final position of the stick in preparation for the next stroke… [Stroke directions] are commonly used to help the performer plan and carry out the right movements."[111] Percussionists use stroke directions in order to change the height

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[109] Nancy Zeltsman, *Four-Mallet Marimba Playing: A Musical Approach for All Levels* (Milwaukee, WI: Hal Leonard, 2003) 10.

[110] Stevens, *Method of Movement for Marimba*, 17.

[111] Sofia Dahl, "The Playing of an Accent – Preliminary Observations from Temporal and Kinematic Analysis of Percussionists," *Journal of New Music Research* 29, no. 3 (2000): 226.

of the mallet from one stroke to the next. An increased stroke height allows percussionists more distance in which to accelerate the speed of the mallet, making it easier to play at a louder dynamic. A relatively low stroke height gives the percussionist less distance to accelerate the mallet and generally lends itself to soft playing. Because of this fact, changes in the height of the mallet, through the use of various stroke directions, are essential to performing dynamic changes efficiently.

There are four main stroke directions that are commonly used by percussionists: The up-stroke, the down-stroke, the full-stroke, and the tap. The up-stroke is any stroke where the mallet begins from a low height and after contact is raised to a higher position. Percussionists use the up-stroke to change from a soft dynamic to a louder one. When moving the opposite way, from a loud dynamic to a softer one, percussionist usually use a down-stroke. A down-stroke is any stroke where the mallet strikes the instrument from a high position and then is left down or lower to the instrument after contact. Full-strokes begin with the mallet in a high position and return to the same position after contact with the instrument. Efficient percussionists use full-strokes to keep the dynamic level constant from one note to the next. Taps begin with the mallet in a low position and return to the same position after contact. Taps are essentially full-strokes that begin and end at a lower height. This has led many performers and teachers to classify only three main stroke directions instead of four.

In terms of articulation, stroke direction can be an effective tool when executing various accent marks. Notes with accent marks (tenuto, marcato, accent) are given an added amount of stress and volume by performers. When preparing to play these accented notes, percussionists usually will lift the mallet higher in order to create a louder sound; unaccented notes are then played by returning the mallet to a lower height. This concept is complicated by the fact that percussionists must not only keep track of stroke direction for one mallet, but most often two or four mallets. For example, the following musical passage, seen in figure 4.1, is played with an alternating hand-to-hand sticking and has been marked with the most efficient use of stroke direction (F=full-stroke, U=up-stroke, D=down-stroke, T=Tap).

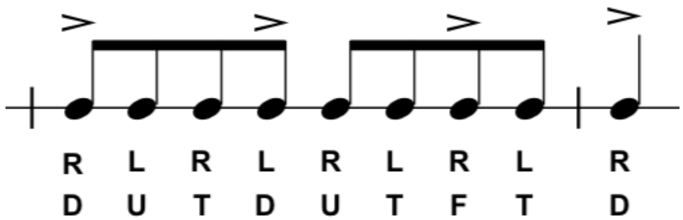

Figure 4.1: Accent Pattern with Stroke Directions

The use of stroke direction on a single surface, like a snare drum, is a relatively simple task. For marimbists, however, the use of efficient stroke direction is a more complicated endeavor. In addition to vertical stroke direction, marimbists must also consider horizontal and sagittal motion when preparing for the next note of a passage. While very few current methods discuss strokes in this way, marimbists constantly have to use stroke directions that move right, left, forward, and backward, in order to move around the instrument.

Using stroke direction correctly can lead to an efficient and successful performance of a piece of music. However, it must be stated that a change in stroke direction only affects the preparation for notes that follow it. Direction of the mallet after making contact with the bar does not, as McMillan and Zeltsman suggest, affect the tone or articulation of a singular note. This fact has been proved by several studies, including the current one. Analysis of these experiments and their data is discussed in the next chapter. An up-stroke, as McMillan has suggested, does not draw more tone out of the instrument on its own, nor will it create a thinner, more airy sound as Zeltsman states; neither does a down-stroke create a fuller tone on its own accord.

What these strokes do change is the height of the mallet in preparation for the next note; this adjustment in height gives the performer the exact amount of space needed to accelerate the mallet before contact. Strokes that begin from a high position will usually create a faster velocity and therefore a louder sound. Strokes that begin from a low height have less room to accelerate and usually create a softer tone. However, there are exceptions to these rules. If the performer is able to substantially accelerate the mallet from a low height, the sound produced will be louder and last longer. If the performer starts from a high position and keeps acceleration to a minimum, the sound produced will be soft and short. What happens after making contact with the bar does not influence the tone of the marimba. As experiments carried out by Saoud, Schultz, and Lipscomb prove, when mallet velocity and energy remains constant there is no difference in whether the mallet is left low to the bar or raised high above it after contact. This is not to discourage the use of stroke direction, but to point out its ineffectiveness on the duration or timbre of a singular note. In groups of multiple notes, stroke direction allows performers to efficiently prepare for changes in dynamics. Up-strokes are most useful when the following note is an accent. The up-stroke does not produce the accent, but simply lifts the mallet into a higher position, making it easier to execute a louder sound through acceleration. When an accent is followed by a softer note, performers' best option is to use a down-stroke on the accent and play the softer note from a lower height.

Stroke direction also has a profound effect on the visual aspect of a performance. While these visual motions have been shown to have no aural effect on a singular note, experiments performed by Schultz and Lipscomb note that they do have an effect on the perception of tone.

This study and others like it will be discussed in full in the next chapter. The results show clearly that visual gestures used by marimbists do change the audience's perceived length of a note. Articulation is a subjective art, and the use of visual gesture in performance is even more so. What is to one audience member a long visual gesture can undoubtedly be interpreted as a short gesture to another audience member. However, many percussionists have attempted to codify and use visual gestures in their performance. Tom Burritt draws influence from pianists in his use of visual gesture on the marimba, stating that piano performers "would never lift [off the keyboard] on a long note… If it's a long note then I will stay down over the note, especially if I'm slurring it to the next note; then I will come up off that slurred note much more quickly."[112] When this visual technique is combined with an audible drop in volume between the two notes, the illusion of true legato playing is achieved.

The concept of visual gesture is important not only for marimba performance, but on all percussion instruments. Jazz drummer and educator Jim White instructs his students that the motion of a stroke creates the sound of our instrument. He draws influence from dancers, the best of which "subdivide the beat with their motion."[113] For White, it is the motion between each note that has the most effect on our visual and aural performance. White credits his thinking on this topic to his teacher and mentor, Ed Soph. On marimba and other percussion instruments, stroke direction influences the motion between a group of notes. While stroke direction does not have a primary influence on the articulation of a singular note,

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[112] Tom Burritt (Professor of Percussion, University of Texas) interviewed by Adam Davis, February 2018.

[113] Jim White (Professor of Jazz Studies and Drum Set, University of Northern Colordao) interviewed by Adam Davis, February 2018.

percussionists should contemplate its use in visual gestures and in the efficiency of a performance.

Stroke Velocity and Stroke Weight

As was discussed in the previous chapter, the amount of energy applied to the marimba is the most important factor when determining the volume and duration of a note. Energy can be calculated by the equation $E=\frac{1}{2}MV^2$, one half mass times velocity squared. By increasing energy, marimbists are able to achieve louder notes that continue to vibrate for a longer period of time. Stevens has written that the length of a marimba note is determined only by the energy applied to the bar, stating, "less energy means shorter ring length."[114] By this same logic, more energy means longer ring length.

The most efficient way of increasing energy is through stroke velocity. Any increase in this variable has an exponential effect on the amount of energy applied to the marimba, and therefore a large effect on the duration and volume of each note. Most marimba methods mention two or three separate stroke velocities in performance, however, just as there are many degrees of articulation, there are many degrees of stroke speed. Marimbist Pius Cheung uses five different stroke speeds in his playing, a concept which he originally learned from timpanist Don Liuzzi. From slowest to fastest, Cheung's list of stroke velocities is comprised of the following:[115]

- Slow-Motion-stroke
- Relaxed-stroke

[114] Stevens, *Method of Movement*, 22.

[115] Pius Cheung, *Colors: Intermediate Etudes for Marimba* (Eugene, Oregon: Pius Cheung, 2011) 7-8.

- Normal-stroke
- Assertive-stroke
- Plosive-stroke

With some practice and experimentation, this list could be expanded to include six or seven distinct stroke velocities. Each increase in stroke speed adds an exponential amount of energy to the marimba. By using progressively faster strokes, marimbists can achieve notes that sound louder and last for longer durations. Perhaps the best quality of Cheung's system for stroke velocity is that it avoids the misleading and confusing association with legato and staccato found in many earlier methods.

Besides its effect on volume and duration, stroke velocity also has an effect on timbre. Because every action has an equal and opposite reaction, the velocity of the mallet is equal to the velocity of the bar at the moment of contact. After impact, the mallet and bar move in opposite directions at equal speeds. As stroke speed increases, the amount of contact time with the bar decreases. Less contact time with the bar means the highest frequency components will vibrate freely. A longer period of contact time between the mallet and the bar resulting from a slower velocity stroke will damp the highest modes of vibration. This dark timbre note, created by the slower velocity stroke, will contain fewer overtones and have a stronger fundamental pitch. A bright timbre sound also can have a strong fundamental, but will contain a multitude of high frequency overtones. When a fast stroke velocity is used on the marimba, the mallet and the bar stay in contact for a shorter amount of time; this in turn creates a brighter timbre note, due to the full activation of the highest modes of vibration.

The direct relationship between velocity and timbre makes it very difficult for percussionists to achieve a loud volume note that has a dark timbre. A crescendo performed on the marimba through an increase in stroke velocity is accompanied by a similar increase in the brightness of the tone. For players who pay no attention to timbre this is a not a problem, however, players who want to control the volume and timbre of the marimba separately must examine this issue closely.

Tom Burritt compares this problem to issues of tone production on brass instruments. Brass players "use their embouchure to control how much air is going through the instrument. When a low brass player blows too much air that's not controlled they get a splatty sound… The best brass players learn how to make a really loud sound, but also protect the tone."[116] The best marimba players must also control their tone and find a way to separate dynamics and timbre. One way to combat this problem is through the use of stroke weight.

Weight, or the amount of force exerted on an object by gravity, is proportional to mass, which is a factor in the amount of energy applied to the bar. By increasing the amount of weight in the stroke, percussionists are able to produce more energy and therefore a louder sound. This increase in energy through stroke weight will not be as significant as that of an increase in stroke velocity. Stevens points out, "Any effect of a change of mass is halved, whereas any effect of a change of velocity is squared."[117] Still, variations in stroke weight are an important part of percussion and marimba technique. Pius Cheung's book of etudes, entitled *Colors,* lists five distinct levels of involvement from

[116] Tom Burritt, interview February 2018.

[117] Stevens, *Method of Movement*, 22.

various parts of the body, which affect stroke weight. From the lightest to the heaviest, the following stroke weights are used by Cheung in performance:[118]

- *Finger-stroke* is a stroke controlled by the fingers or grip. It is the smallest and weakest of the five muscle groups, and therefore produces the lightest tone.
- *Wrist-stroke* is a stroke controlled by the wrist. It produces a slightly heavier sound than a finger-stroke.
- *Forearm-stroke* is a stroke controlled by the forearm. Since it is a much bigger muscle group than the fingers and wrist, the sound produced with a forearm-stroke is much heavier than that of a finger or wrist-stroke.
- *Full-Arm-stroke* is a stroke controlled by the entire arm. It is an extremely heavy stroke that I only use sparingly for 'special peasante' moments.
- *Body-stroke* utilizes the entire body. I use this stroke extremely sparingly. The focus is to use all the body's energy from one's center on one note or chord.

Because stroke weight affects the amount of energy applied to the bar, marimbists can use this variable to change dynamics and the length of each note. Burritt and other marimbists also use stroke weight in an attempt to better control marimba timbre. When increasing stroke velocity, the amount of contact time with the bar is significantly reduced, resulting in a tone with many high frequency components. The inverse relationship between stroke velocity and contact time creates a bright timbre, however, stroke weight has no relation to contact time. By keeping stroke velocity at a minimum and increasing volume through stroke weight, the timbre of each note remains dark. Burritt explains his approach to this method as follows:

> The important thing is to keep the mallets low. If you're in a slow piece or a slower rhythm then you have the benefit of more motion, but the key is to not turn the stroke until the very last minute, because if you get the stroke velocity going too fast you're in real trouble. I come down really close to the keyboard with more weight from the shoulders and the core of your body, and then turn the wrist with a little bit of tension at the very last minute before contact. The result is that the stick hits the keyboard before it gets moving too quickly, but it has all this weight behind it. This is easier to do in slower music obviously, but I still do it in faster pieces. It's just

[118] Cheung, *Colors: Intermediate Etudes for Marimba*, 6.

> the same motion, but smaller. For me it was a way of separating timbre from dynamics, so now when I crescendo and I want to keep the sound darker you won't see me change height, but you'll hear a big crescendo.[119]

This technique and others like it require a great amount of control from the performer. It also requires marimbists to refine their ears in order to hear subtle differences in timbre. Through careful study of stroke weight and stroke velocity marimbists can gain control over the volume, timbre, and duration of each note.

Sticking Patterns

Gary Chaffee offers another solution to the problem of marimba articulation. Chaffee believes that "one of the primary ways of teaching concepts of articulation can be through sticking pattern types."[120] Chaffee states that hand-to-hand or alternating sticking is the most staccato option available to percussionists and that "double stroke patterns (RRLLRRLL), when played in an open fashion, can produce a very legato sound".[121] This notion is echoed by Alison Shaw who writes, "A double can also be used to imply a slur… Using a double, and allowing the first stroke to sound with a little more weight than the second stroke, creates this effect nicely."[122] By using what Chaffee calls "compound patterns," or combinations of double and single strokes, percussionists can achieve a wide variety of articulations. In this method a common slur-two-tongue-two articulation in the winds could be matched with the sticking pattern RRLR LLRL. These combinations can be permutated to create limitless patterns of articulation. Chaffee believes that by using this

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[119] Tom Burritt, interview February 2018.

[120] Gary Chaffee, "Sticking Patterns: A Musical Approach," *Percussionist* 10, no. 2 (Winter 1972): 47.

[121] Ibid., 48.

[122] Alison Shaw, "Guidelines on Two-Mallet Sticking," *Percussive Notes* 40, no. 3 (June 2002): 37.

system a percussionist playing in tandem with another instrument "could match not only the rhythmic aspect, but could also use a matching articulation, making for a much greater degree of similarity between the parts."[123]

The concept of using sticking patterns to create articulation has been used by a number of leading percussionists on a variety of instruments. Jim White points to several characteristic sticking patterns used in bebop drumming, where combinations of single and double strokes "create patterns of accents and imitate melodic shapes."[124] These sticking patterns can help percussionists match more closely with what other musicians are doing.

While many percussion instruments are played with only two sticks, marimbists are familiar with techniques allowing them to hold four or even six mallets at a time. When using four or more mallets marimbists have more choices in creating unique sticking patterns. Marimbists usually number their mallets from left to right, or low to high (1-2-3-4), and create sticking patterns using these numbers. While many beginning players rely on the two inner mallets for the majority of their playing, more advanced players will utilize all four mallets in a concept called sequential sticking. A common sequential sticking pattern for an ascending major scale is 2-3-4-1-2-3-4-2, but many other possibilities exist.[125] By using this type of sticking, marimbists can group multiple notes together visually and aurally.

One marimbist who has taken this concept to the next level is Theodor Milkov, by combining the above sticking principles with the Moeller method. The Moeller method is a

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123 Chaffee, "Sticking Patterns: A Musical Approach," 48

124 Jim White, interview February 2018.

125 Stevens, *Method of Movement*, 97.

concept codified and taught by Sanford Moeller as a natural way of playing the snare drum. While this concept has evolved over many years, one of the most important aspects is the ability of performers to group multiple notes into one large motion making playing more efficient. Milkov has adapted this technique to the marimba by performing "many notes in one motion… instead of hitting many notes separately."[126] By grouping many notes into one motion, Milkov effectively creates the illusion of connection or legato. He can change the grouping of notes by carefully selecting "the spot to place the Moeller movement."[127]

Carefully crafted sticking choices on the marimba have a direct impact on the visual component of performance as well. While the focus of this study is mainly on auditory effects alone, visual gestures do have an influence on the perception of sound. If these visual gestures are coupled with changes in dynamics and timbre, marimbists can create the illusion of a wide variety of articulations. For many percussionists sticking is a personal choice, however, marimbists who are comfortable with many different sticking patterns can apply them in a musical context and have a great amount of impact on the perceived articulation of the instrument.

The Marimba Roll

Buster Bailey asserts that, "there is no way to produce a natural sustained tone [on the marimba] other than the quasi sustained sound produced by trills or rolls."[128] Traditionally marimba rolls are executed by alternating single strokes between each hand

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[126] Theodor Milkov, *Transparent Fluidity*, 2014: 40'02''.

[127] Ibid., 49'40''.

[128] Bailey, *Mental and Manual Calisthenics for the Modern Mallet Player*, V.

in an attempt to keep the bars ringing for a longer period of time. Marimba rolls are subject to the same considerations of sound production as other techniques, including playing area, stroke velocity, and stroke weight. While the term roll is used by many percussionists, a more accurate description of the sound produced by this technique is a tremolo.[129] For other instrumentalists, performing a tremolo is a special effect that creates an audible alternation between two notes. However, when asked to sustain a sound, most marimbists will use this technique without question. With hard mallets this technique can sound rhythmic and even abrasive, but with softly wrapped mallets the impact of each stroke can be minimized enough to imitate a sustained sound. In addition to soft mallets, Zeltsman notes the importance of roll speed in different registers of the instrument.

> In general, on marimba, it's best to roll rather slowly on low notes, at a medium speed in the middle register, and quite fast in the high register. This acknowledges the natural length of resonance in different registers. We can roll slower in the low register because the resonance is naturally long and full; we need to play a fast roll in the upper register because the natural resonance is short.[130]

Many other considerations go into creating a sustained sound on the marimba including how to start and end a roll. When rolling on a chord, marimbists have the option to start on the left hand, on the right hand, or to begin by striking all notes in unison. Marimbists can end a roll with a clear release or by decreasing the volume to nothing.

The options for marimba rolls increase dramatically in the context of four-mallet playing. Stevens lists five basic roll types for four-mallet marimba playing.[131]

1. The traditional "two against two" roll, in which the two mallets of the right hand alternate with the two mallets of the left hand.

[129] Nathan Daughtrey, "The Marimba Roll: A Necessary Evil?" *Percussive Notes* 52, no. 4 (July, 2014): 36.

[130] Zeltsman, *Four-Mallet Marimba Playing*, 15.

[131] Leigh Howard Stevens, "Rolls and Notation." *Percussive Notes* 19, no. 1 (Fall 1980): 61.

2. The double lateral roll (also called the Musser, Stevens, or Ripple roll), in which each mallet strikes the marimba consecutively in various permutations. The most common sticking for this roll is 1-2-4-3 or 4-3-1-2, but other possibilities exist.
3. The "Guatemalan" roll, in which all four mallets strike the keyboard simultaneously. This is an adaptation of a two-mallet Central American technique.
4. The independent roll, in which the rotation of one hand creates an alternation between two pitches. This technique is the traditional two-mallet roll executed by one hand.
5. The "mandolin" roll, in which the mallets of one hand are held in a vertical position so that one mallet strikes the bar from above and one mallet strikes from below. This roll is only effective on the lower manual of the instrument.

Stevens applies these techniques in a variety of combinations in his playing, sometimes using a traditional roll in one hand and a double lateral roll in the other. More recently, Stevens has coined another type of roll based on the independent roll mentioned above. When using the right hand to roll independently on a single bar, Stevens often uses the other hand to initiate a roll on a new pitch. This technique allows "a few precious micro-seconds additional time for the right hand to get into position."[132] A touch roll, as Stevens calls it, can eliminate the space that is often heard when a player has to shift the mallets from one bar to the next.

If executed correctly, rolls can create the illusion of sustained sound on the marimba; however, this technique can be ineffective in many situations. Nathan Daughtrey argues that rolls are less effective in extended passages of much dynamic variation, in the upper range of the marimba, and in widely voiced chords.[133] All of these scenarios bring attention to the alternation, or tremolo, of different pitches. When the attack of each note in

[132] Stevens, *Marimbist Guide to Performing Bach*, 21.

[133] Daughtrey, "The Marimba Roll," 37.

a roll is clearly heard, the tendency of the listener is to hear a fast rhythm rather than a sustained sound. Daughtrey asks marimbists to listen to their sound like a non-percussionist and question whether a their "roll/tremolo actually creates a smooth, sustained sound."[134]

Mallet Choice

Various other methods for marimba articulation have been described in articles, master classes, or lectures. Some of the most prominent ones focus on playing area and mallet choice.[135] Mallet choice is perhaps the biggest factor in marimba articulation, as each mallet creates a slightly different attack than the next. Doug Demorrow states that mallet choice gives percussionists control over the "shape or the type of attack… whether we make it pointed or soft."[136] With the wide array of implements available to percussionists today, variations in articulation through mallet choice are virtually limitless. Strangely enough, most method books tend to gloss over issues of mallet choice or leave it out entirely. Stevens offers the most insight, stating, "Softer mallets can often produce longer sounds than hard mallets."[137] This counterintuitive notion is explained through images of the sound envelope created by two different mallets, seen in figures 4.2 and 4.3.

[134] Ibid., 38.

[135] Douglas Overmier, "Within Striking Distance: A Look at Percussion Articulation," *The Instrumentalist* 65, no. 9 (April 2011): 38-43. Mark Ford, "Interpretation on Marimba," *Percussive Notes* 37, no. 6 (December 1999): 48-49.

[136] Doug Demorrow (President and Owner, Demorrow Instruments LTD.) interviewed by Adam Davis, March 2018.

[137] Stevens, *Marimbist Guide to Performing Bach*, 18.

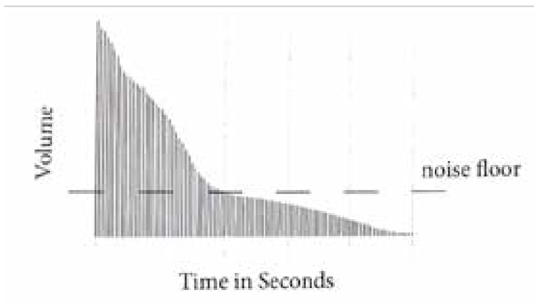

Figure 4.2: Sound Envelope of a Hard Mallet

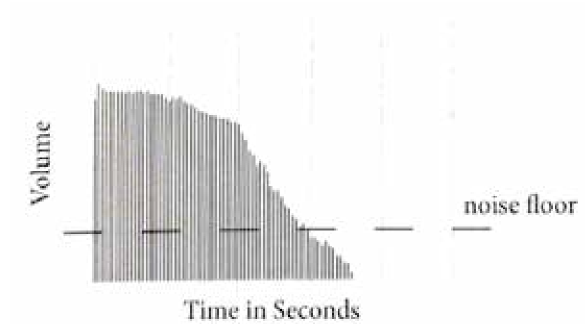

Figure 4.3: Sound Envelope of a Soft Mallet

As demonstrated by these graphs, the harder mallet creates a sound that ultimately lasts longer, however, the sound created by the softer mallet stays above the noise floor for a longer amount of time. The noise floor is the sum of all ambient background noise; any sound produced below the level of the noise floor cannot be heard by an audience. The sound of a hard mallet will produce a sharp, pointed attack that decays quickly, while a softer mallet will create a fatter and warmer response. In addition to changes in duration, James Moore found that differences in mallet hardness also affect timbre. In comparing soft and hard mallets, Moore found that "the harder mallet displayed many quickly decaying, high frequency elements of a very complex nature and high amplitude."[138]

Mallet hardness or softness depends on two main properties: the core material and the type of wrap. The majority of marimba mallets today are made with either rubber or plastic cores. A variety of plastics can be used and even blended with rubber to create a unique synthetic material. Each mallet core has different properties of elasticity or flexibility. When a core material is soft, or more flexible, the mallet will deform slightly on contact with bar and stay in contact for a longer period of time. Hard core materials are less

[138] James Moore, "Acoustics of Bar Percussion Instruments" (PhD diss., The Ohio State University, 1970) 131.

prone to deformation and stay in contact with the bar for a shorter amount of time. The result is that softer, more flexible core materials tend to damp the highest modes of vibration, which creates a darker overall sound. Harder core materials create a brighter attack, because of less contact time with the bar.

Most mallet manufactures use harder core materials in what they call multi-tonal mallets. The reasoning behind this being that when played with a slow velocity stroke these mallets will achieve a dark timbre, and as velocity is increased they will get progressively brighter. This effect is present in both rubber and plastic cores; however, the change is more significant in mallets made with plastics. Mallets with soft rubber cores, in which changes of timbre are less apparent, are often called single-tone mallets.

The amount of contact noise or impact sound is an important consideration in mallet articulation as well. These factors are mainly influenced by the tightness and material of the mallet wrap. A large variety of different yarns are used in marimba mallets today, each with unique properties of attack. While clarity of attack can be an issue in wind and string performance, marimba and percussion performers rarely have this problem. This had led several marimbists to create mallets that minimize the effect of attack through a relatively loose mallet wrap. Mallets made in this manner include the mallet lines of Leigh Stevens, Mark Ford, Tom Burritt, and others. When designing his signature mallets, Tom Burritt's goal was to minimize the sound of the attack "so we can actually hear the sustain of the bar."[139]

[139] Tom Burritt, interview February 2018.

Other factors that affect the articulation of a marimba mallet include its size, shape, and weight. Mallet weight affects the amount of energy that can be applied to a bar. A heavier mallet will ultimately produce a louder sound. The size and shape of the mallet affect the contact area with the bar. A larger contact area produced by a large mallet head will damp out some of the high frequency components contained in the bar. When using mallets with a small head, Moore found that "fewer higher partials will be damped since the area of contact is smaller on the surface of the bar."[140]

Considerations of mallet choice certainly are one of the most important factors in marimba articulation. The amount of variety found in marimba mallets today gives performers almost unlimited articulation possibilities. Variables of mallet shape, size, weight, core material, type of wrap, and tightness of wrap, all contribute to a unique sound for each mallet. However, once a marimbist has chosen a set of mallets for a piece of music they will need ample time to make a change, and many pieces do not offer this luxury. When marimbists need to change articulation during the course of a piece, their options are limited to variations in technique.

[140] Moore, "Acoustics of Bar Percussion Instruments," 28.

CHAPTER 5

SCIENTIFIC RESEARCH

Previous Studies

Percussion method books present a wealth of opinions on the techniques that affect marimba articulation, however, the majority of these pedagogical works are based on their author's personal beliefs rather than scientific research. In order to gain a better understanding of the techniques that are most effective in changing marimba articulation, one must study previously published research and conduct new experiments that examine these techniques. As seen in the previous chapters, the marimba stroke is fairly complex and can include many variables. Stroke velocity, stroke angle, stroke direction, stroke weight, grip tension and stroke placement are just some of the techniques mentioned by leading percussionists. While some of these variables directly affect the sound, many others have a secondary purpose. To review, the following eight variables, mentioned in chapter 3, are effective tools in changing the tone of the marimba:

Variables of Mallet Choice

1. The weight of the mallet
2. The total area of contact of the mallet
3. The flexibility or elasticity of the mallet core
4. The mallet wrap

Variables of Technique

5. The velocity of the mallet at the moment of contact
6. The weight of the mallet at the moment of contact
7. The point of contact on the bar
8. The angle of contact with the bar

The other variables mentioned by various method books have not been shown to have an audible effect on the sound of the marimba, on their own accord. Instead, secondary techniques like grip tension and stroke direction make changes of stroke velocity or stroke weight more efficient. As shown by the following experiments, changes of grip tension or stroke direction without a subsequent change in velocity or weight will have no effect on the sound of the marimba.

Erick Saoud's study of stroke type on the tone production of the marimba examines grip tension and stroke direction specifically.[141] In his experiment, Saoud recorded four subjects performing a legato stroke followed by a staccato stroke on three different pitches of a marimba. Saoud's definition of these strokes is similar to the ones found in methods by McMillan, Bailey, and Kite.

> The legato stroke, or relaxed stroke, used in this experiment can be defined as a free, uninhibited stroke allowing for maximum rebound off the bar, put into motion with the absolute minimal amount of tension in the hand and fingers. A combination of fingers, hand, wrist, and forearm (from the elbow to the wrist) were used to perpetuate the stroke. There were no extraneous lifting or pulling motions of the mallet off the bar. The stroke was made from an approximate height of 12 to 14 inches.
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> The staccato stroke, or inhibited stroke, used in this experiment can be defined as a sharper stroke achieved by supplying a moderate amount of tension in the fingers and hand in the grip on the mallet. A combination of fingers, hand, wrist, and forearm were used, but with more focus placed on a quick, snapping motion of the wrist. The stroke was made from an approximate height of 4 to 7 inches.[142]

The main difference between these two stroke types, in this experiment, centers on grip tension, stroke direction, and stroke height. Subjects of the experiment were asked to

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[141] Erick Saoud, "The Effect of Stroke Type on the Tone Production of the Marimba," *Percussive Notes* 41, no. 3 (June 2003): 40.

[142] Ibid.

perform these two strokes in the same place on each bar and with the same amount of amplitude or volume. In order to achieve the same amplitude from each stroke, the subjects would have to apply the same amount of energy to the bar, energy being a function of mass and velocity ($E= \frac{1}{2}MV^2$). While the subjects changed stroke direction, grip tension, and stroke height from one stroke to the next, the stroke weight and stroke velocity remained the same.

The results of this study focused on the duration of each sound produced. By comparing the duration of each legato stroke to that of the corresponding staccato stroke, Saoud found that out of 24 pairs of strokes, only one had a difference above .10 seconds. All other pairs were either identical or differed by less than .10 seconds. As Saoud points out, "It is highly questionable whether this difference would be audible to any listener."[143] He concludes, "Duration cannot be affected through grip manipulation, with either a 'staccato' or 'legato' stroke."[144] This again proves that the traditional terminology for strokes in marimba and percussion articulation is flawed. The amount of energy applied to the bar is paramount to determining how long and how loud the marimba will sound.

The marimba is still a relatively young instrument, and studies of this type have been conducted only in the last fifty years. James Moore was one of the first to examine the acoustics of keyboard percussion instruments at length. Besides discussing the important topics of bar tuning and resonators, Moore also looks at the effects of mallet size, mallet hardness and stroke placement on the marimba bar. Moore was able to prove that changes in these variables cause a significant difference in the sound of the marimba. Mallets made

[143] Ibid., 45.

[144] Ibid.

from a hard material are less flexible and are less prone to deformation under impact. Moore's recordings of these mallets found because they stayed in contact with the bar for less time, the resultant tone had more higher frequency partials. This was compared to a mallet made from softer material, which stayed in contact with the bar longer due to a higher flexibility and therefore canceled out more of the high frequencies. Moore states, "In comparisons of the wave form produced by hard and soft mallet heads, the relations between the fundamental and second partial were the same. The differences came with the higher frequency elements. The harder mallet displayed many quickly decaying, high frequency elements of a very complex nature and high amplitude."[145] Moore found that the size of the mallet head had much the same effect on the tone of the marimba. A large mallet head will make contact with a larger percentage of the bar and cancel out some of the highest frequencies, where a small mallet head will allow these frequencies to fully activate.

While changes in mallet size and hardness are very effective, Moore's study found that the placement of each stroke on the bar had the greatest effect on tone quality. Each bar has multiple nodal points and anti-nodal points for each mode of vibration. By striking each bar in different areas, the performer can emphasize the different frequency components contained within. Moore found that just "moving half an inch from the center on a fourteen inch bar showed significant difference."[146] He offers more detail, stating, "If the point of contact between the mallet and the vibrator is at the anti-nodal point of the fundamental, the tone produced will emphasize this component and the partial tones will

[145] James Moore, "Acoustics of Bar Percussion Instruments" (PhD diss., The Ohio State University, 1970) 131.
[146] Ibid., 130.

be less prominent. By moving the point of contact away from this anti-node point of the fundamental the higher partials will become increasingly prominent."[147]

More recent studies of tone production on marimba have gone in a different direction to Moore and Saoud. There is a large quantity of research now in existence that focuses on the visual aspect of making a marimba stroke and how this influences the perception of sound. While many of these studies have proven a correlation between visual gestures and auditory perception, the main goal of this study is not to focus on imagined perceptions, but instead on authentic aural results. Several studies have attempted to classify which gestures are most effective and how to put them to use in marimba performance.[148] However, the use of visual, or ancillary, gestures is a subjective art and can have positive or negative effects depending on the intended audience. As Tyson Voigt's in-depth study of these gestures concludes, "Determining the exact way in which ancillary gestures alter audience perception is impossible due to its subjective nature. Perception is different from person to person because of variation in first-hand experiences, preconceived notions, musical training, and philosophical principles within musical aesthetics."[149] Also, music is not always accompanied by a visual component. How can percussionists alter articulation on audio recordings or in blind auditions without the aid of visual enhancements? As Michael Schutz argues, "No gesture can substitute for attention to

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[147] Ibid., 94.

[148] Broughton, Mary C. and Catherine J. Stevens. "Analyzing Expressive Qualities in Movement and Stillness: Effort-Shape Analyses of Solo Marimbists' Bodily Expression." *Music Perception* 29, no. 4 (2012): 339-357. Broughton, Mary C. and Catherine J. Stevens. "Music, Movement and Marimba: an Investigation of the Role of Movement and Gesture in Communicating Musical Expression to an Audience." *Psychology of Music* 37, no. 2 (2009): 137-153.

[149] Tyson Voigt, "Hearing What You See: A Case for the Use of Ancillary Gesture in Individual Percussion Performance" (DMA diss., University of Miami, 2016) 34.

phrasing, sound quality, note accuracy, or any of the other myriad factors important to music making."[150] These studies of visual perception are only included in this study because they prove a fundamental point about the aural results of stroke types on marimba articulation.

One of the first experiments in this field was carried out by Michael Schutz and Scott Lipscomb.[151] For this experiment, marimba virtuoso Michael Burritt was video and audio recorded performing a series of three notes. The three notes were performed with the following gestures:

1. Long gesture – referred to in various method books as a legato stroke
2. Short gesture – referred to as the staccato stroke
3. Damped Stroke – referred to as the dead stroke, where the performer stops the vibration by pressing the mallet head into the bar.

The visual and auditory components of these recordings were split and shown in various combinations to a group of trained musicians. When analyzing the audio data alone Schutz and Lipscomb were able to see clear differences between damped and un-damped stroke types, however, the difference between the long gesture and short gesture was indistinguishable.[152] When listening to the audio components alone, the subjects could also not distinguish between the sound of a long gesture or a short gesture. However, when given the appropriate visual stimuli, the subjects correctly identified the intended stroke. More importantly, when the subjects were given mismatched audio and visual records the

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[150] Michael Schutz and Fiona Manning, "Effectively Using Affective Gestures: What Percussionists need to know about movement and perception," *Percussive Notes* 51, no. 2 (March, 2013): 30

[151] Michael Schutz and Scott D. Lipscomb, "Hearing Gestures, Seeing Music: Vision Influences Perceived Tone Duration," *Perception* 36, (2007): 888-897.

[152] Ibid., 892.

visual gesture was shown to influence their perception of the sound. When the visual component of the long gesture was shown in conjunction with the audio portion of the short gesture, the subjects' perception was of a longer duration note. These findings lead Schutz and Lipscomb to conclude that "the difference in duration between long and short marimba notes is 'perceptual' rather than 'real', caused by visual artifacts of the performer's acoustically inconsequential gesture," adding, "gesture length is irrelevant in the absence of visual information."[153] A similar study conducted six years later by Schutz and Fiona Manning confirmed these results, stating, "long and short gestures are acoustically ineffective."[154] These studies, and others like them, prove that visual aspects are a central part of live performance, but they do not alter musical articulation on their own. Visual gesture is the means to the end, not the end in and of itself.[155]

The Current Study

In the course of this study, several experiments were carried out in order to demonstrate some of the ways performers can change marimba articulation. While previous research has focused on visual influence over perception and matters of stroke type, very few studies have looked specifically at stroke velocity. One study did conclude that stroke velocity could be quantified by a performer but did not determine the relationship between stroke velocity and sound quality.[156] Because stroke velocity is such

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[153] Ibid., 894-896.

[154] Schutz, "Effectively Using Affective Gestures," 29.

[155] Voigt, "Hearing What You See," 43.

[156] Michael Edward Haldeman, "Stroke Velocity in Two-Mallet Marimba Performance" (DMA diss., The University of North Carolina at Greensboro, 2008).

an important factor in the duration and amplitude of the marimba's sound, the following experiments were devised to explore its effect further.

Also, Moore's examination of hard and soft mallets yielded important results, but today mallet choice goes far beyond these two categories. There are many elements that are hypothesized to affect the sound created by a marimba mallet, including the core material, the weight of the mallet head, the size of the head, the material of the mallet handle, and the type of yarn used for the wrap. Because questions of mallet hardness have been explored in previous research, this current study looks at mallets within the same degree of hardness. The mallets chosen for this study vary in their weight, size, type of wrap, type of core, and type of handle.

Finally, the current study confirms what others have found in regards to stroke placement and stroke direction. The results show a great amount of difference in the frequency components created by each beating spot on the bar. Stroke direction was also tested and found to have no effect when the amplitude of the bar remained the same, confirming what Saoud and Schutz have concluded in previous experiments.

Method

The instrument used for this experiment was a Malletech 5.0 Octave Roadster Marimba. The instrument was allowed to adjust to the room temperature of the recording studio, whereafter the resonators were tuned in direct relation to pitch of each bar. Three *Earthworks SR30* microphones were setup directly above the marimba bars that were to be tested: E_2, E_4, and E_6. In order to assure the same stroke placement for each recording the pitches directly to the right of these bars (F_2, F_4 and F_6) were marked with tape, see figures 5.1-5.3. Three stroke placements were marked and tested on each bar:

- The center, or anti-nodal point for the fundamental and the 3rd mode of vibration
- The node, or nodal point of the fundamental
- Just off-center, at the anti-nodal point for the 2nd mode of vibration

Figure 5.1: Stroke Placement Markers, Bar E_2

Figure 5.2: Stroke Placement Markers, Bar E_4

Figure 5.3: Stroke Placement Markers, Bar E_6

Figure 5.4: Microphone Placement, Bar E_2

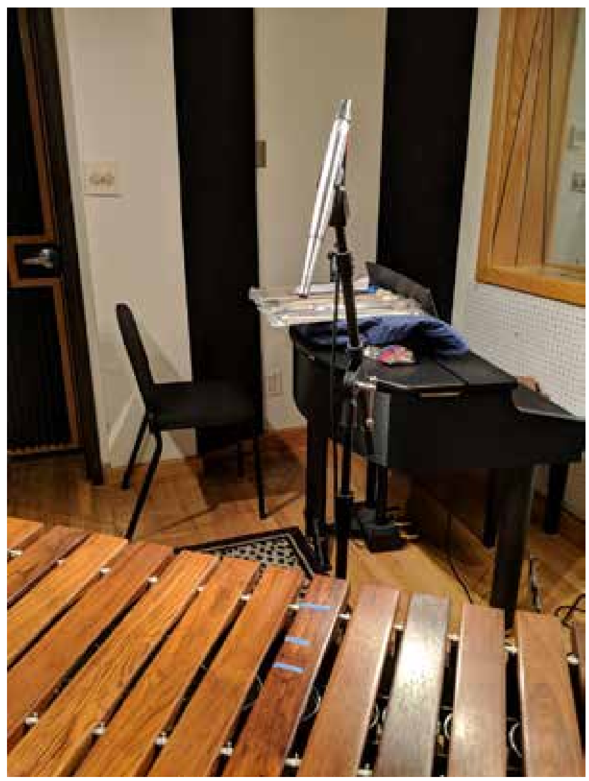

Figure 5.5: Microphone Placement, Bar E_4

Figure 5.6: Microphone Placement, Bar E_6

For each placement on the bar two recordings were made, one with a fast stroke velocity and one with a slow stroke velocity. The velocity of these two strokes was relative and not measured precisely, however, the relationship of the two strokes remained constant. In other words, there were no slow velocity strokes that were faster than their counterparts. The strokes were executed by the author and the data was processed through a 3D Spectrogram made by the audio software company *Izotope*. This type of graph shows duration of a tone on the left axis, frequency components on the right axis, and displays the amplitude or volume on a color spectrum.

In all, nine different mallets were tested in this experiment, bringing the total number of recordings to 162. The nine different mallets, all made by *Innovative Percussion*, are a small cross section of the many options available to percussionists today. The mallets all fall within the range of medium hard and vary in the type of core material, mallet weight, type of wrap, mallet handle, and mallet size. A list of the recorded mallets and their specifications are found in Table 5.1, along with pictures (with and without wrap). Of note is the WU 3 which has a plastic core topped with a rubber tip, which makes changes in mallet angle even more important.

An additional 4 recordings were made to test the effect of stroke direction. These recordings were conducted on the pitch E_4, using the IP 3106 B mallet and striking in the anti-nodal point for the 2nd mode of vibration (just off-center of the bar.) In this experiment a fast velocity stroke was executed using an up-stroke. The mallet started from a height of 4cm off the bar and after making contact with the bar, the mallet was raised to a height of 30cm above the instrument. The opposite stroke direction, down-stroke, was then tested with the same velocity stroke. The mallet began at a height of 30cm above the instrument and after contact was left down at a height of 4cm off the bar. The last two recordings were made in the same manner, but with a slow velocity stroke for both. These recordings were again processed using the *Izotope* 3D Spectrogram in order to show duration, amplitude, and the frequency components of each stroke.

Table 5.1: List of Recorded Mallets

Mallet Name	Core Material	Weight	Wrap	Handle	Image
IP 3106 B	Rubber	32g	Wool Blend	Birch	

Mallet Name	Core Material	Weight	Wrap	Handle	Image
IP 3106	Rubber	32g	Wool Blend	Rattan	
Weighted IP 3106 B*	Rubber	38g	Wool Blend	Birch	
* This mallet was augmented with the addition of several rubber bands just below the mallet head, adding weight to the mallet.					
ENS 20	Rubber	36g	Latex	Rattan	
IP 813	Rubber	29g	Extra-Soft Wool	Birch	

Mallet Name	Core Material	Weight	Wrap	Handle	Image
IP 240	Hard Rubber	26g	100% Wool	Birch	
IP 504	Hard Acrylic	24g	Imported Wool	Birch	
TB 3	Synthetic	31g	Alpaca Blend	Ramin	
WU 3	Acrylic and Rubber	27g	Wool Blend	Birch	

Variation in Playing Area

The results of this research is mainly shown in 3D spectrogram images. The images of all 166 recordings are found in the appendix. The 3D spectrogram shows the duration, amplitude, and frequency components of each recorded stroke. By examining these graphs, the artificial harmonic tuning of the marimba can be easily seen. As discussed in Chapter 3, the tuning of each mode of vibration is an important process that enhances the perception of pitch for each marimba bar. The first three modes of vibration for a marimba bar are tuned to the ratios of 1:1, 4:1, and approximately 10:1 with the fundamental. Modern manufacturers will focus on these first three modes and sometimes tune the fourth mode in the lowest octave, however, there are many other vibrations that are natural to the bar and cannot be tuned specifically.[157] As the pitch of the bar increases, the modes of vibration become harder to tune and are often above the range of human hearing. In the following recordings the following tuned modes of vibration were observed.[*]

Bar E_2

- Mode 1: 82.4 Hz (E_2), 1:1
- Mode 2: 330.8 Hz (E_4), 4:1
- Mode 3: 830.5 Hz ($G\#_5$), 10:1
- Mode 4: 1559.4 Hz (G_6), 19:1
- Mode 5: 1774.4 Hz (A_6), 21:1

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[157] Doug Demorrow (President and Owner, Demorrow Instruments LTD.) interviewed by Adam Davis, March 2018.

[*] Pitches and ratios are approximate and are often several cents sharp or flat depending on the amount of octave stretching in the tuning.

- Mode 6: 2495.2 Hz (D#$_7$), 30:1
- Mode 7: 3276.9 Hz (G#$_7$), 40:1

Bar E$_4$

- Mode 1: 331.0 Hz (E$_4$), 1:1
- Mode 2: 1321.7 Hz (E$_6$), 4:1
- Mode 3: 3419.8 Hz (G#$_7$), 10:1
- Mode 4: 5549.2 Hz (F$_8$), 17:1

Bar E$_6$

- Mode 1: 1329.5 Hz (E$_6$), 1:1
- Mode 2: 3968.2 (B$_7$), 3:1
- Mode 3: 6659.6 (G#$_8$), 5:1

As seen in the above data, the highest octave of the marimba is tuned slightly different than the bottom two-thirds of the instrument. This is because there is not enough material, in these smaller bars, to tune the ideal ratios. The modes of vibration can be seen in the spectrogram images as peaks or spikes in the color spectrum. These peaks are often connected with what looks to be a wall of extraneous frequencies. This wall of pink and purple seen in all the spectrogram images is the contact noise caused by the mallet hitting the bar. Some mallets exhibit less contact noise, but no mallet strikes without some degree of contact sound.

Musicians often discuss timbre in terms of relative brightness and darkness. A sound that activates more high frequency components will sound brighter compared to a sound with less high frequency components. By examining the 3D spectrogram one can determine how many modes of vibration are activated in a stroke, and therefore the relative timbre of that note. Recordings that activate a higher number of vibrations will sound brighter than recordings that only activate a few modes of vibration. By striking the bar at various points the performer can emphasize or deemphasize each frequency or mode of vibration contained within the bar. The experiments carried out in the current study focused on three striking locations: The center of the bar, the node, and just off-center.

When striking the bar directly in the center, the recordings show a strong response from the fundamental pitch and the third mode of vibration for each bar. The second mode of vibration is present, but greatly diminished in the recordings from the center of the bar. This is because the second mode of vibration has a nodal point directly in the center of the bar, a fact that is also true for the fourth mode of vibration. In many recordings, striking in the center of the bar causes the second mode of vibration, two octaves above the fundamental, to be indistinguishable from contact noise.

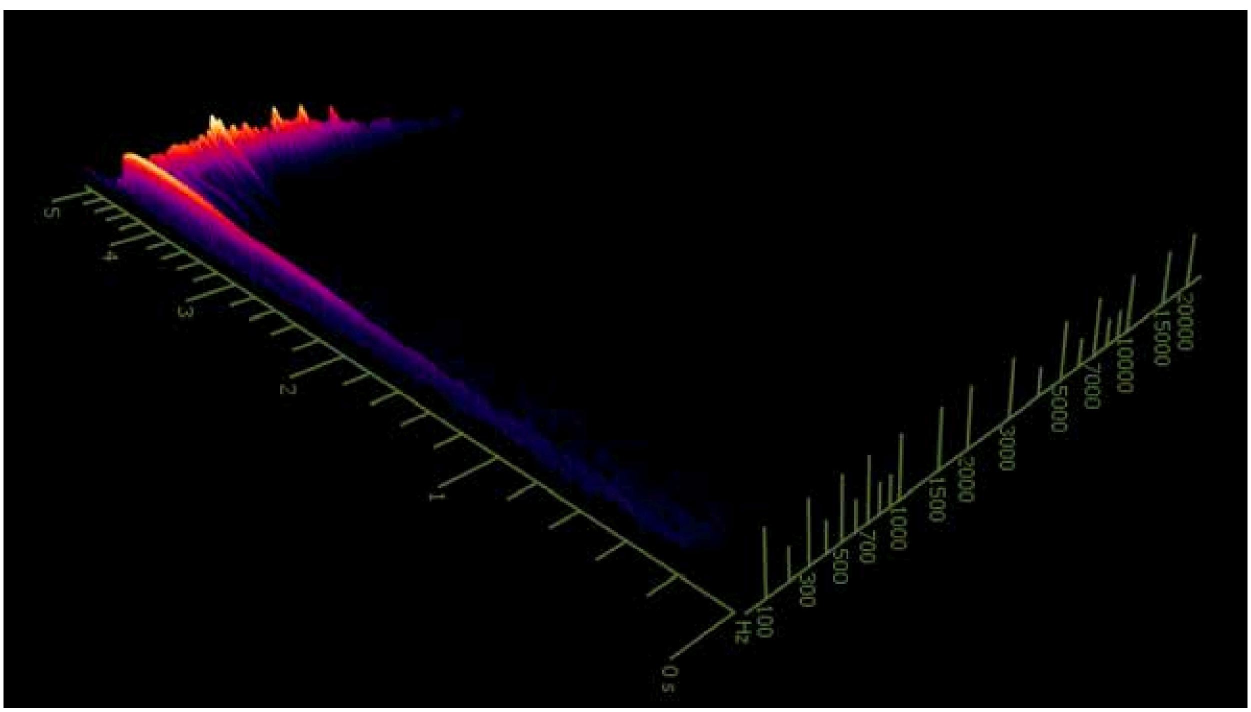

Figure 5.7: Mallet IP 504, Center of the Bar, Pitch E_2

In recordings from bar E_2, striking in the center of the bar also elicited a strong response from the fifth mode of vibration, and slightly weaker responses from the sixth and seventh modes of vibration. This is clearly visible in the recording from mallet IP 504 seen in Figure 5.7.

The spikes in volume seen in this spectrogram correspond with the fundamental or first mode of vibration, third mode, fifth mode, sixth mode, and seventh mode. Modes two and four, from pitch E_2, are present, but do not rise above the volume of contact noise. The highest amplitude vibration, or the loudest pitch, at contact is actually the third mode of vibration, $G\#_5$. This frequency decays within 0.8 seconds, at which point the fundamental is the only lasting vibration. The fundamental in this recording lasts for a duration of approximately 3.4 seconds.

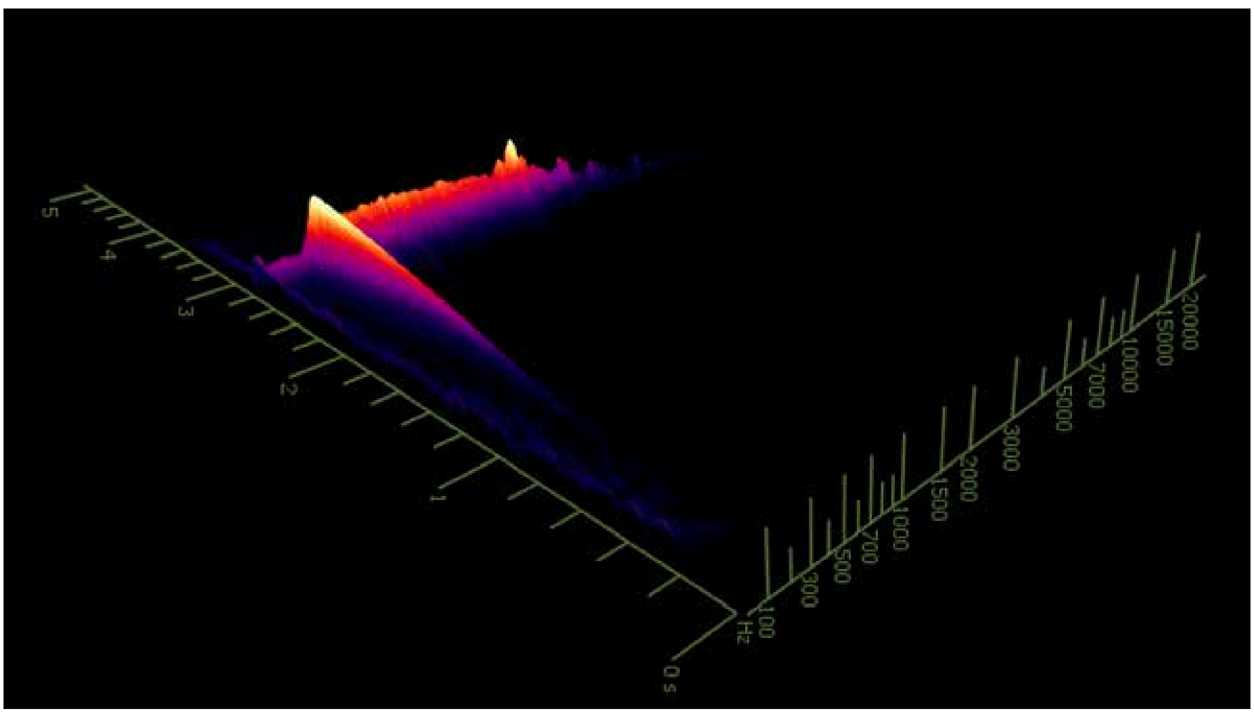

Figure 5.8: Mallet TB 3, Center of the Bar, Pitch E_4

On pitch E_4, striking the center of the bar had a similar effect. The strongest frequencies were from the fundamental and third mode of vibration, and the second and fourth modes were greatly diminished. The recording from mallet TB 3 (Figure 5.8) shows spikes in amplitude only on the fundamental and third mode of vibration.

Again the third mode of vibration actually exceeds the amplitude of the fundamental on contact, however, this frequency decays almost instantly. The fundamental lasts for a duration of about 1.7 seconds in this recording.

In the highest octave of the marimba, striking the center of the bar activated the fundamental pitch almost exclusively. The second mode of vibration is indistinguishable from the contact noise of the mallet and the third mode is absent as well. The spectrogram from mallet IP 3106 on pitch E_6 is shown in Figure 5.9. The sound produced by this pitch lasts for the least amount of time, less than 0.7 seconds.

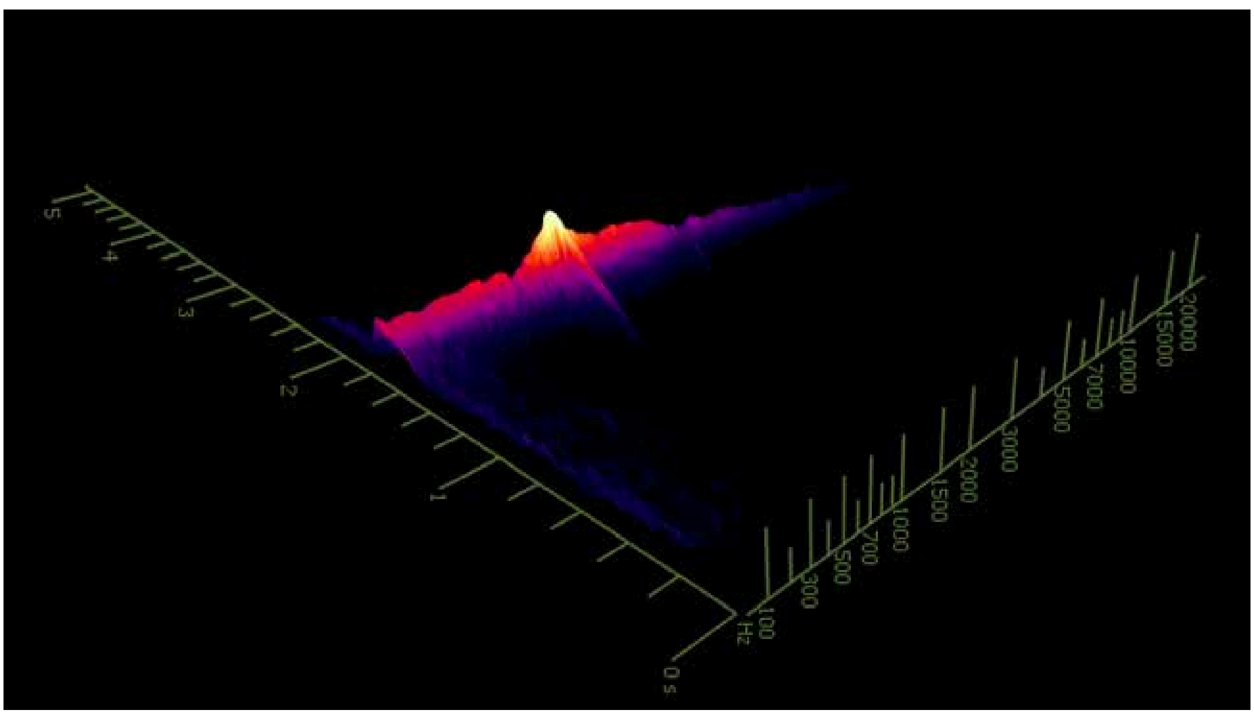

Figure 5.9: Mallet IP 3106, Center of the Bar, Pitch E_6

The node of the fundamental pitch on a marimba bar occurs at approximately 0.224 of the length of each bar. Manufacturers drill holes through this point and suspend the bar freely using string or chord. Most beginning percussionists are told to avoid this spot of the bar, because the fundamental pitch is extremely weak when striking there. While this beating area may not be ideal for normal playing situations, it can be useful in certain circumstances. Striking at the node of each bar elicited strong responses from second and third modes of vibration, with slightly weaker responses from higher modes of vibration. The fundamental pitch, or first mode of vibration, was present, but overall exhibited the weakest response of any mode.

On pitch E_2, the recording of mallet WU 3 shows a characteristic response when striking at the node.

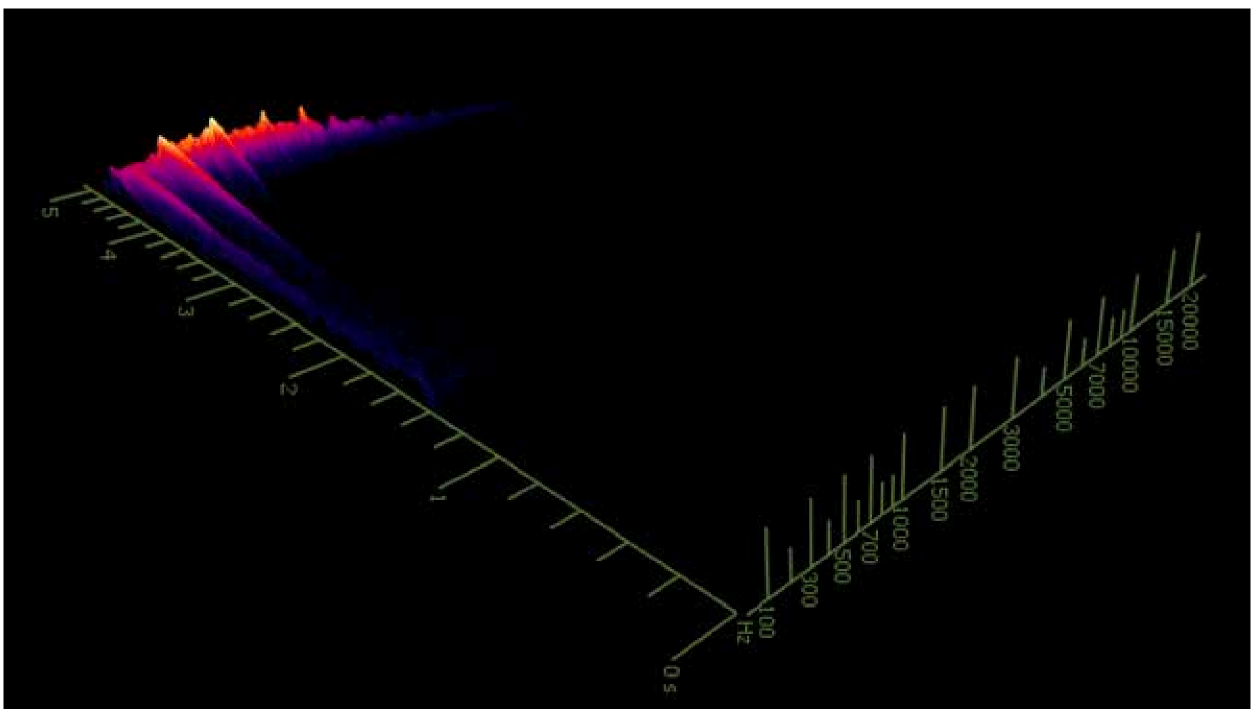

Figure 5.10: Mallet WU 3, Node, Pitch E_2

Modes of vibration one, two, three, four, and six are present above. The fifth mode of vibration is not present, as it shares this nodal point with the fundamental. The strongest amplitude at the time of contact is seen in the third mode of vibration, or $G\#_5$, which after its quick decay is overpowered by the sound of the second mode, E_4. The fundamental elicits the weakest response and never swells above the amplitude of the second mode of vibration. The relatively bright timbre of this note, only lasts for approximately 1.8 seconds; a marked difference between the duration of a strike in the center of this same bar, which lasted 3.4 seconds.

On the pitch E_4, a similar response is observed. The recording of mallet ENS 20 striking the node of bar E_4 is seen in Figure 5.11. Here the second mode of vibration has the strongest response, followed by weaker responses in the third and fourth modes. The fundamental is soft, but still present and outlasts the decay time of the higher frequencies. This note lasts for about 1.3 seconds.

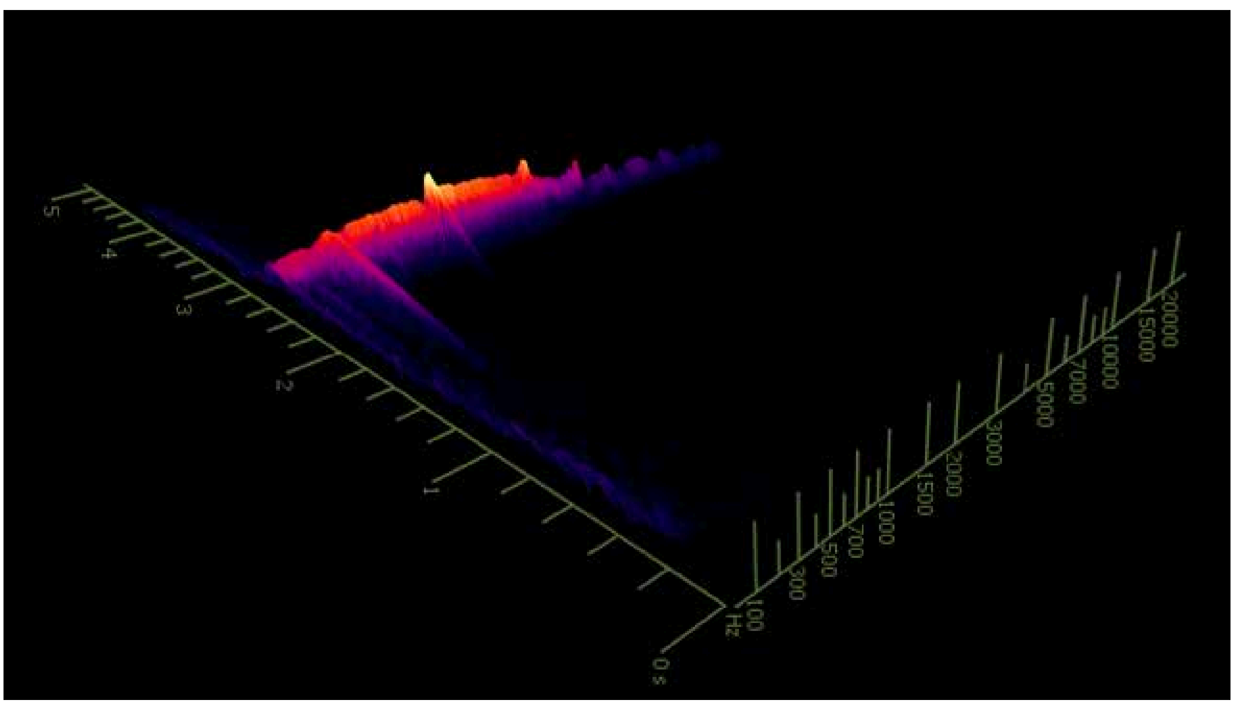

Figure 5.11: Mallet ENS 20, Node, Pitch E_4

Striking the node on bar E_6 activated the vibration of modes one and two and can be seen in the recording of mallet IP 240 in Figure 5.12. The duration of this note was approximately 0.5 seconds.

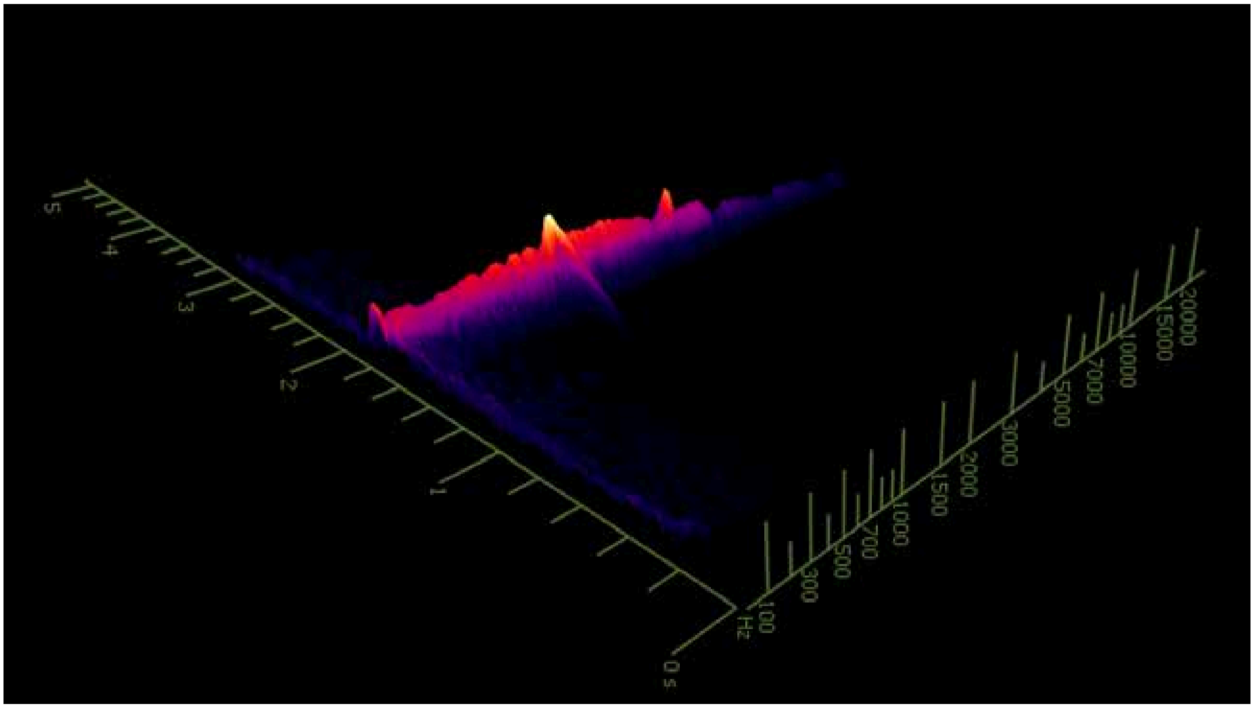

Figure 5.12: Mallet IP 240, Node, Pitch E_6

Most percussionists agree that striking just off-center on a marimba bar elicits the most ideal tone. This is because striking at this point, the anti-node for the second mode of vibration, fully activates the frequency two octaves above the fundamental, helping to solidify the perception of pitch. The third mode of vibration is slightly diminished, however, the fundamental pitch exhibits a strong response.

On pitch E_2, striking just off-center activates all seven modes of vibration, which can be seen in the recording of mallet IP 813 (Figure 5.13).

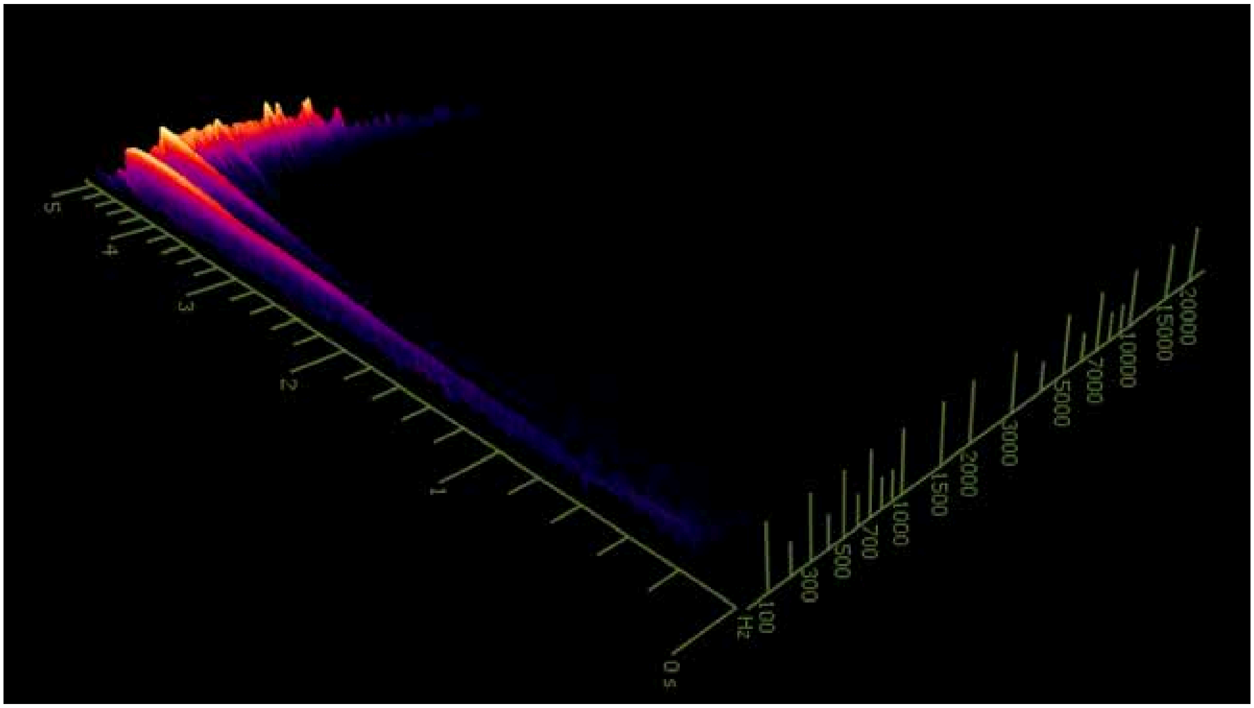

Figure 5.13: Mallet IP 813, Just Off-Center, Pitch E_2

As seen in this spectrogram image, modes two and six elicit the strongest amplitude at the time of contact. Modes three and seven are present in the sound, albeit with slightly weakened responses. After about 0.3 seconds, the amplitude of the fundamental pitch blooms above the second mode of vibration, which decays relatively quickly. The duration of this note lasts for about 3.5 seconds, which is similar to the duration observed when striking this bar in the center.

The recording of mallet IP 504 striking bar E_4 just off-center (Figure 5.14) shows strong responses from the first three modes of vibration, with a weaker response from the fourth mode of vibration.

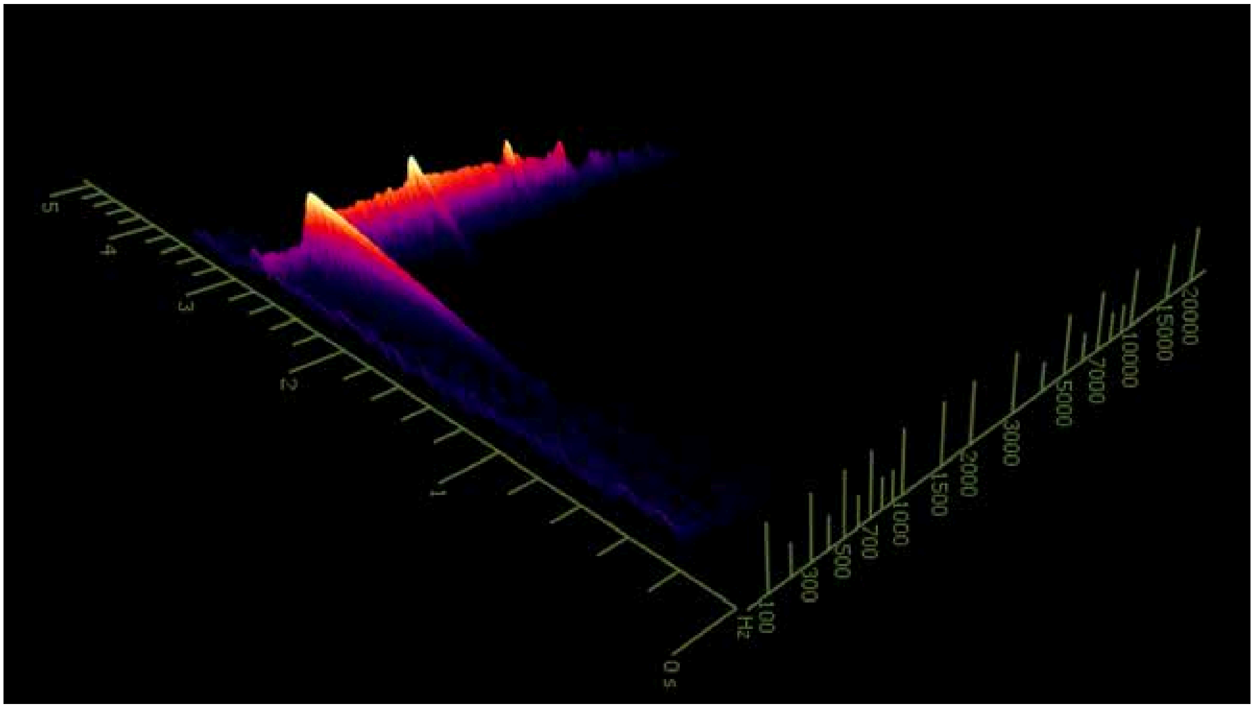

Figure 5.14: Mallet 504, Just Off-Center, Pitch E_4

Again, the initial sound of this note contains the highest amplitude response from the second mode of vibration, which vibrates approximately at the frequency for E_6. This frequency decays quickly and is outlasted by the fundamental pitch, which remains audible for about 1.7 seconds.

When struck just off-center the bar E_6 contains strong activation of the first and second modes of vibration. This is clearly seen in the recording of mallet TB 3 (Figure 5.15).

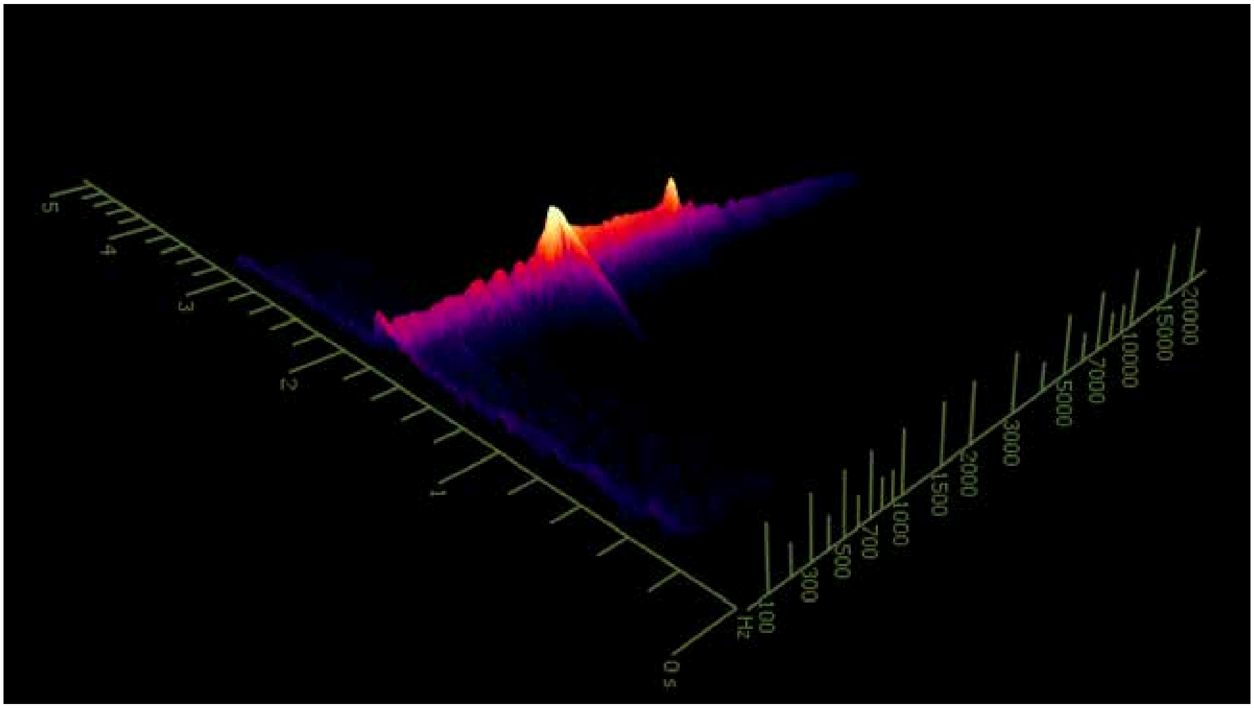

Figure 5.15: Mallet TB 3, Just Off-Center, Pitch E_6

The initial response of the second mode of vibration decays almost instantly, and the fundamental lasts for about 0.6 seconds.

The findings discussed above concerning stroke placement on the marimba are not new and are consistent with similar experiments carried out by James Moore. Moore's study examined even more striking areas on the bar and found that even small adjustments in the playing area had a great amount of impact on the timbre of the marimba tone. Marimbists that understand the multiple modes of vibration present in each bar can and should use this knowledge to their advantage when creating timbre changes in performance.

Variation in Stroke Velocity

While stroke placement has a direct impact on the timbre of the marimba, stroke velocity was also shown to have an impact. Stroke velocity has been discussed at length in the previous chapters and is an important factor in determining the amount of energy applied to the marimba bar ($E = \frac{1}{2}MV^2$). As more energy is applied to the marimba bar, the result is a louder and longer lasting note. An increase in velocity increases the amount of energy applied to the bar exponentially and is the most effective way of creating louder and longer notes. Velocity also impacts the amount of contact time with the bar. Because every action has an equal and opposing reaction, a faster stroke will, after impact with the bar, rebound quicker than a slow velocity stroke. When the mallet is allowed to stay in contact with the bar for a longer period of time, as in a slow velocity stroke, more of the high frequency vibrations will be damped. A sound containing less high frequency vibrations is perceived to have a darker timbre. In this way a slow velocity stroke can create a darker timbre than that of a fast velocity stroke. The timbre change between slow and fast strokes is present in all mallets; however, mallets with a plastic or synthetic core have a greater impact. Because of this fact, manufacturers often brand plastic core mallets as multi-tonal.

As seen in the previous chapter, many percussionists still refer to fast velocity strokes as staccato strokes and to slow velocity strokes as legato strokes. While debate over these strokes has continued for many years, it should be noted that neither of these motions connect or detach notes in a legato or staccato manner. The effect of these strokes will be most apparent on the attack of each note; however, the terms legato and staccato refer not to the front of each note, but to their decay. The decay of a fast velocity stroke actually takes a longer amount of time than that of a slow velocity stroke. Comparison of the recordings from fast velocity and slow velocity strokes show a great amount of difference, however, neither stroke resembles anything like legato or staccato. The following images (Figures 5.16-5.19) show some of the differences between fast and slow velocity strokes on pitch E_2.

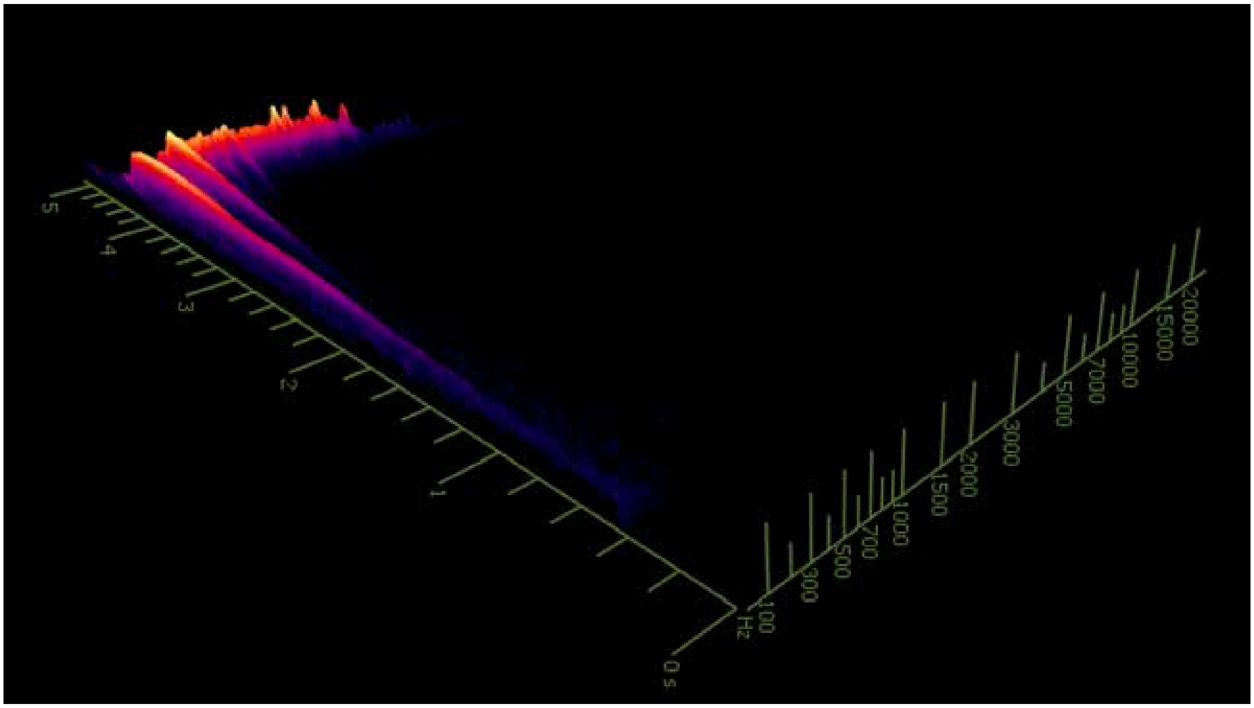

Figure 5.16: Mallet TB 3, Fast Velocity Stroke, Just Off-Center, Pitch E_2

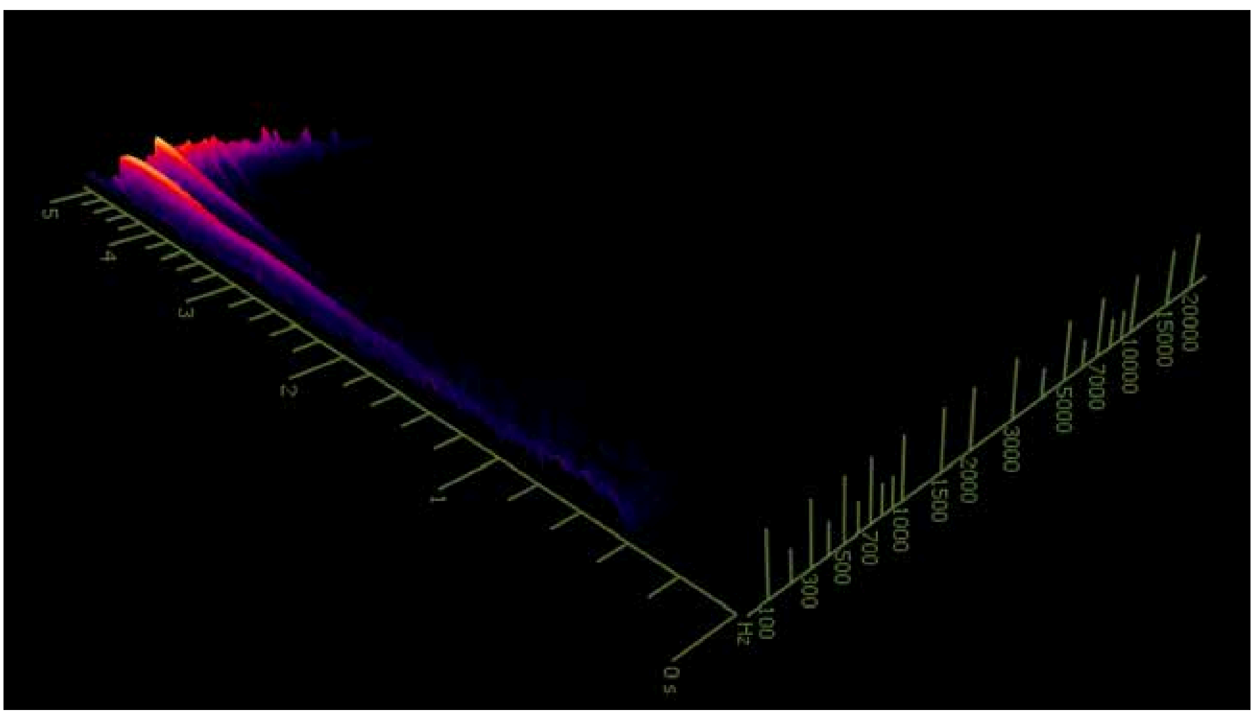

Figure 5.17: Mallet TB 3, Slow Velocity Stroke, Just Off-Center, Pitch E_2

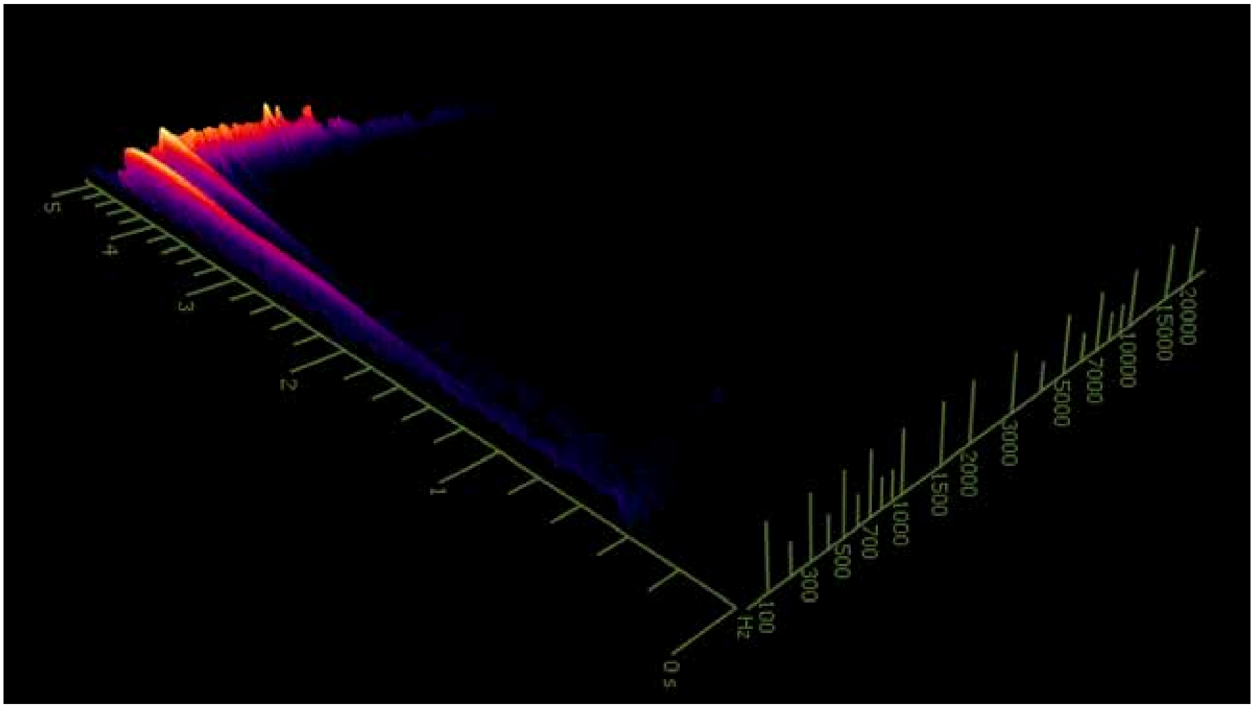

Figure 5.18: Mallet IP 240, Fast Velocity Stroke, Just Off-Center, Pitch E_2

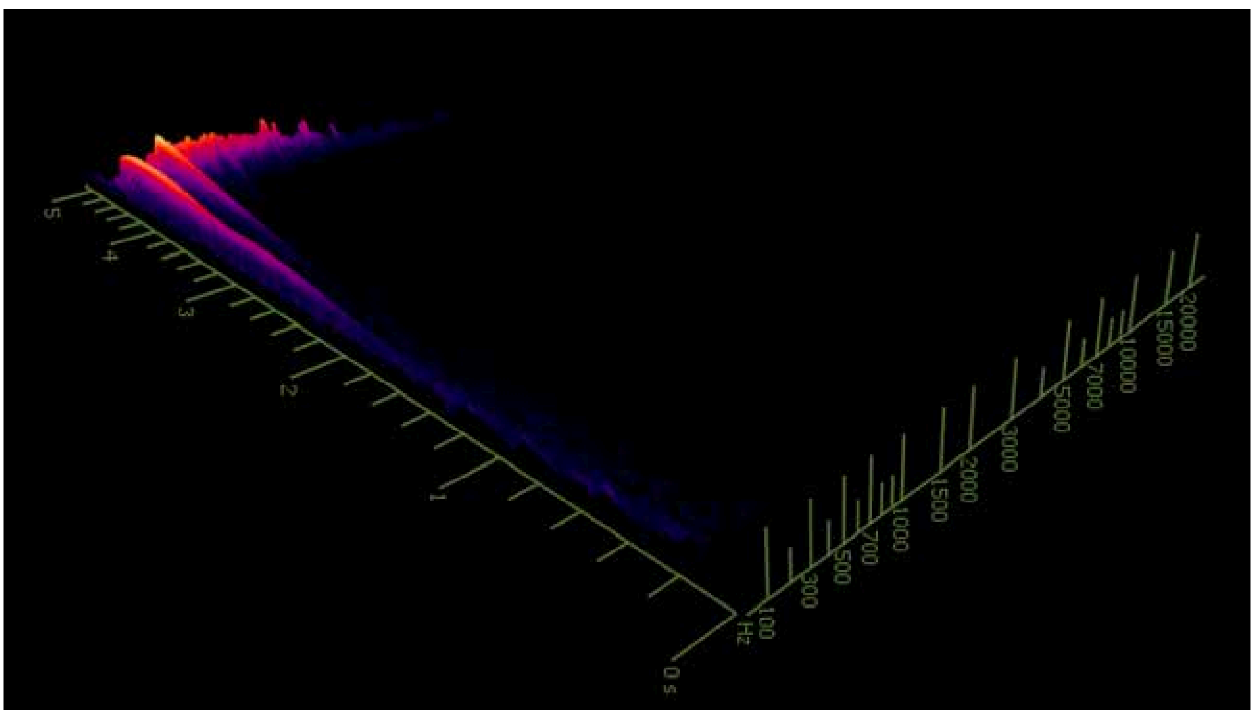

Figure 5.19: Mallet IP 240, Slow Velocity Stroke, Just Off-Center, Pitch E_2

Besides activating a louder sound, the above fast velocity stroke is audible for about 3.5 seconds compared to the slow velocity stroke, which lasts for only 2.9 seconds. The spectrogram image of the fast velocity stroke clearly shows all seven modes of vibration, whereas the slow velocity stroke only activates five of these modes at greatly diminished amplitudes. The TB 3 mallet has a synthetic core, which lends itself to much greater changes in timbre between these two strokes. This timbre change will still be present in mallets like the IP 240, but they will not be as noticeable, due to a rubber core.

In general, the softer rubber core, found in mallets like the IP 240, is more flexible than the hard plastic material used for mallets like the TB 3. The more flexible material is prone to deformation on contact with the bar, causing many of the higher frequencies to be damped. The initial response from the IP 240 is quite different than that of the TB 3, however, similar differences are observed between the fast and slow velocity strokes. The fast velocity stroke on pitch E_2 creates a sound that is louder and lasts about 3.2 seconds compared to that of the slow velocity stroke, which only lasts 2.7 seconds. While both strokes activate the same modes of vibration, the highest frequencies are significantly reduced in amplitude in the slow velocity stroke.

These same effects can be seen in recordings from bar E_4 as well. The spectrogram images from mallet ENS 20 show clear difference in the highest modes of vibration between fast and slow velocity strokes.

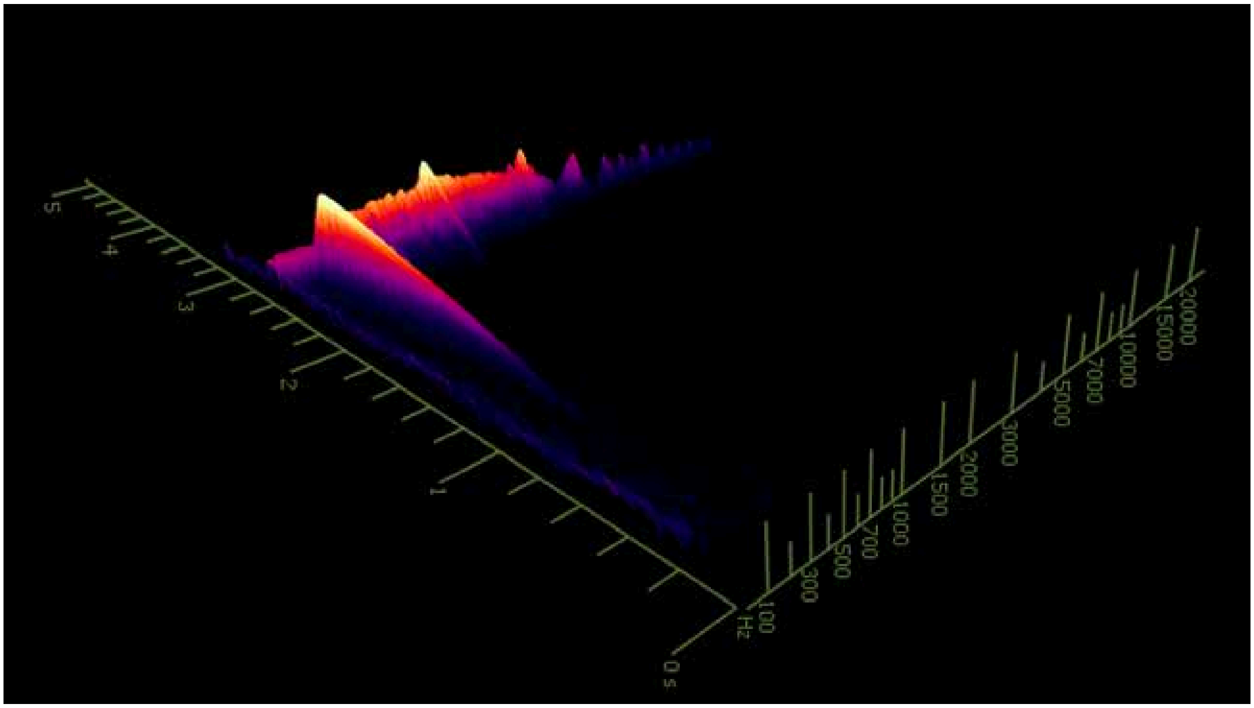

Figure 5.20: Mallet ENS 20, Fast Velocity Stroke, Just Off-Center, Pitch E_4

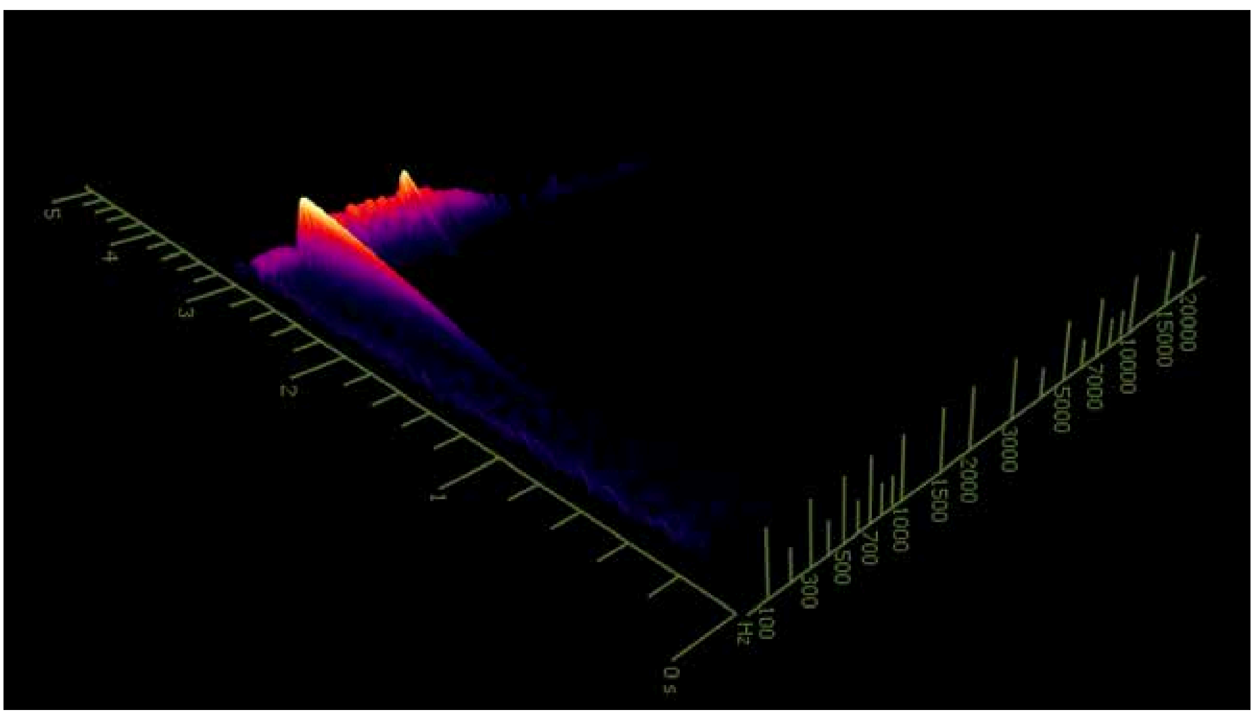

Figure 5.21: Mallet ENS 20, Slow Velocity Stroke, Just Off-Center, Pitch E_4

The above fast velocity stroke activates four clear modes of vibration, whereas only two modes are seen in the slow velocity recording. This mallet has a rubber core, which is not wrapped in yarn, but instead covered with a thin layer of latex. The fast velocity stroke applies more energy to the bar resulting in a louder sound, which lasts around 1.7 seconds. The slow velocity stroke applies less energy and lasts only about 1.5 seconds. Similar results are shown for mallet WU 3, which has a plastic core with a soft rubber tip.

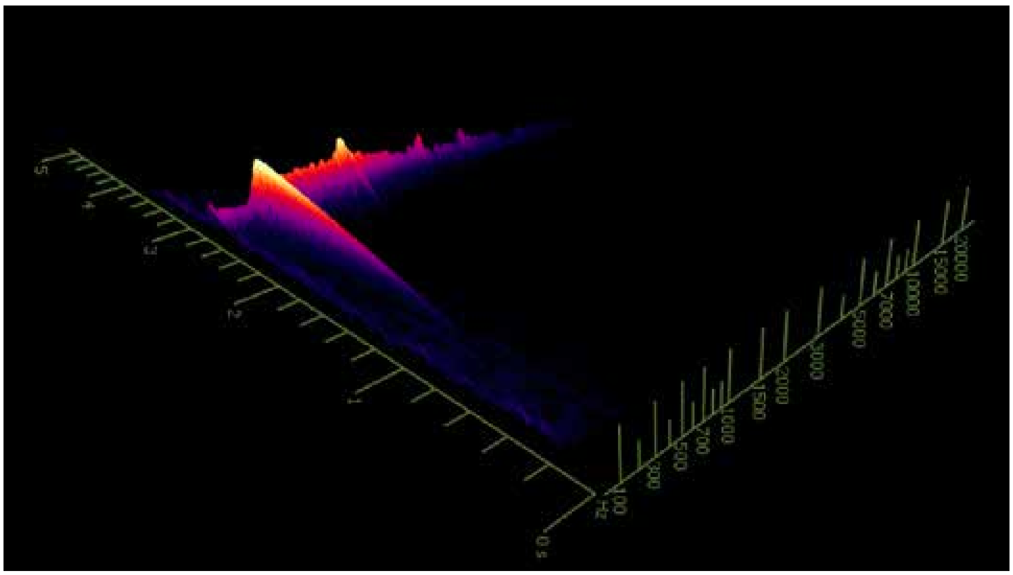

Figure 5.22: Mallet WU 3, Fast Velocity Stroke, Just Off-Center, Pitch E_4

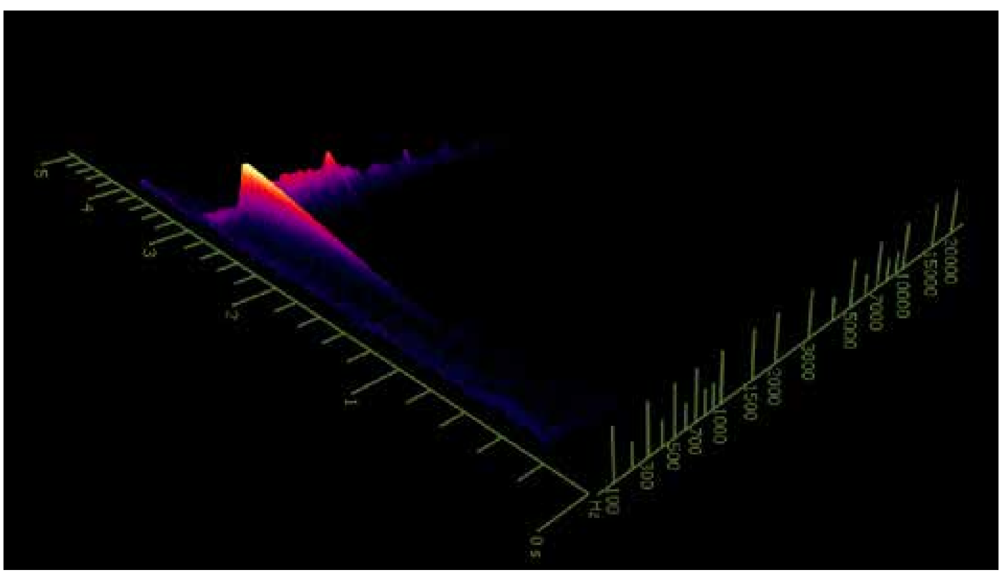

Figure 5.23: Mallet WU 3, Slow Velocity Stroke, Just Off-Center, Pitch E_4

In the highest octave of the marimba, a certain amount of velocity is needed to even elicit an audible response. Some slow velocity strokes on pitch E_6 yielded tones that were devoid of the usual pitch information. In the following recording from the node of E_6, the majority of the sound is contact noise alone.

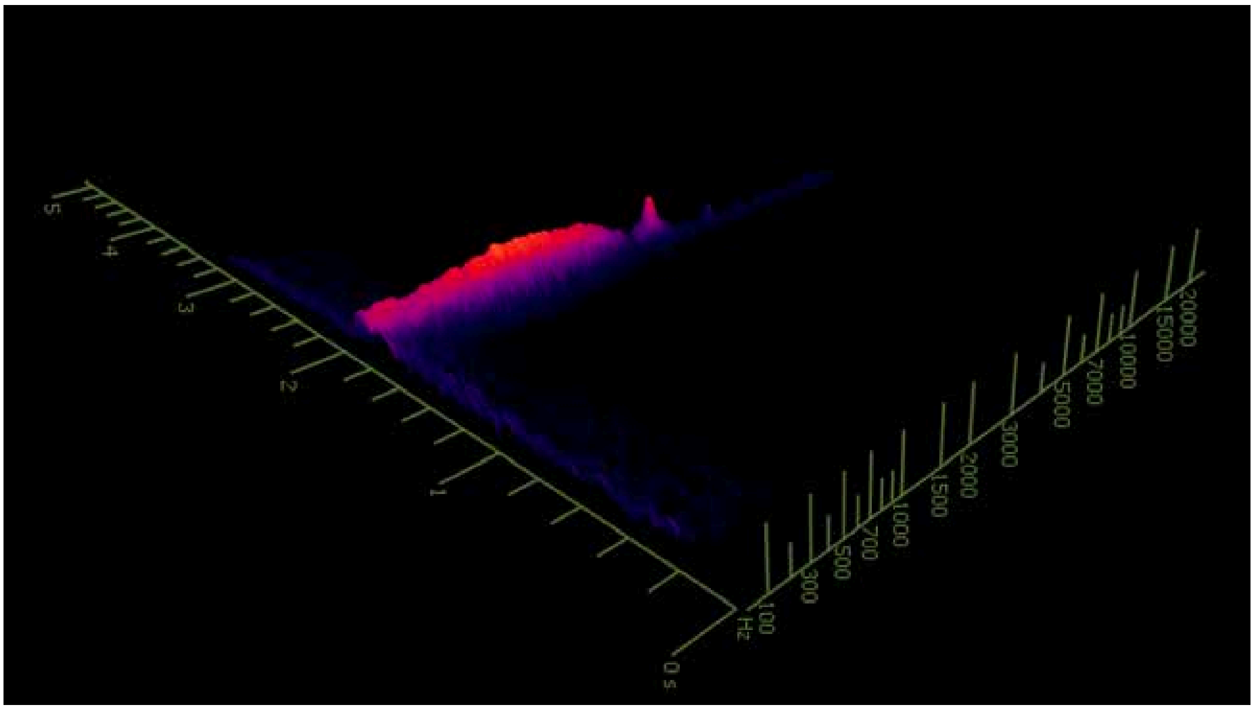

Figure 5.24: Mallet ENS 20, Slow Velocity Stroke, Node, Pitch E_6

Besides these occasional outliers, the recordings of stroke velocity on bar E_6 were consistent with the findings on lower octaves of the marimba. The fast velocity stroke creates a louder, longer duration, and brighter timbre note than the slow velocity stroke.

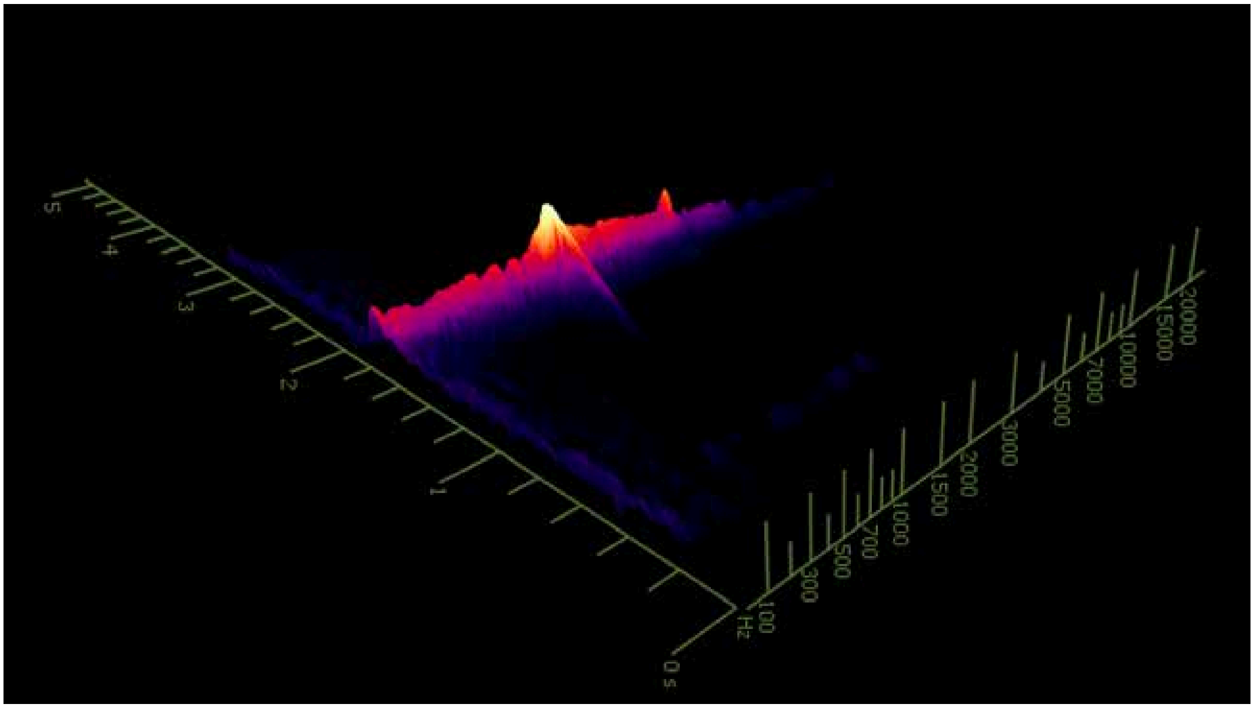

Figure 5.25: Mallet IP 813, Fast Velocity Stroke, Just Off-Center, Pitch E_6

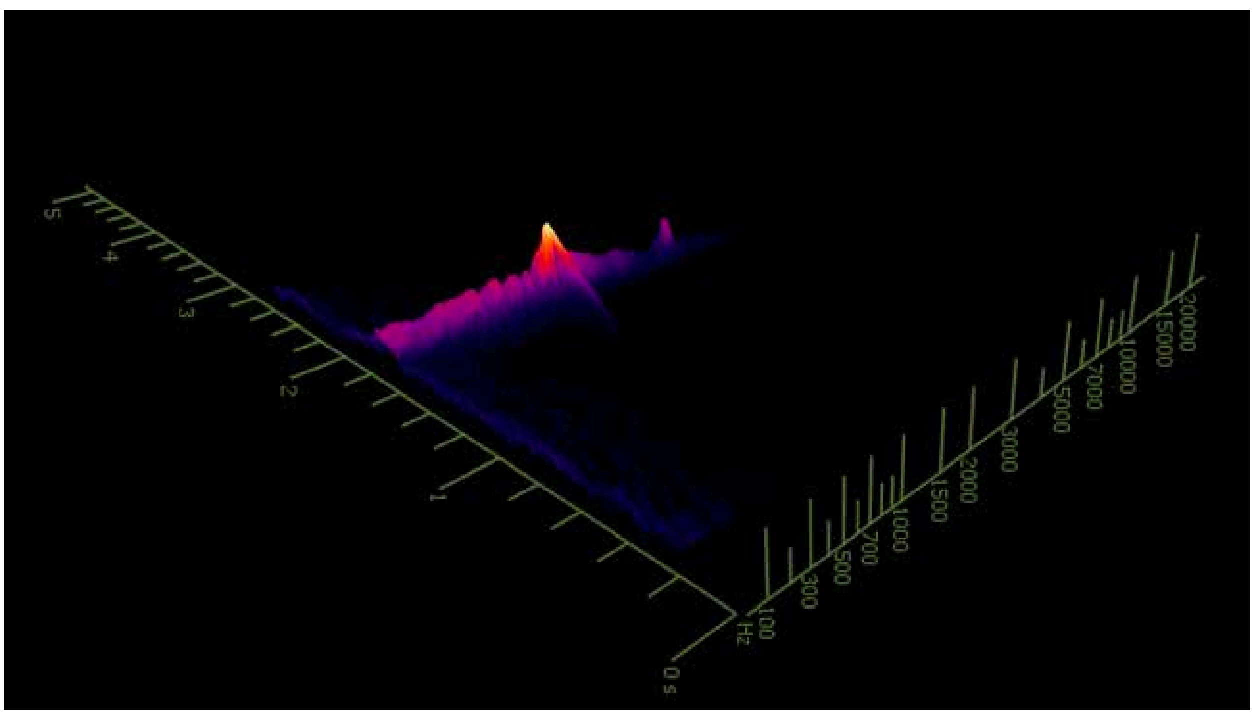

Figure 5.26: Mallet IP 813, Slow Velocity Stroke, Just Off-Center, Pitch E_6

Variation in Mallet Weight

As mentioned previously, the other factor in the amount of energy applied to the bar is mass or weight. Some percussionists add weight to the stroke with the use of the arm or body. While the current study did not attempt to examine this technique, it did examine the addition of weight through the variation of mallets. For one set of recordings rubber bands were added to the base of the mallet head on an IP 3106 B mallet. This augmented mallet weighed approximately 38g, six grams heavier than the regular IP 3106 B, which weighs in at 32g. In comparing the recordings of these two mallets, the addition of weight did make a slight difference.

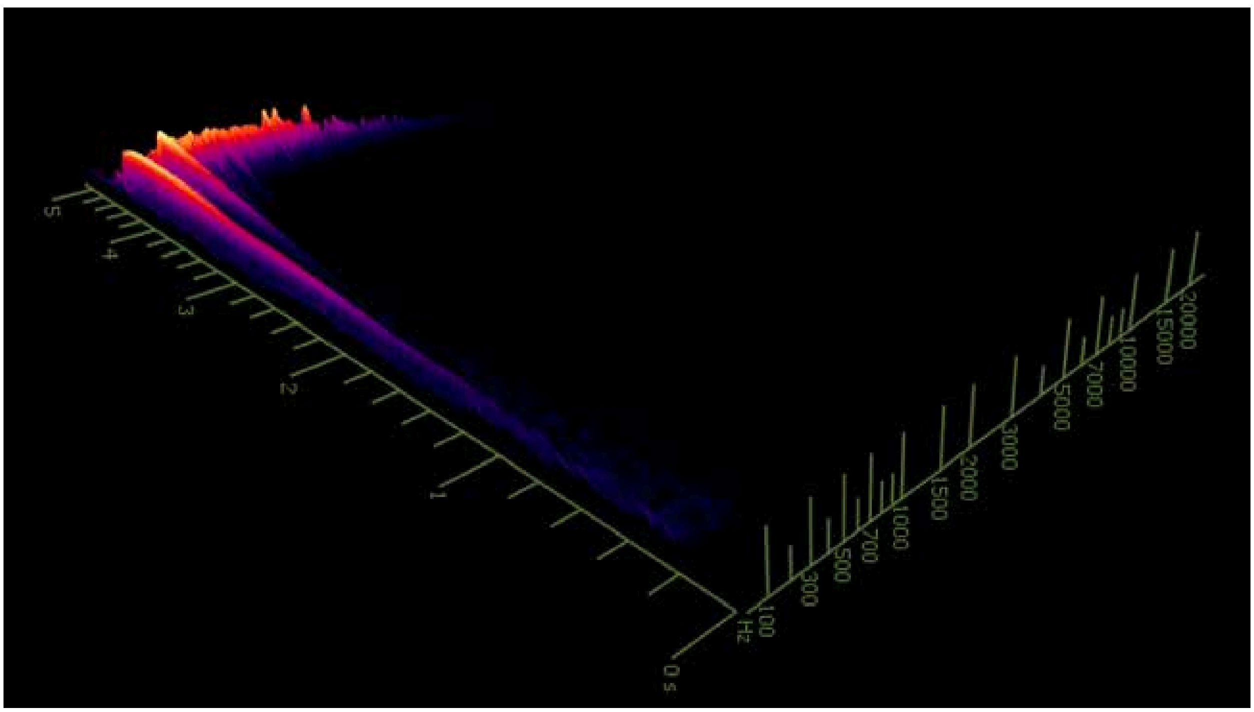

Figure 5.27: Mallet IP 3106 B, Fast Velocity Stroke, Just Off-Center, Pitch E_2

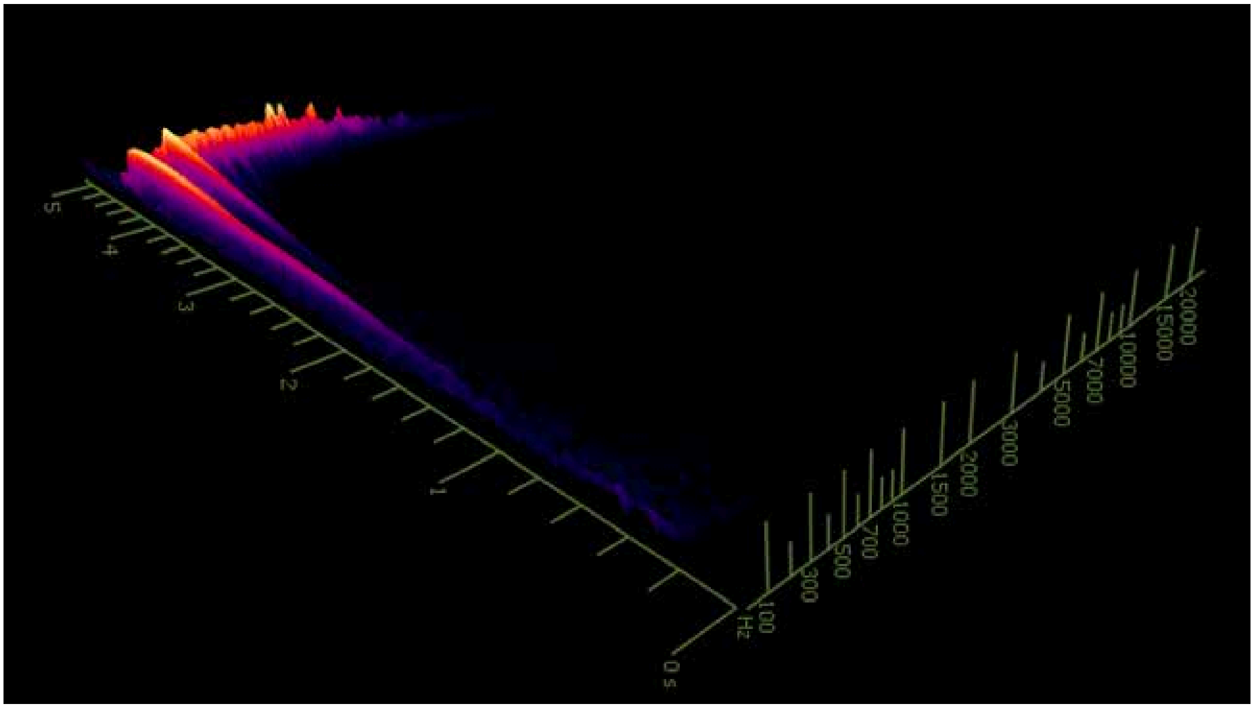

Figure 5.28: Mallet Weighted IP 3106 B, Fast Velocity Stroke, Just Off-Center, Pitch E_2

As expected, the recording created by the weighted mallet produced higher amplitudes in every mode of vibration. This increase is audible although not as striking as the difference in amplitude created between a fast and slow velocity stroke. This makes sense because while velocity has an exponential effect on the amount of energy applied to the bar, the effect of weight is always halved. Further research is needed to conclude if performers can reliably affect the amount of energy applied using stroke weight, however, these recordings show that weight is indeed a factor, even if a miniscule one.

Variation in Mallet Handle

Another factor debated by percussionists is the effect created by different types of mallet handles. For much of the marimba's history, mallets were made with flexible rattan handles. Marimbists who prefer a less flexible handle now have the option of birch wood, an innovation that has become more popular due the increased adoption of the Stevens' Method for four-mallet playing. Several other types of wood are in use in mallet handles today, including cedar and ramin, which is used on the TB 3 mallet. Some percussionists disagree whether the type of handle has any influence on the sound of the marimba or whether the choice of handle is only a matter of preference. In a description of a listening test carried out by the company Malletech, the use of rattan or birch mallet handles was found to have no audible effect on wrapped mallets, however, this same test found that handle type was audible in unwrapped xylophone mallets and glockenspiel mallets.[158]

In this study the comparison of IP 3106 B, with a birch handle, and IP 3106, with a rattan handle, seems to confirm the results of Malletech's listening test. Across the full range of the instrument and in various playing spots, only minor differences were observed between these two mallets. Future experiments should examine how different types of handles affect the transfer of stroke weight to the bar; however, the current research suggests that type of mallet handle is only a matter of preference.

[158] "Taste, Tone, Ticks, Handle Types: The Research and Development of the Orchestral Series," Malletech Learning – Enlightenment, last modified 2010, accessed February 21, 2018, https://www.mostlymarimba.com/inspiration-and-enlightenment/enlightenment/886-handles.html.

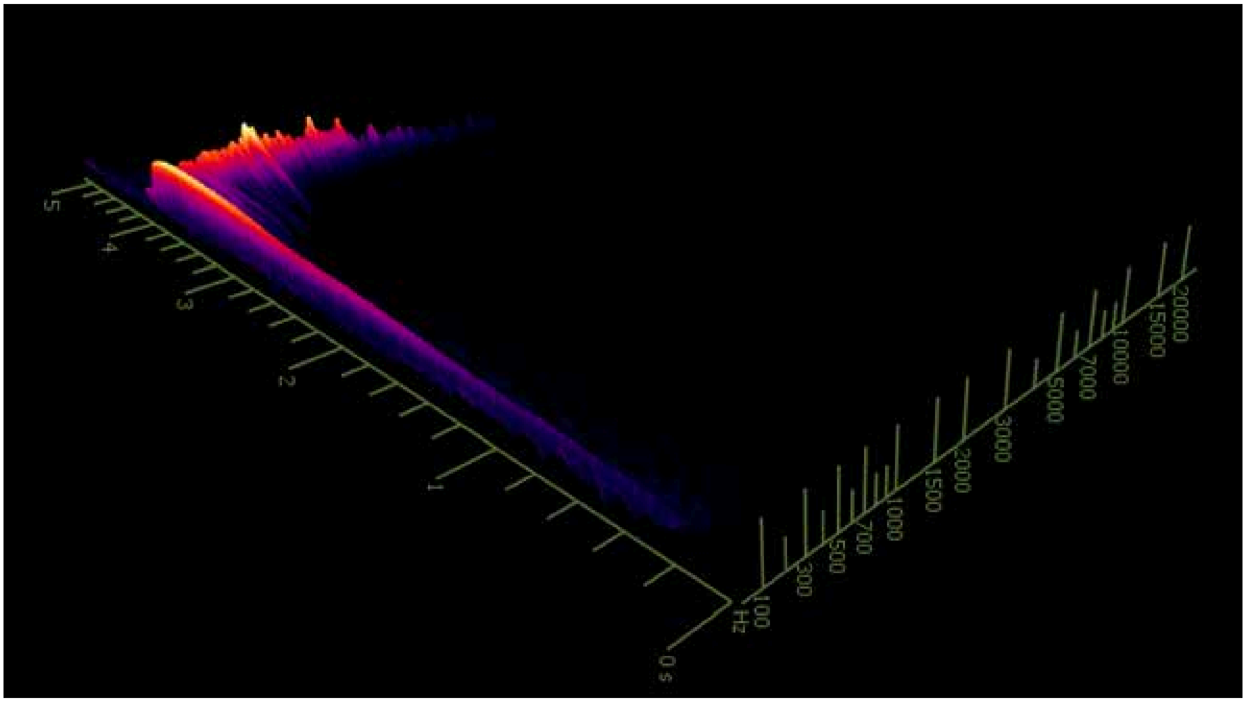

Figure 5.29: Mallet IP 3106 B, Fast Velocity Stroke, Center of the Bar, Pitch E_2

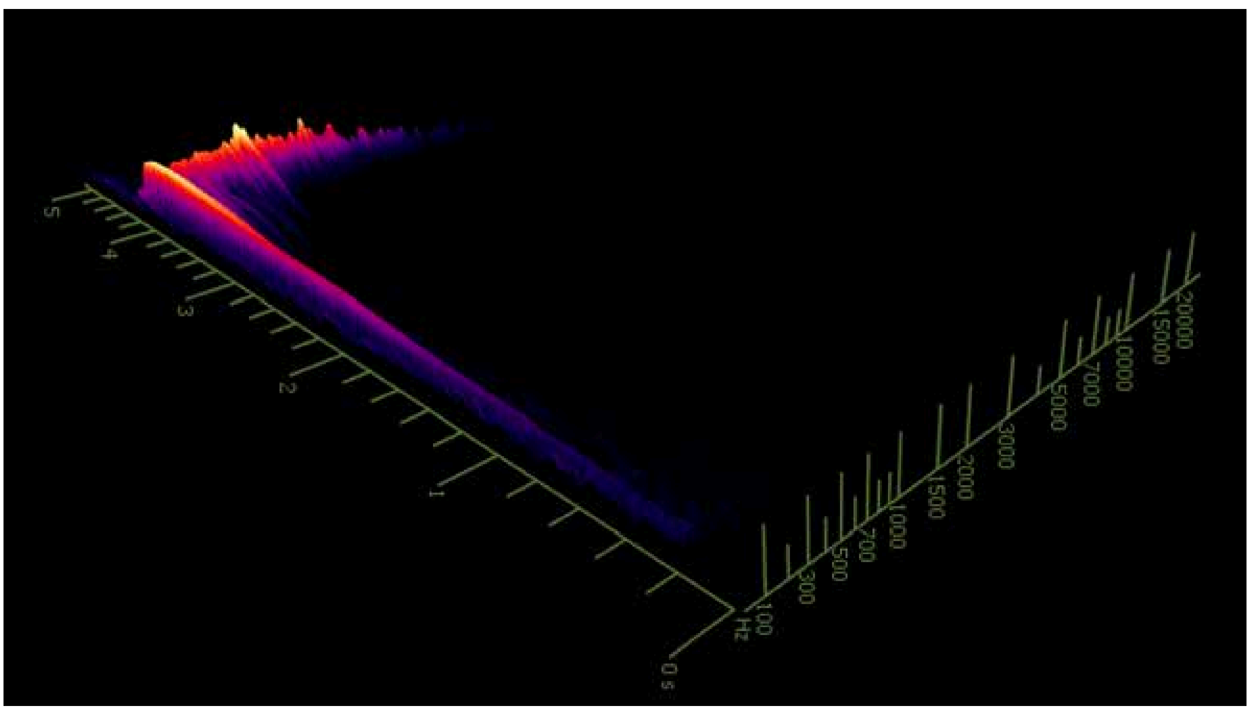

Figure 5.30: Mallet IP 3106, Fast Velocity Stroke, Center of the Bar, Pitch E_2

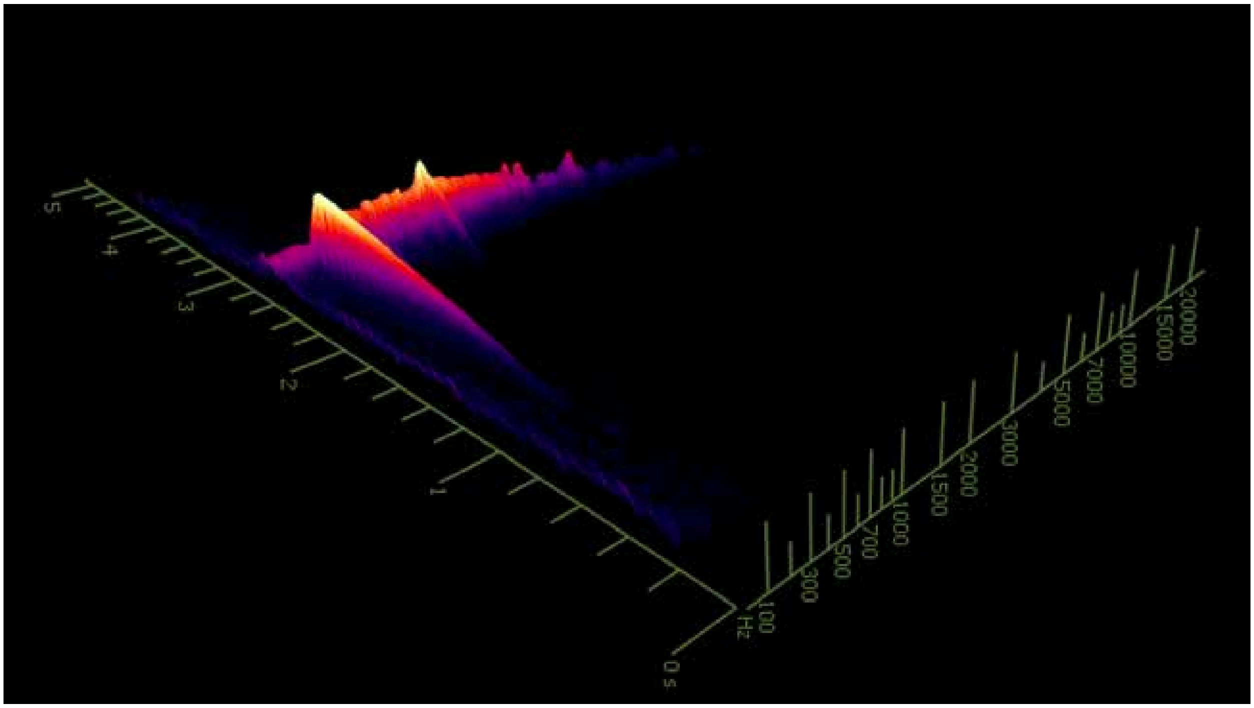

Figure 5.31: Mallet IP 3106 B, Fast Velocity Stroke, Just Off-Center, Pitch E4

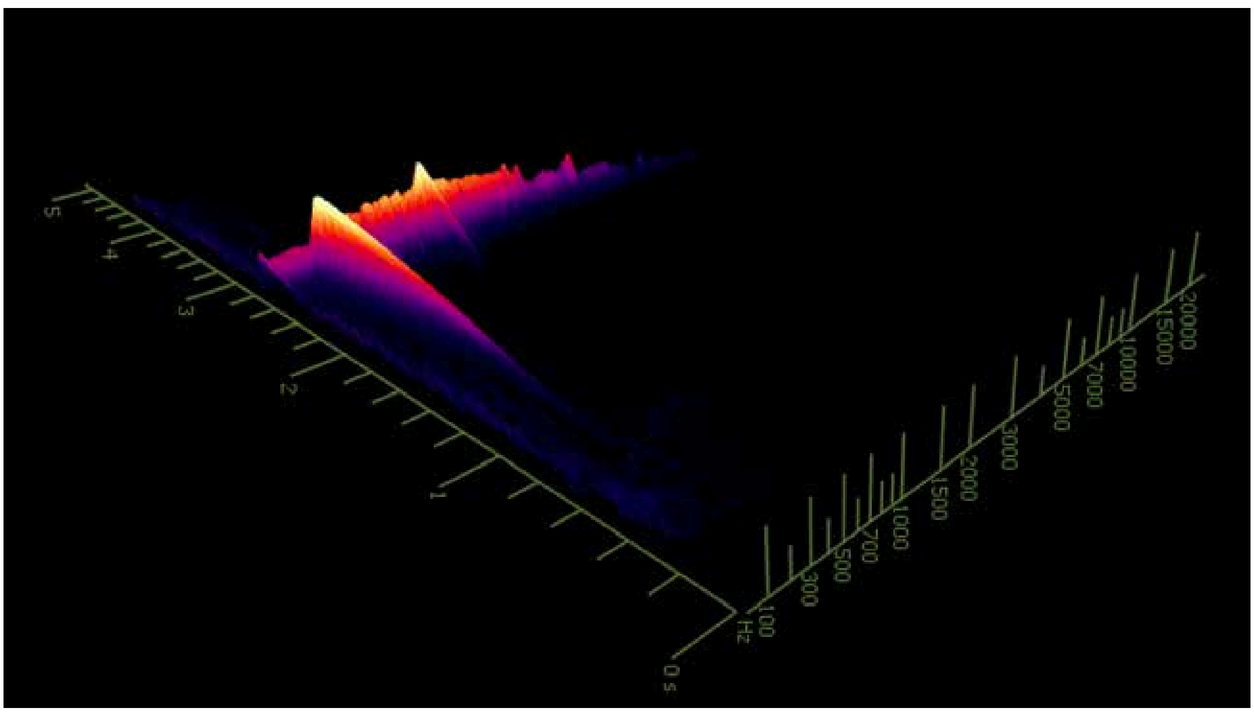

Figure 5.32: Mallet IP 3106, Fast Velocity Stroke, Just Off-Center, Pitch E4

Variation of Stroke Direction

Examining the recordings of different stroke directions has confirmed what other researchers have found in this area. As seen in various marimba methods, many performers believe stroke direction can influence the sound of the marimba bar on its own. Some educators believe that an up-stroke draws the most sound out of the instrument, while others believe that using a down-stroke traps the resonance of the bar, creating a full sound. The following recordings, however, show little difference between the up-stroke and down-stroke in terms of volume, duration, or timbre. The volume and duration is influenced only by how much energy is applied to the bar at the moment of contact. If the same amount of energy is applied from an up-stroke to a down-stroke the resulting tones will be the same. Energy applied to the bar is influenced exponentially by the velocity of the stroke; therefore a clear difference is seen between the fast velocity strokes and the slow velocity strokes, but not between strokes of the same velocity. The following data was collected from an analysis of the four stroke direction recordings.

Table 5.2: Up Stroke, Fast Velocity

Mode of Vibration	Amplitude
1. E_4	-24.6 dB
2. E_6	-25.7 dB
3. $G\#_7$	-60.3 dB
4. F_8	-65.1 dB

Table 5.3: Down Stroke, Fast Velocity

Mode of Vibration	Amplitude
1. E_4	-25.0 dB
2. E_6	-25.3 dB
3. $G\#_7$	-60.3 dB
4. F_8	-65.1 dB

Table 5.4: Up Stroke, Slow Velocity

Mode of Vibration	Amplitude
1. E_4	-27.2 dB
2. E_6	-31.3 dB
3. $G\#_7$	-65.6 dB
4. F_8	-75.5 dB

Table 5.5: Down Stroke, Slow Velocity

Mode of Vibration	Amplitude
1. E_4	-27.2 dB
2. E_6	-31.6 dB
3. $G\#_7$	-66.1 dB
4. F_8	-75.3 dB

Slight variations in the decibel levels are present in several of the modes; however, these differences are below the threshold of human hearing. Most listeners will only notice a change in volume above a 5 dB difference in amplitude. The largest decibel difference observed between strokes of the same velocity was a 0.5 dB change, seen in the third mode of the slow velocity strokes. Because this change is high above the fundamental pitch and less than 1 dB difference, its effect would be inaudible to the human ear. The minimal differences that do exist can be explained through the inability of the author to apply the exact amount of energy to both strokes up and down strokes without the use of a machine. Figures 5.33-5.36 show the spectrogram images of each stroke.

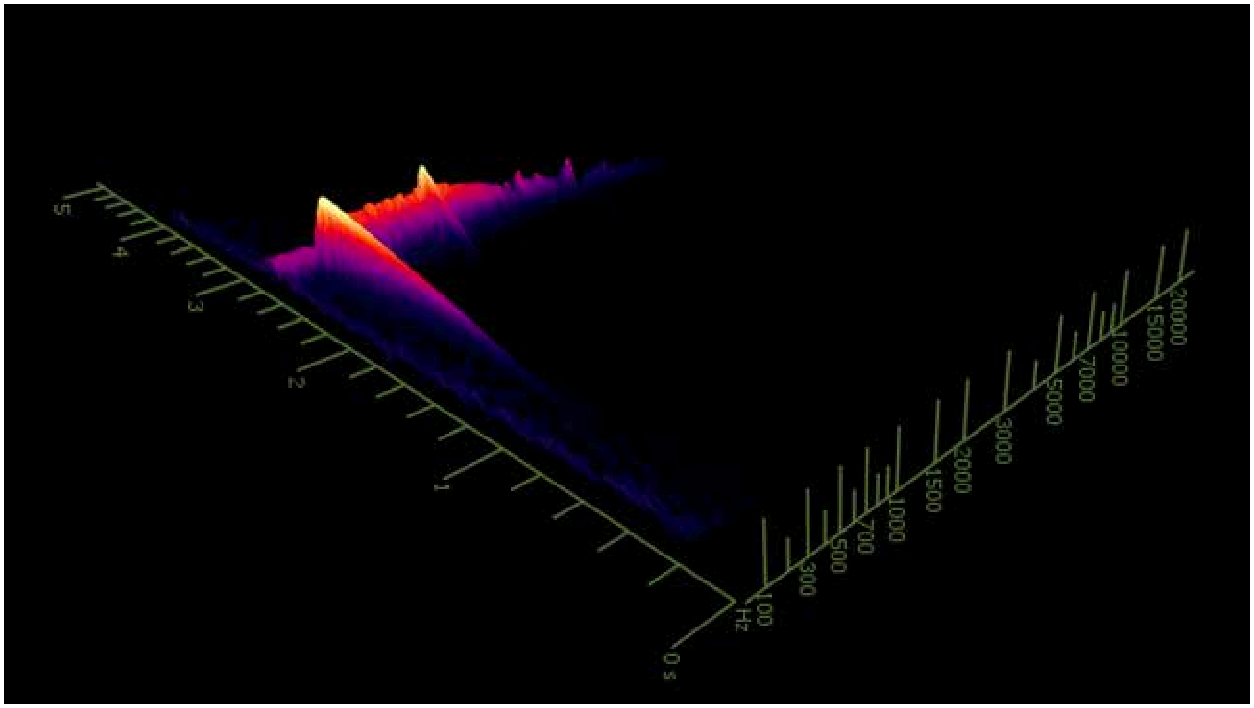

Figure 5.33: Fast Up Stroke, Pitch E4

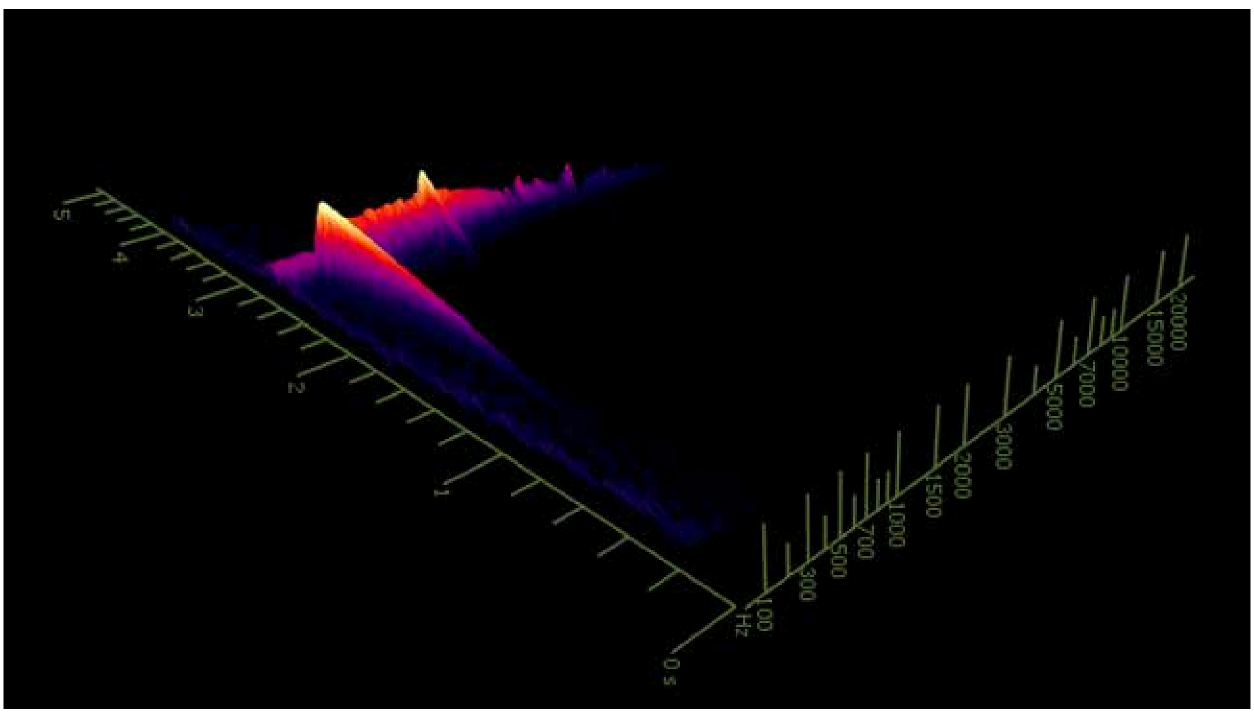

Figure 5.34: Fast Down Stroke, Pitch E4

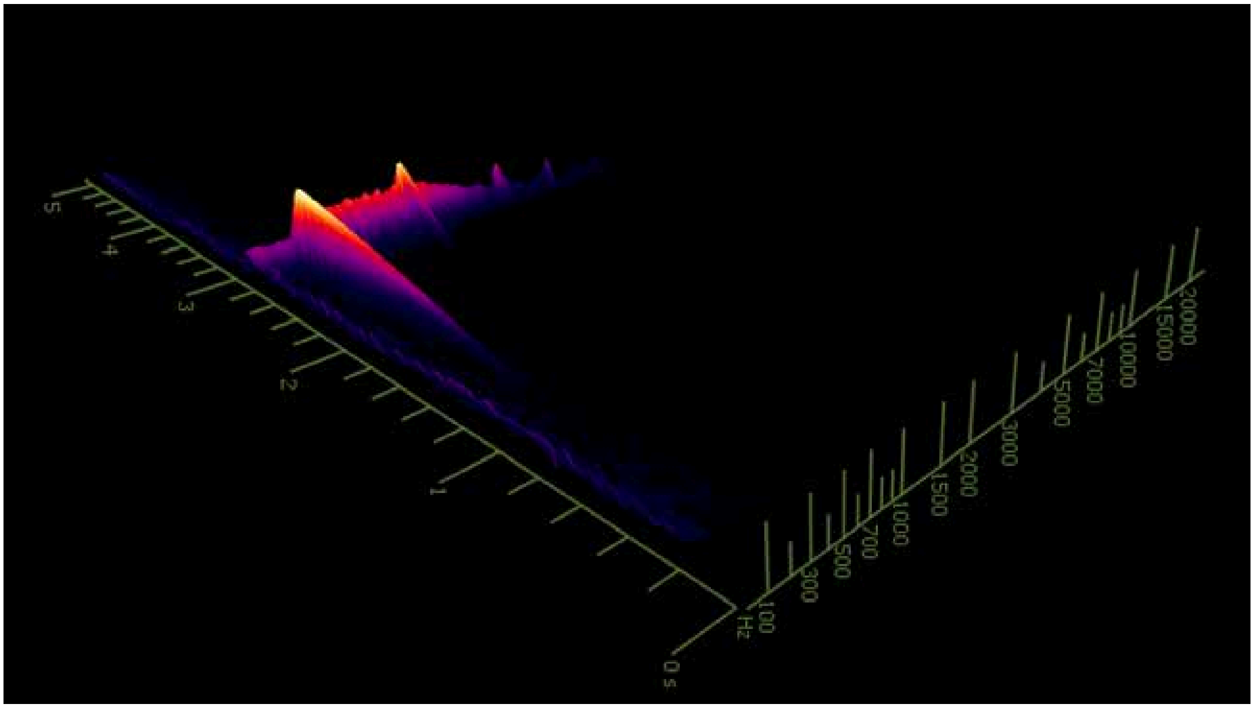

Figure 5.35: Slow Up Stroke, Pitch E_4

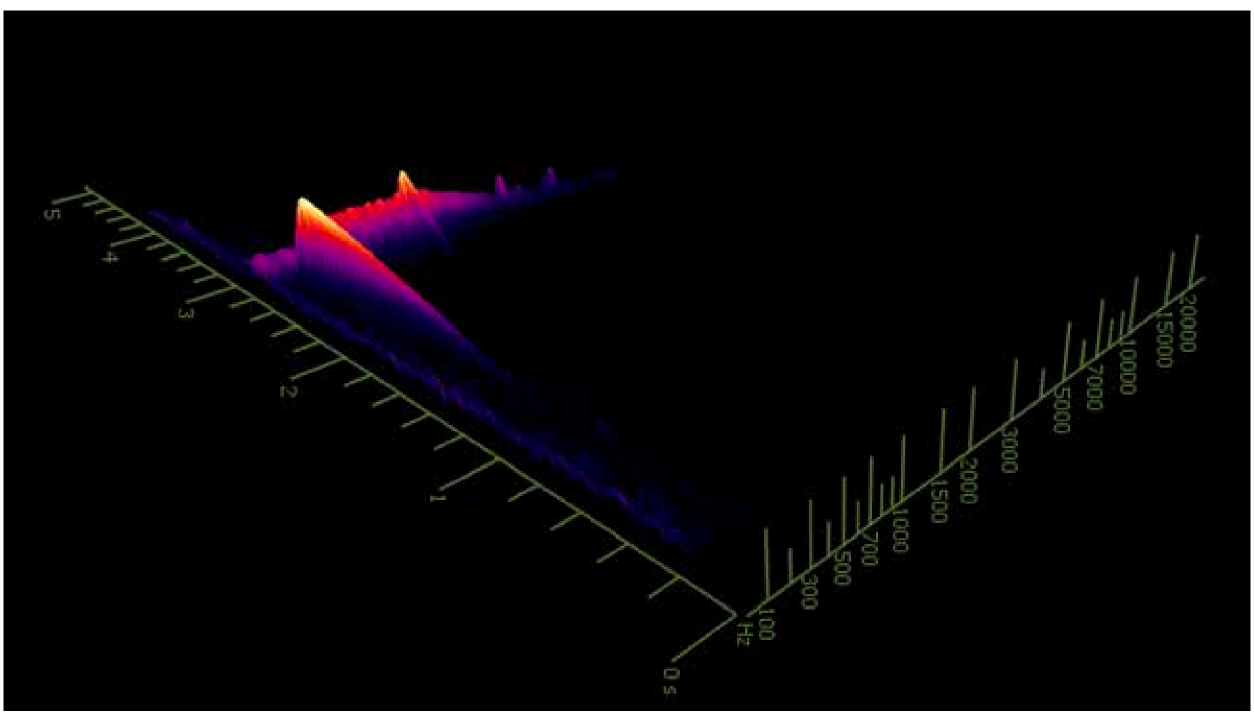

Figure 5.36: Slow Down Stroke, Pitch E_4

The duration of both fast velocity strokes is approximately 1.7 seconds, in comparison to 1.5 seconds for the slow velocity strokes. The fast velocity strokes, without regard to direction, both elicit a clear response from all four modes of vibration. The four modes are also present with the recordings of both slow velocity strokes, however, with a much weaker response from the highest two modes. Again these images prove that sound production on the marimba is not affected by stroke direction alone. If the amount of energy applied to the bar remains the same, stroke direction will have no audible effect. While stroke direction does not influence the sound of the bar, it is still an essential part of percussion technique.

It should be noted that performing these two opposite direction strokes with the exact same amount of energy is an inherently unmusical act and only serves the purpose of this experiment. As shown by this study, it is technically possible to produce the same amount of energy from a starting point of 4cm from the bar and 30cm from the bar, however, it is not a simple task for any performer. Attempting to the strike the bar from 4cm away, as in an up stroke, requires a great amount of acceleration in a short amount of time. Conversely, attempting a down stroke from 30cm above the bar without a large amount of acceleration is also difficult. The reason these strokes have been discussed in terms of articulation is because under normal circumstances, these strokes do create different sounds. Because the mallet has less room to accelerate in an up stroke, the amount of velocity, and therefore energy, is greatly diminished, leading to a softer and ultimately shorter note. When striking from a larger distance away, as in a down stroke, the performer has ample room to accelerate to a fast velocity and create a louder and longer sound.

Stroke direction also has a clear effect on the visual aspect of percussion performance. The studies conducted by Schutz and Lipscomb prove that gestures used by marimbists do influence the perception of sound. While many of these gestures may be aurally inconsequential, their effect on the perceived sound is significant. When used under normal conditions, the performance of a down stroke followed by an up stroke can create the illusion of a slur, both visually and audibly. The down stroke creates a loud note through faster velocity and is followed by a note with softer attack created through slow velocity. This type of visual and aural connection is common in the technique of Tom Burritt and is not dissimilar to the Moeller technique used by Milkov. If the performer uses the Stevens approach of keeping the attack of the second note softer than the decay of the first note, the illusion of a slur will be at its most effective.

Final Observations

Several other interesting observations were made from the current recordings, all of which can be seen in the appendices. Because every mallet, besides IP 3106 B and IP 3106, has different characteristics in their core material, weight, and wrap, variations in articulation were readily apparent. Many of these differences can be seen in the amount of contact sound created by each mallet. Mallets with relatively loose wrap create less contact sound, whereas tightly wound mallets will produce a clear sound on impact with the bar. The effect of this is most clearly seen in the highest register of the marimba. In the spectrogram images, contact sound can be seen as a pink wall of frequencies that is only present at the beginning of each note.

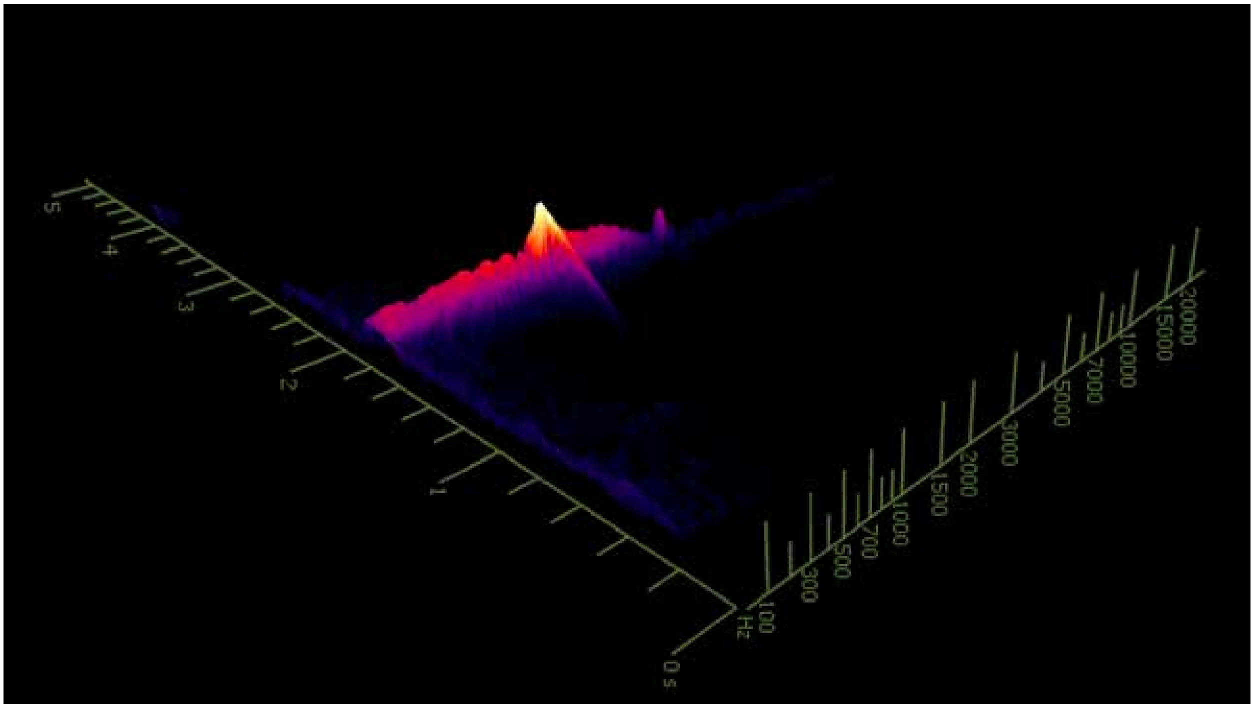

Figure 5.37: Mallet ENS 20, Just Off-Center, Pitch E_6

The recording of mallet ENS 20, which is only wrapped with latex, shows a prominent amount of contact sound compared to the TB 3, which has a loose wrap comprised of alpaca wool.

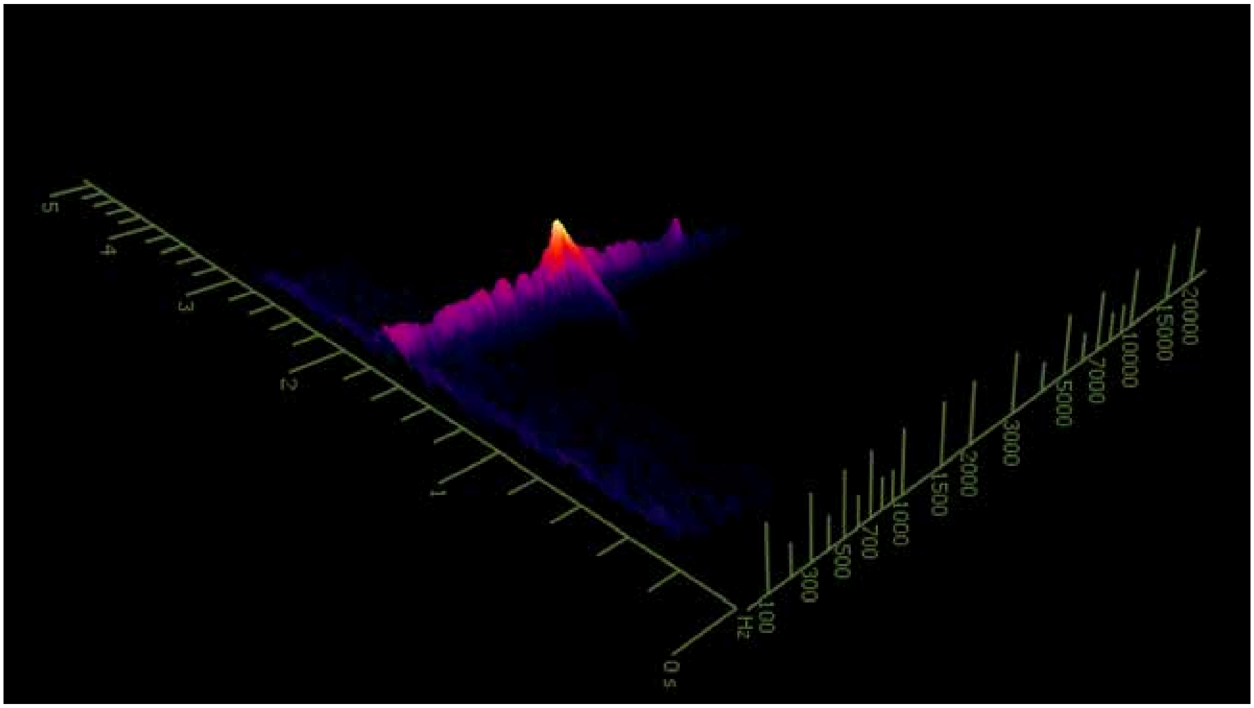

Figure 5.38: Mallet TB 3, Just Off-Center, Pitch E_6

At the moment of impact, the contact noise created by the ENS 20 has a maximum amplitude of -48.1 dB. In comparison, the contact noise created by the TB 3 has a maximum amplitude of only -55.4 dB. The maximum amplitude for the contact noise created by mallet IP 3106 B, with a relatively tight yarn wrap, falls between these other mallets at around -50.8 dB.

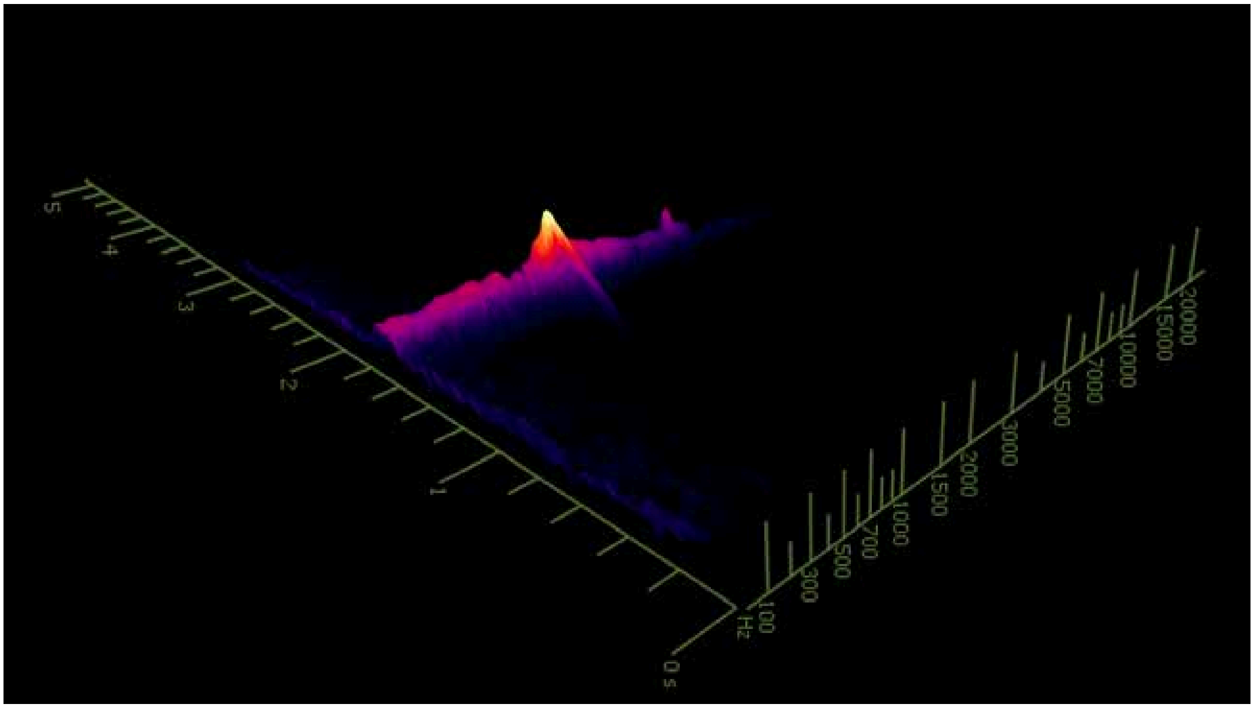

Figure 5.39: Mallet IP 3106 B, Just Off-Center, Pitch E_6

While the sustain and decay of the marimba remains much the same, the choice of mallet can have a great effect on the character of each attack. In fact, percussionists and marimbists have a greater control of attack than any other acoustic instrumentalist. This large amount of control over the front of each note is juxtaposed with marimbists' lack of control over the sustain and decay of each note, which pales in comparison to wind, string, and vocal musicians.

CHAPTER 6

CONCLUSIONS AND RECOMMENDATIONS

The topic of musical articulation is often a divisive subject due its contextual nature, however, it is one of the most important elements of musical performance as it affects the degree of clarity between notes and creates a sense of musical style. The notation of pitch and rhythm is in most cases objective, however, the notation of articulation is and always will be a subjective art. The exact interpretation of a staccato dot will never be standardized, just as the exact volume level indicated by the word *forte* can never be standardized. Articulation and dynamics depend a great deal on outside factors, including the acoustics of the performance space, ensemble balance, tessitura of the note, and character of the music. While the interpretation of articulation marks will always change depending on the context of the music, less precise definitions can be agreed upon. The Italian origins of many of these terms give clues to their musical application. Some of the most common articulation marks today include legato, staccato, portato, tenuto, marcato, and the accent. Understanding these terms is the first step in performing different articulations on the marimba and other percussion instruments.

The second step in affecting articulation change on the marimba is understanding the acoustics of the instrument itself. The modern marimba has a relatively short history and innovations are still being made to the design of the instrument. However, the acoustic principles of vibrating bars and resonators are based on scientific facts. Unlike vibrating strings, marimba bars do not have a naturally occurring harmonic series. Manufacturers cut material from the bottom of a marimba bar in order to create synthesized harmonic relationships. The fundamental pitch of each bar is based on its length and thickness, but not on its width. Striking the marimba at various places along the bar will achieve very different results. Performers who know each nodal and anti-nodal point for a bar can effectively change the timbre of the marimba by striking in different areas. Marimba resonators amplify the vibrations of the bar and in turn actually decrease the amount of ring time. Resonators and bars are affected by temperature and humidity and can often go out of tune with each other. In order to achieve the full effect from the resonators some manufacturers have added adjustable caps, allowing performers to change the length of each tube depending on the weather. Performers who have control over the tuning of the resonators have a great amount of control over articulation.

Tone production on the marimba is a topic of great debate and controversy. Method books offer a multitude of different techniques that affect articulation. Stroke velocity, stroke weight, stroke direction, grip tension, mallet damping, and sticking choice are just a few of the variables that go into a marimba performance. While some of these techniques are more effective than others, it is important for percussionists to understand all of them in order to have the greatest impact on musical expression. The following techniques can and should be used on marimba to change articulation.

Mallet Choice

As seen in the last chapter, mallet choice is one of the leading factors in changing articulation on marimba. Each mallet has unique characteristics in terms of mass, shape, wrap, and core material which all affect the sound produced on the marimba. Heavier mallets increase the amount of energy applied to the bar and therefore are capable of creating louder and longer duration notes. The size of each mallet can influence how many modes of vibration are activated in the stroke, with larger mallets canceling out some of the highest frequencies. The type of yarn and the tightness of the wrap used on a mallet has a great amount of influence on the amount of contact sound created in each stroke. The elasticity or flexibility of the core material is also important. Harder materials stay in contact with the bar for less time compared to softer materials, which are more prone to deformation during contact. With the number of mallets in production today, percussionists' options when it comes to articulation are virtually endless. Non-traditional implements can also be used on marimba for special effects, as long as the material used to strike the instrument is softer than the material of the bars. Some commonly used non-traditional mallets on marimba include plastic brushes, leather "slap" mallets, and superball mallets. These unique implements can be used to achieve a variety of articulations that are uncommon to the marimba.

One effect that is often used on percussion instruments is bowing. The advantage of using a bow on the marimba is that impact noise is absent or at least significantly reduced. By using two or more bows to move between each note, a performer can create a truly legato sound on the marimba; however, this technique does have limitations of speed. A different effect entirely can be produced by the use of *col legno*. Italian for "with the wood" this technique is most frequently seen in the string section of the orchestra. This term in marimba music refers to using the shaft of the mallet to strike the bar. For a quick transition to this technique, performers can play with the shoulder of the mallets on the edge of the bars. If given more time the performers can turn the mallets around and play with the tip of the mallet handle in various places on the bar.

Mallet Angle

Marimba mallets come in a variety of different weights, and sizes, but they also come in a variety of shapes. The shape of the mallet head determines how much impact mallet angle will have on the sound of the instrument. Angle changes with teardrop or oval-shaped mallets have more effect on the sound than if using uniform ball-shaped mallets. By changing angle, performers are essentially creating a second mallet. The angle of the mallet changes the mallet's mass, contact area, and flexibility. It also lowers the maximum stroke velocity available to the player. These variations are made more dramatic with mallets like the WU 3, which have both plastic and rubber sections of the core. Changing mallet angle is an effective tool in marimba articulation that should be used more in percussion performance.

Playing Area

In addition to changing mallets, playing on different spots on each bar can significantly alter the sound produced by the marimba. Because of the way marimba bars vibrate, players can emphasize or deemphasize various modes of vibration based on where they strike the bar. Playing directly at the anti-nodal point for each mode of vibration will subsequently emphasize that mode while deemphasizing others. Playing area can also affect the amount of contact noise in each stroke. Playing at the node significantly damps the fundamental pitch, making the highest frequency pitches and contact noise much more audible. The current study examined the effects of three distinct playing areas on the bar, but even slight variations in beating spot can significantly affect the tone of the marimba.

By changing playing area, percussionists can alter the attack characteristics and timbre of a note.

Stroke Velocity

Stroke velocity at the time of contact with the bar affects the amount of energy transferred to the bar, which in turn affects how loud and how long the bar will vibrate. As seen in the findings from the last chapter, faster strokes activate the higher modes of vibration more fully. This is due in part to Newton's third law of motion, which states that for every action there is an equal an opposing reaction. This reaction in fast velocity strokes means the mallet will stay in contact for a shorter amount of time. Slower strokes stay in contact with the bar for a longer period of time and therefore decrease the intensity of the upper partials. Due to this fact, stroke velocity increases volume and timbre at the same time. If percussionists want to increase volume without increasing timbre they will have to focus more on stroke weight.

Stroke Weight

The effect of adding weight to a stroke is not as dramatic as adding velocity. An increase in energy through velocity is exponential, while an increase in energy through weight is always halved. However, by increasing the volume of a note mainly with stroke weight, performers can keep the mallet moving at a slower velocity and therefore keep the timbre of that note dark. This approach is used and taught by marimbist Tom Burritt, who likens this issue to that of tone control on brass instruments. While more experiments are needed to examine this method, keeping stroke velocity to a minimum should decrease its effect on timbre. This study has found that variation in the weight of a mallet did influence the volume and duration of note. The same should hold true for variations of stroke weight.

Stroke Direction

Stroke direction alters the height of the mallet after making contact with the bar. An up-stroke lifts the mallet into a higher position above the bar, whereas a down-stroke lowers the mallet position. Full-strokes and taps keep the height of the mallet constant. While it has been proved that stroke direction does not change the sound of a note on its own, it does create the necessary conditions to create changes of stroke velocity. By changing the height or distance from the instrument, marimbists effectively change the amount of acceleration that is possible in a stroke. Because of this up strokes, which start from a position low to the bar, have less room to accelerate and normally create a softer sound. Down strokes are given much more room to accelerate and can produce louder tones. Stroke direction is an important part of performing accents and other variations in dynamics efficiently. The visual aspect of changes in stroke direction can also affect the perception of sound.

Volume

As mentioned by Leigh Howard Stevens, one of the main ways that percussive articulation is perceived is through the volume of successive notes. When the volume of a note exceeds the volume of the previous note, the sharpness of its attack is heard as clear articulation. Notes that have a clear attack, louder than the surrounding notes, are perceived as disconnected, even though their sound may blend together. When the attack of a note is softer than the decay of a previous note clarity is decreased, and the notes are perceived as connected. This illusion resembles the way wind and string players execute slurs on their instruments. Wind and string players can easily move from one note to the next without re-articulating. Marimbas, and all idiophones, cannot produce sound without external excitation and therefore each note must be struck to vibrate. By keeping the volume of slurred notes underneath the ring of previous notes, marimba players can create the illusion that the subsequent notes are not being re-attacked. This is one way to interpret legato articulation on marimba.

Damping or Muting

One method that wind players use to play staccato is to stop the air with their tongue.[159] Marimba players can achieve a similar effect by stopping the vibration of the bar with damping. Damping can be done with the mallets, with the hands, or with the body. By changing the amount of pressure and when it is applied to the bar, performers can create a wide variety of note lengths. While there are many method books that refer to damping as a "dead-stroke", the sound produced is most closely related to staccato articulation. Marimbists can also use a variety of methods to mute the instrument. Placing towels or felt directly on top of the bars can result in a shorter sound with a unique attack. Recently Majestic Percussion Inc. has created a custom marimba with a damping bar for virtuoso Pedro Carniero. It remains to be seen if this model will become available commercially, but it is another possible way that marimbists can affect articulation.

[159] Daniel Bonade, *Clarinetist's Compendium* (Kenosha: Leblanc Publications, 1957).

Rolls

There is no way to produce a natural sustained sound on the marimba. Rolls or tremolos are the best attempt to rectify this problem. On the marimba rolls are executed by alternating strokes between each hand at a fast-enough tempo so that a sustained sound is heard. With hard mallets this technique can sound rhythmic and even abrasive, but with softly wrapped mallets the impact of each stroke is soft enough to not be heard. If executed correctly, rolls can create the illusion of sustain. With the use of four mallets, players have a multitude of options when it comes to rolls, however, they can be ineffective in certain situations. Marimbists must think like wind, string, or vocal musicians when attempting to create the effect of sustained sounds.

Sticking Choice

For many percussionists sticking is a personal choice, however, carefully crafted sticking choices can have an effect on articulation. Gary Chaffee believes that a percussionist can use carefully crafted sticking patterns to "match not only the rhythmic aspect [between instruments], but could also use a matching articulation, making for a much greater degree of similarity between the parts."[160] In Chaffee's opinion hand-to-hand or alternating sticking most closely resembles staccato articulation. Chaffee also states that double stroke sticking patterns can produce a relatively legato sound. Therefore, through the use of "compound patterns" or double and single stroke combinations, percussionists can imitate a multitude of articulations played by other instruments.

[160] Gary Chaffee, "Sticking Patterns: A Musical Approach," *Percussionist* 10, no. 2 (Winter 1972): 48.

Sticking concepts from a variety of percussion instruments can be applied to marimba with successful results on articulation. The Moeller method allows performers to group multiple notes into one large motion. By connecting notes into larger groups, percussionists are able to play more efficiently. This has a profound effect on the visual aspect of a performance, but also on the dynamics of each note. The Moeller method has been used on marimba to create larger note groups by Theodore Milkov, Thomas Burritt, and many others.

When using four or more mallets marimbists can also use a concept called sequential sticking. Sequential sticking makes use of all four mallets when considering the sticking for a passage. In contrast to two-mallet sticking patterns, sequential sticking can create larger groups of notes similar to the Moeller method and therefore assist in changing articulation. Marimbists who are comfortable with a variety of sticking patterns and can apply them in a musical context, have a great amount of impact on the articulation of the instrument.

Visual Gestures

While it is not the focus of this dissertation, the visual aspect of a performance has been proven to affect the perception of articulation. Experiments in the visual perception of sound have been carried out on many instruments, with many focusing on the marimba. By switching the audio and visual components of different marimba strokes, Michael Schutz and Scott Lipscomb have proven that visual information can affect the way a sound is heard.[161] This study and others like it suggest that even when two sounds are acoustically indistinguishable, visually gestures can influence the perceived duration of a note. These visual gestures can be quite subjective and are often different from one player to the next. Because not every performance includes a visual aspect, marimbists should focus on creating true aural variations in articulation. Once performers have mastered this, visual gestures are a great way to enhance performance and perception of sound.

Electronic Modification of Sound

The advent of technology has changed many aspects of music performance and pedagogy. Through the use of pickups or microphones, the sound of the marimba could be captured, processed, and altered to create uncharacteristic articulations. This altered sound would have to be amplified through speakers to the audience. This idea is not farfetched, as similar modifications of sound are already being applied to other acoustic percussion instruments like the drum set.

Recommendations for Composers

When composing for the marimba and other percussion instruments there are many factors that must be taken into account. The more composers can learn about the instruments they are writing for, the more comfortable the part will be for the performers. Grant Fletcher stresses, "Style of attack and release and the problems of tone production

[161] Michael Schutz and Scott D. Lipscomb, "Influence of Visual Information on Auditory Perception of Marimba Stroke Type," *ANAIS do VIII International Conference of Music Perception and Cognition* (2004).

must be studied and understood by both performer and composers."[162] Samuel Solomon offers the following advice to composers writing for percussion:

> Although real control over different articulations is not always possible or practical, either because of the nature of a given instrument or the context of a passage, articulation and phrasing markings are still helpful. Percussionists realize these notations through dynamic phrasing, mallet choice, and variations in muting or beating spot. A composer should not hesitate to write slurs into a glockenspiel or even a snare drum part; the slur sound can be achieved even though each note must be articulated. The effect will not be as apparent as it would be on a clarinet, but these notations will make a difference.[163]

Due to the nature of the instrument, percussionists' control over sustain and decay on the marimba is certainly limited, however, when notated in their part percussionists will use a variety of techniques to create the illusion of different articulations. True legato is not possible on the marimba as it is for other instruments, but that does not mean that slur markings should be avoided. Percussionists who understand these markings will utilize techniques that minimize the attack of successive notes, whether through mallet choice, rolling, dynamic phrasing, or velocity and weight of stroke.

In addition, slurs that connect a small group of notes offer more information to the performer than curved lines that connect a large group of notes. Phrase marks, as they are called, often encompass multiple measures of music and contain little or no information about each note within the passage. According to Keller, articulation is concerned with "the binding together or the separation of the individual notes."[164] Phrase marks should not be

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[162] Grant Fletcher, "Effect of Other Musical Elements Upon Rhythmic Stress Perception," *Percussionist* 10, no. 4 (Summer 1973): 114.

[163] Samuel Z. Solomon, *How to Write for Percussion: A Comprehensive Guide to Percussion Composition* (New York: Oxford University Press, 2016) 71.

[164] Keller, *Phrasing and Articulation*, 4.

confused with articulation marks, because they offer an insignificant amount of information about how to interpret or articulate individual notes.

The dot is an important notational device for percussion composers as a true staccato is possible on the marimba and many other percussion instruments. This is done by damping the bar at a certain point after striking. Some argue that percussive damping has a speed limit and is not effective at fast tempos; however, this is true for wind and string instruments as well. When notating a dot in marimba music, composers should expect a shortening of the note, just as it is intended for other instruments. Using the staccato dot to mean something different for percussion instruments is ill advised and can create a great amount of confusion.

All other types of articulation marks can be interpreted on the marimba, and composers should not shy away from giving performers more information about musical expression. If desired, composers can find ways to notate playing area and mallet choice using symbols or writing comments above the staff. If composers know the exact articulation they want, they can specify mallets and techniques that will achieve their concept as well.

Recommendations for Conductors

Conductors have the responsibility and the privilege to create a cohesive interpretation of a piece of music for an ensemble. In an academic setting, conductors also have a duty to help their students grow as musicians. The percussion section should be a strong part of conductors' study of articulation and phrasing, for "musical considerations such as articulation and dynamics are just as important for percussion as they are for wind and strings."[165] Percussion instruments and the marimba occupy an important role in ensemble music and it goes without saying that conductors can greatly benefit by understanding the factors that affect tone production in the percussion section. Knowing about the types of implements and techniques used by percussionists will give conductors the upper hand when trying to craft the sound of an ensemble. When it comes to the marimba, conductors who know about the many variations found in marimba mallets can give their percussionists a better idea of the sound that they want.

As educators, conductors have a profound effect on their students. In many cases students spend more time in rehearsal than in private lessons. Conductors have a great responsibility to help all their students learn to be better musicians. Because of this fact, conductors should not limit the information that they give to the percussion section. The belief that percussionists and marimbists have little control over articulation is only exacerbated by their exclusion from this topic in an ensemble setting. When changing articulation in the ensemble, conductors should make an effort to include the percussion section. By knowing the limitations and abilities of percussionists, conductors can help the entire ensemble better match articulation. Conductors may even find it important to give percussionists articulation markings that have been left out by a composer. Phillip Coffman stresses that "alert teachers and conductors should advise their students of the advantages of coordinating bowing, [tonguing], and sticking articulations in a musical phrase."[166]

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[165] Kevin A. Mixon, "Helping Percussionists Play Musically," *Music Educators Journal* 88, no. 4 (January, 2002): 55.

[166] Phillip H. Coffman, "Articulation in the Percussion and String Families: A Similitude," *Percussive Notes* 17, no. 2 (Winter 1979): 33

Conductors who include the percussion section in all aspects of a rehearsal will find their students to be better listeners, performers, and musicians.

Recommendations for Percussionists

Imagine for a second that musicians had no control over articulation; that every note was exactly the same in terms of attack, sustain, and decay. Music in this scenario would be void of any expression. This is why considerations of articulation are so important, not only for percussionists, but for all musicians. Musical articulation is the tool that brings each note to life and imbues it with meaning and context. Percussionists who want to express music more fully must consider articulation in their playing. By understanding the terminology and interpretation of articulation by other instrumentalists, percussionists can begin to approach this topic from a different angle. A further understanding of acoustics and the principles of sound production on any instrument will ultimately help percussionists affect articulation in a meaningful way.

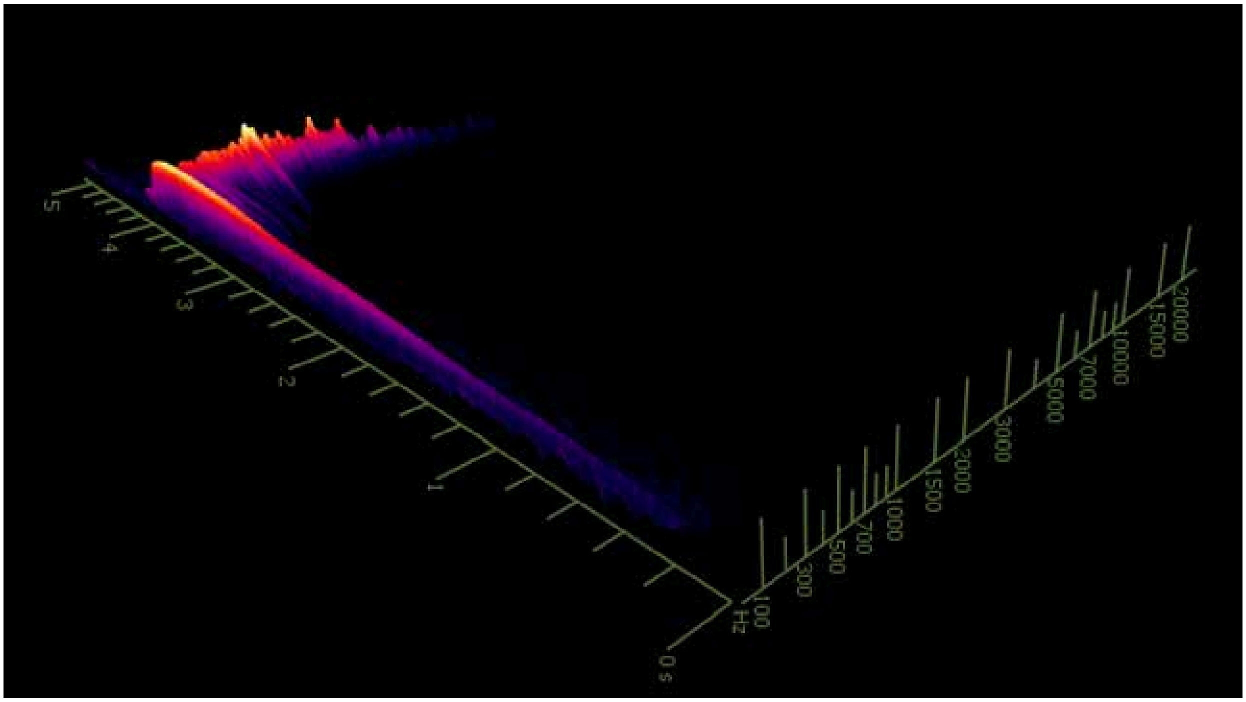
Some may see percussion instruments at a disadvantage when it comes to articulation; however, the truth is that every instrument has unique strengths and weaknesses. All performers must overcome the limitations of their instrument to fully express music. Percussionists have an almost unlimited control of the front of each note, but their limitations exist in the sustain and decay of each sound. On the marimba, the techniques discussed in this project are important tools that can help to overcome these limitations. While some tools may be more effective than others, it is the careful consideration and implementation of "all aspects of articulation that give percussionists the greatest potential for musical expression."[167] It is my sincere hope that this project has increased the potential for marimbists to play with greater musical expression and that further research will do the same for other percussion instruments.

[167] Gary Cook, *Teaching Percussion* (Belmont, CA: Schirmer, 2006) 188.

APPENDIX A

3D SPECTROGRAM IMAGES, BAR E_2

Fast Stroke, Center of the Bar



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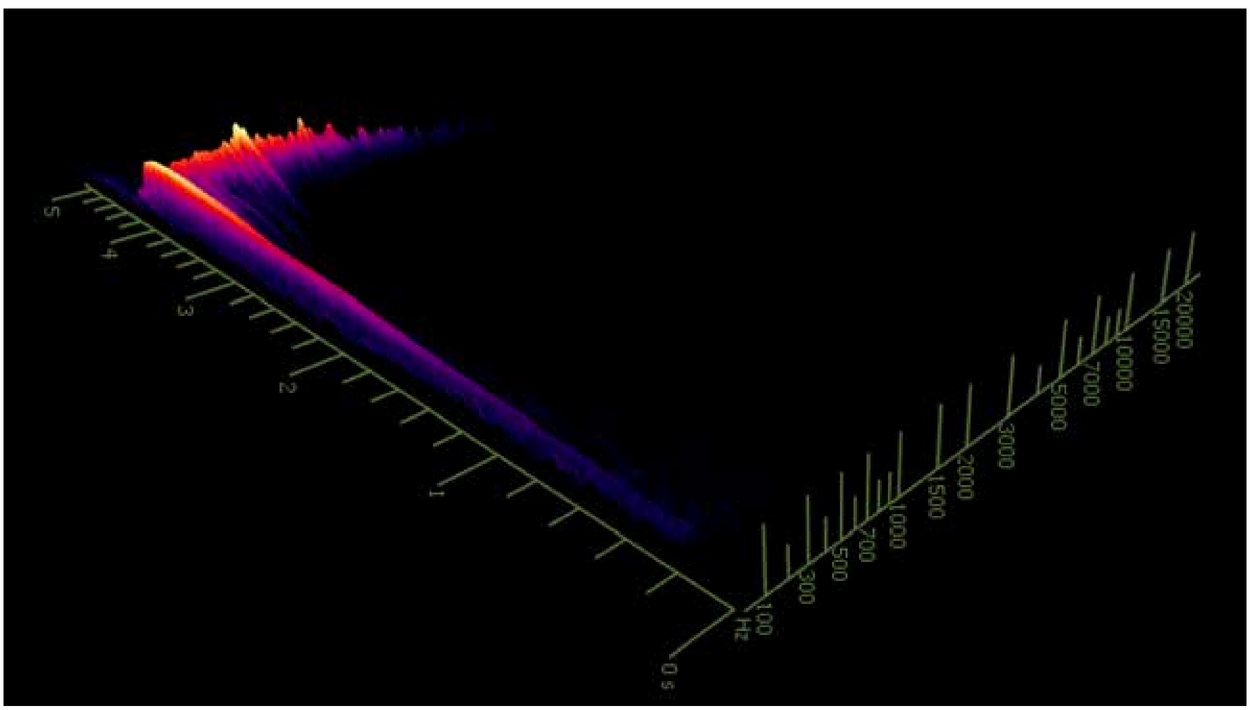

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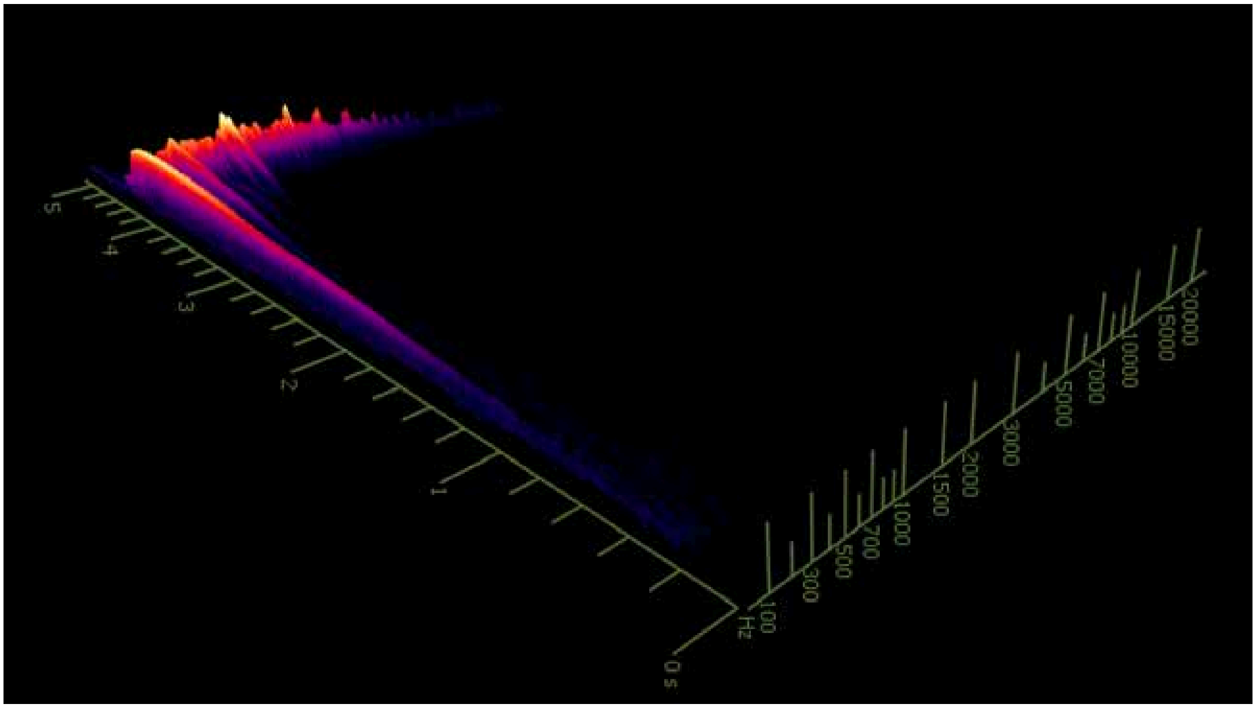

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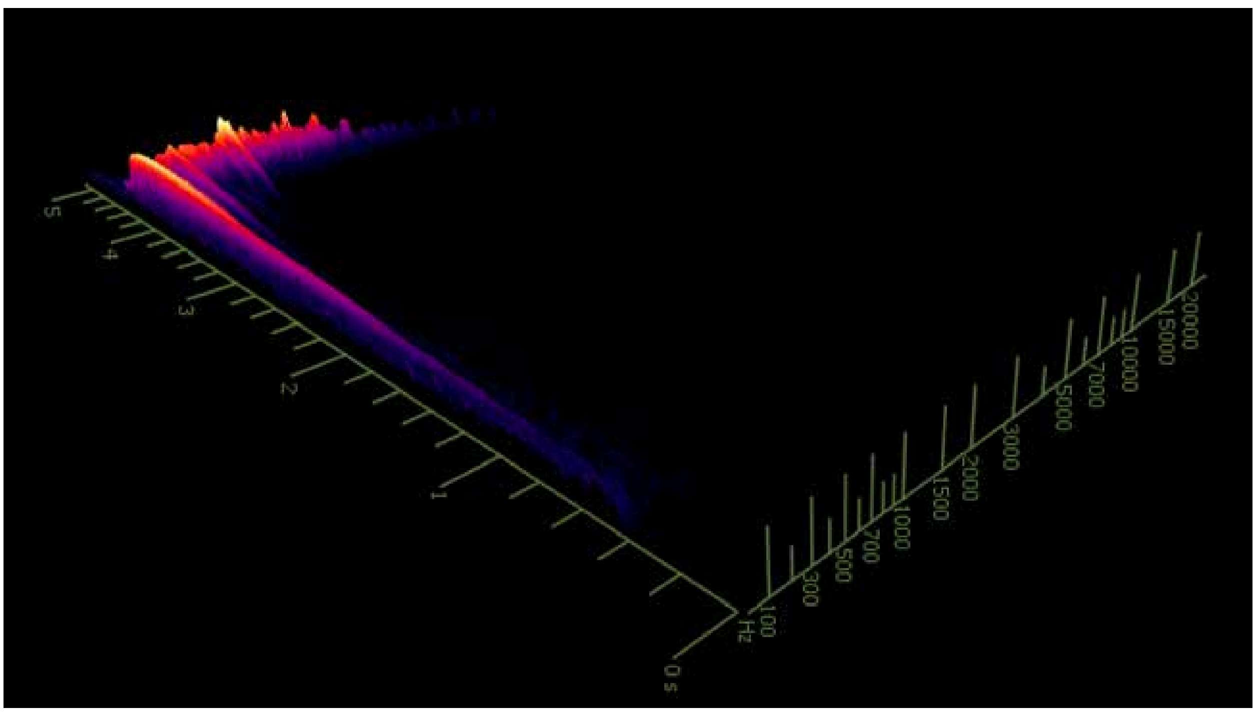

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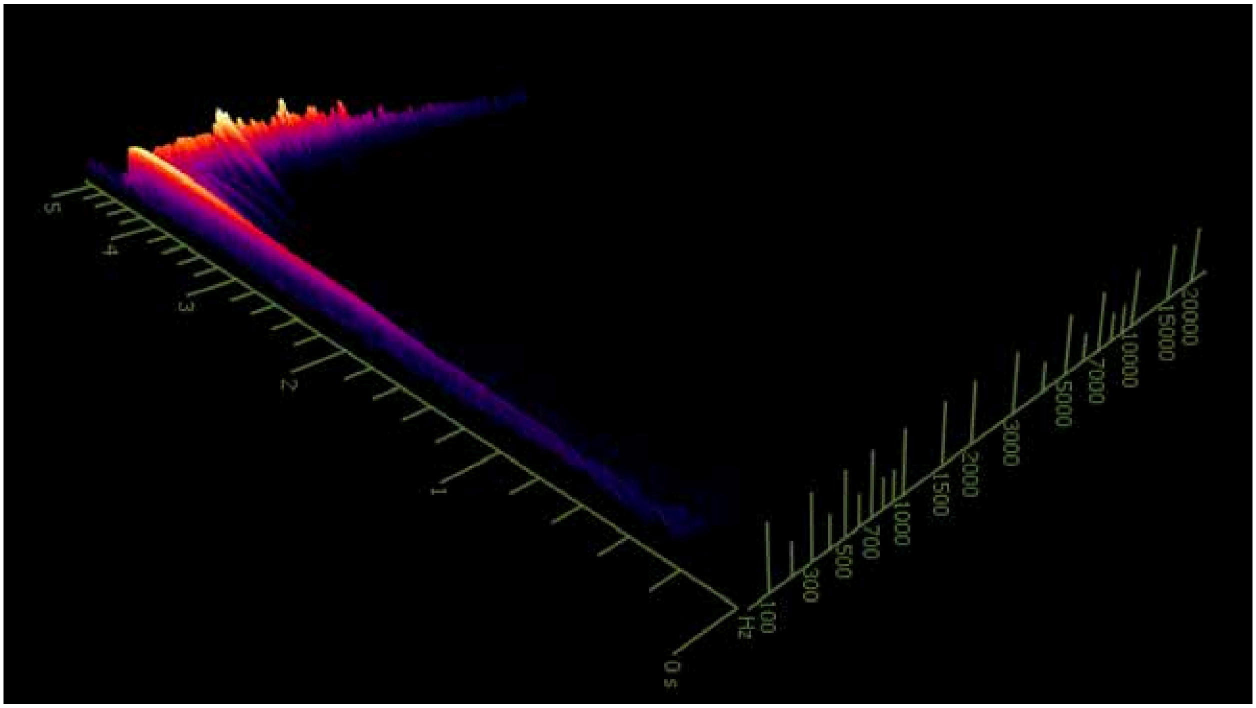
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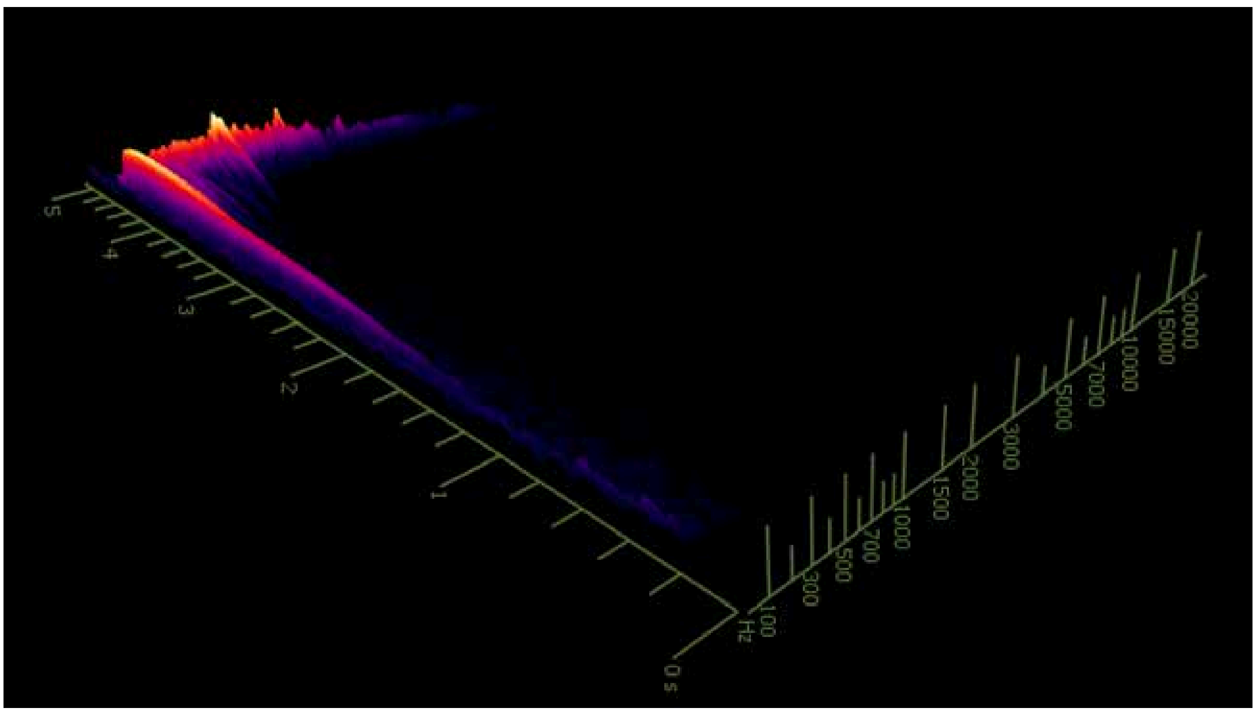
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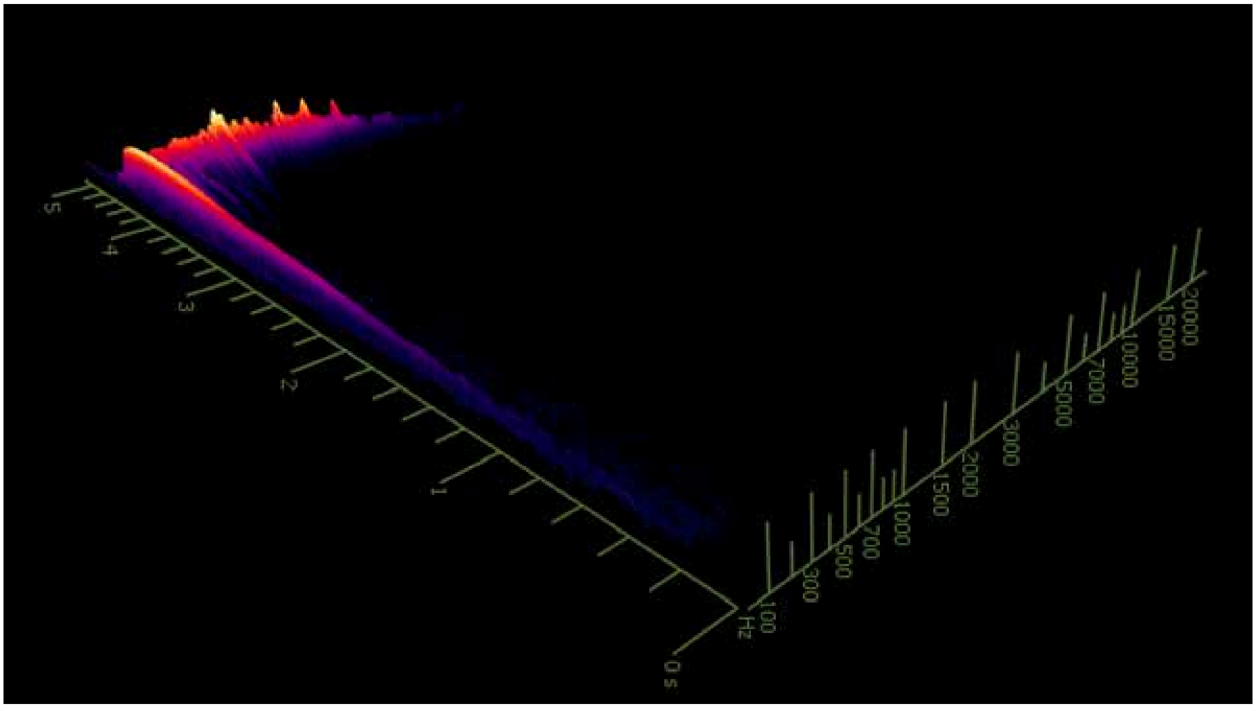
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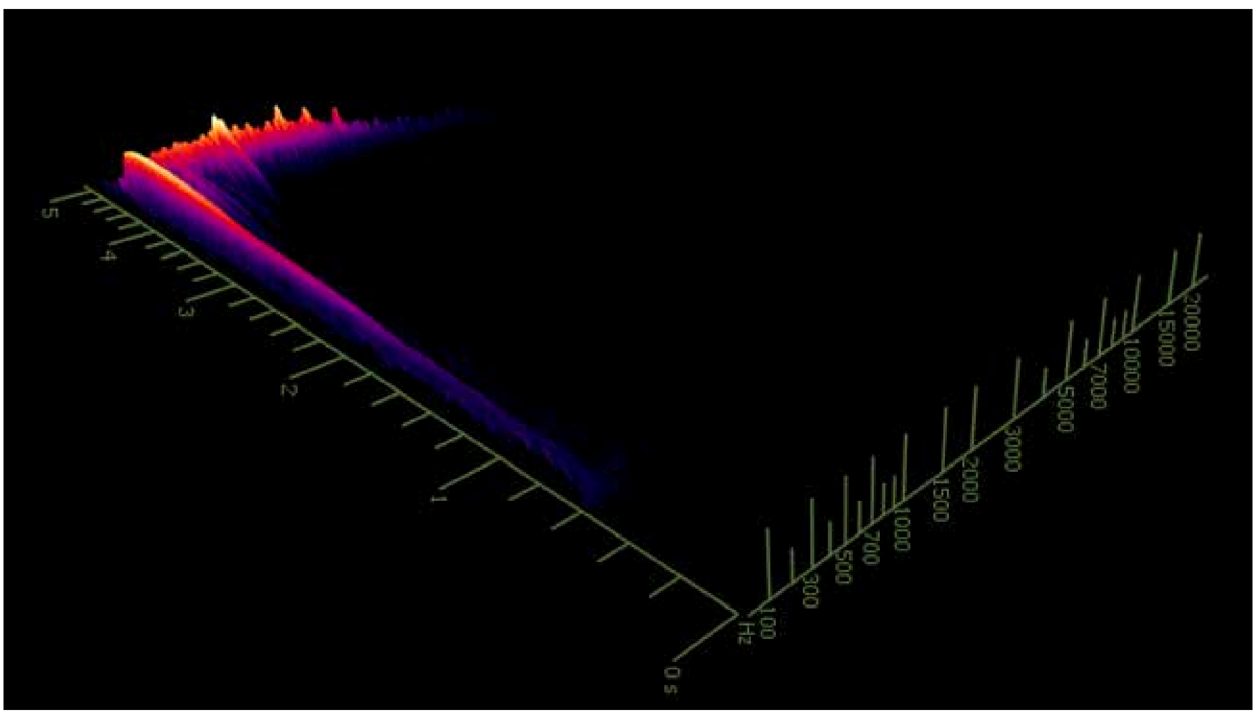
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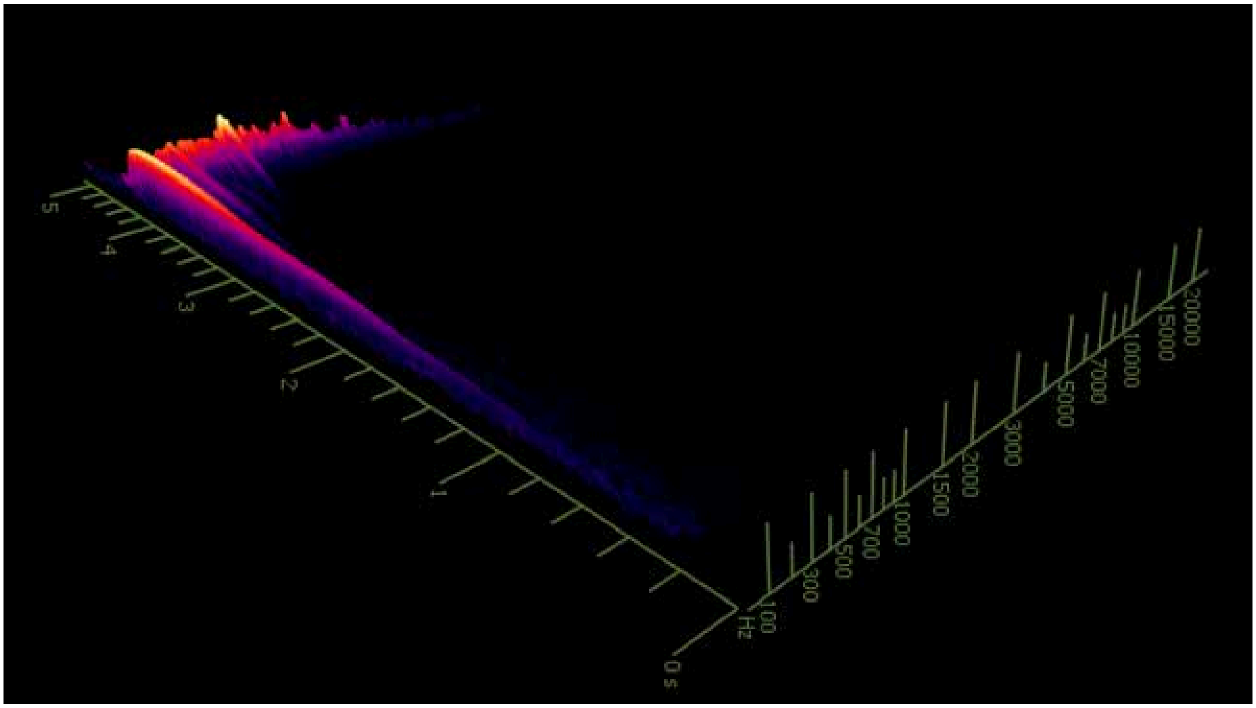

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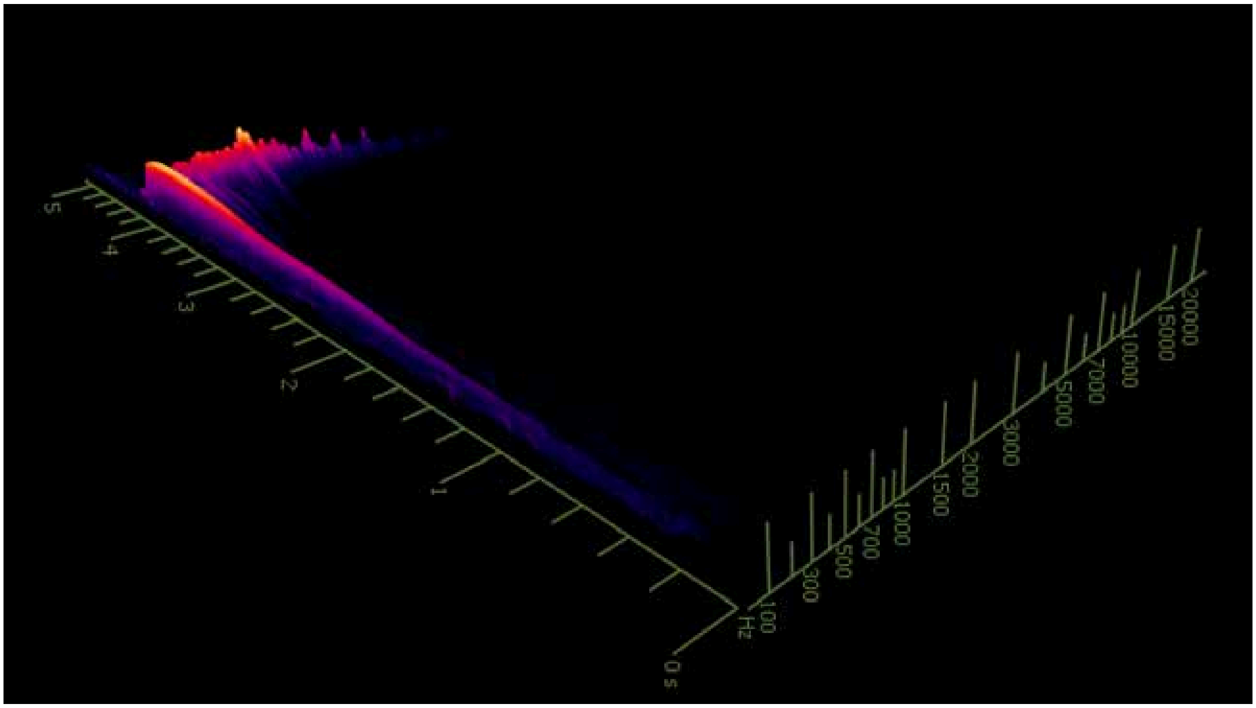
Slow Stroke, Center of the Bar



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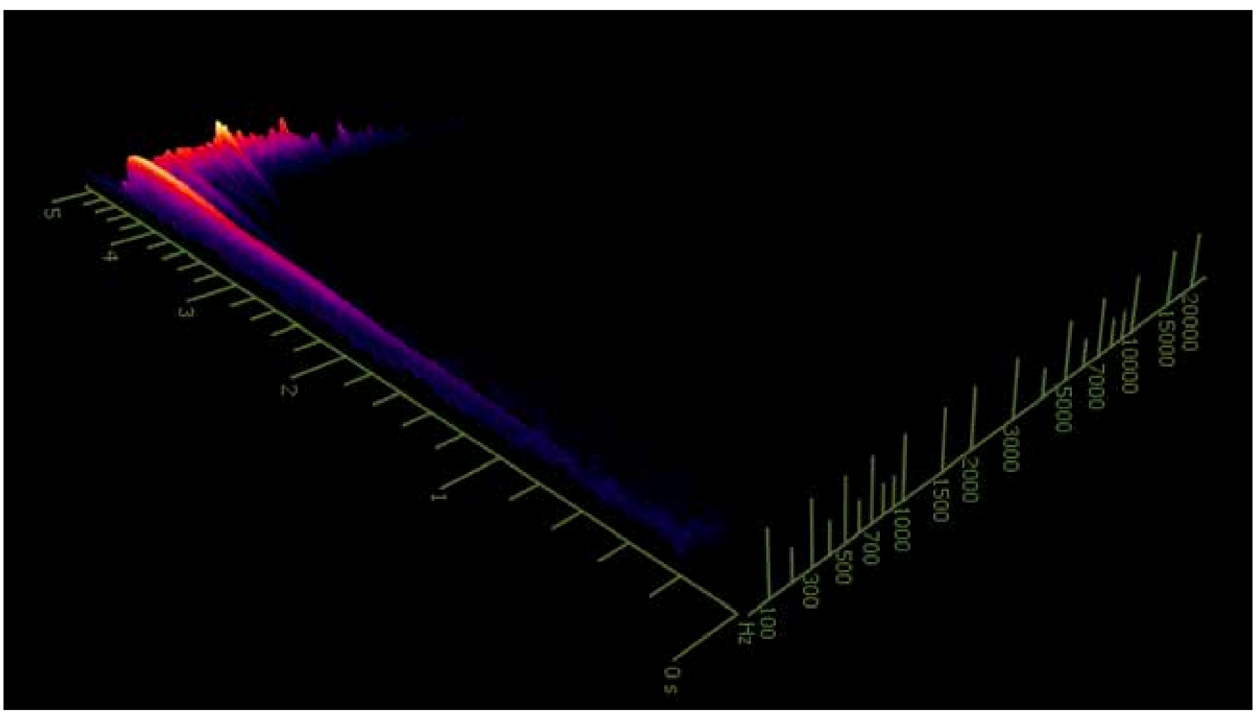

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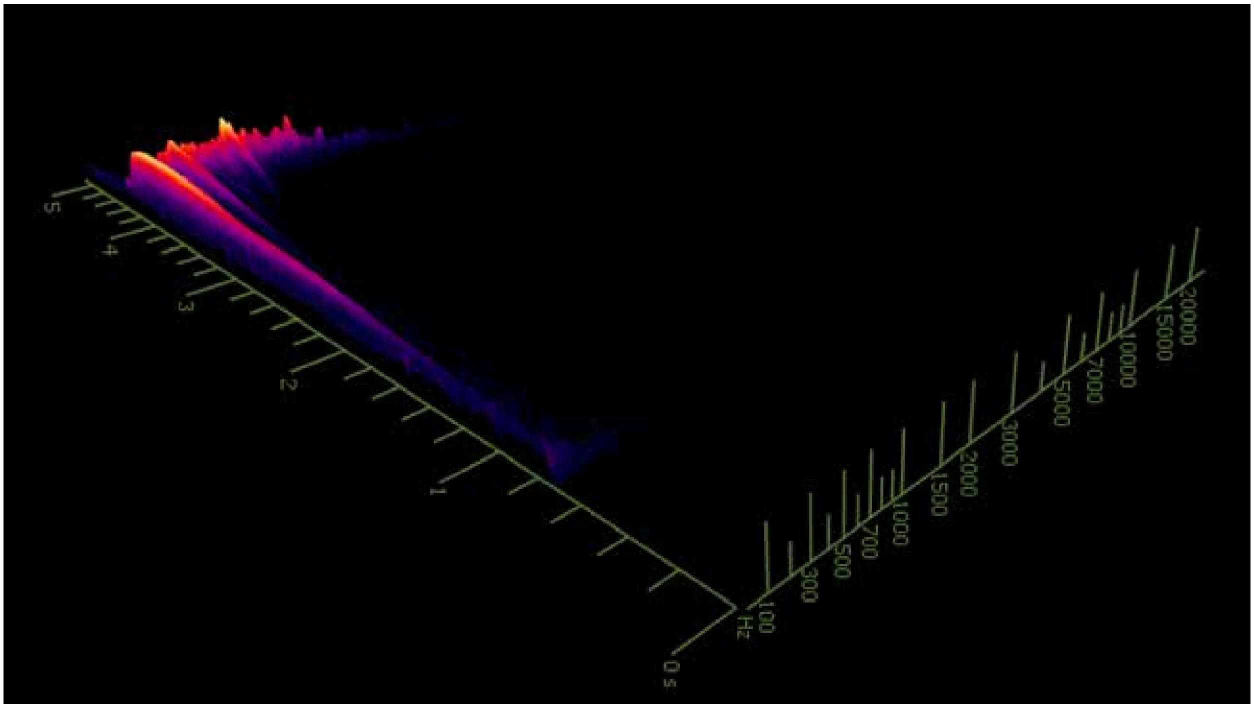

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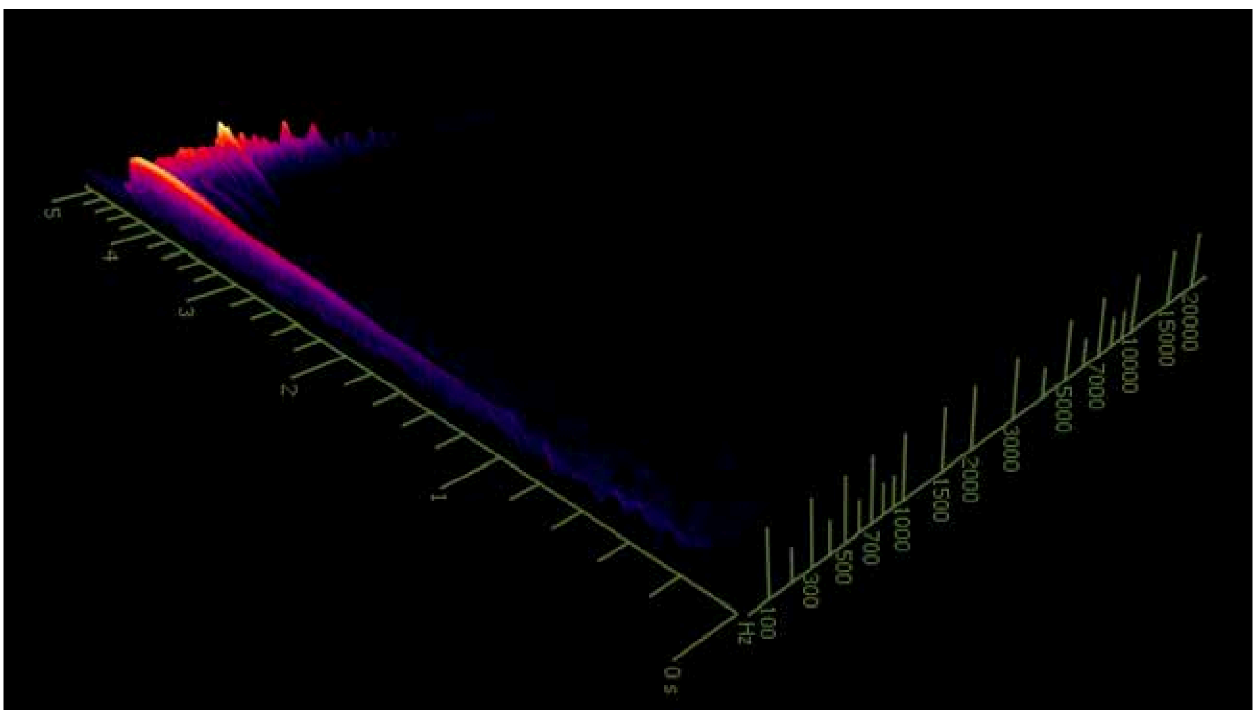

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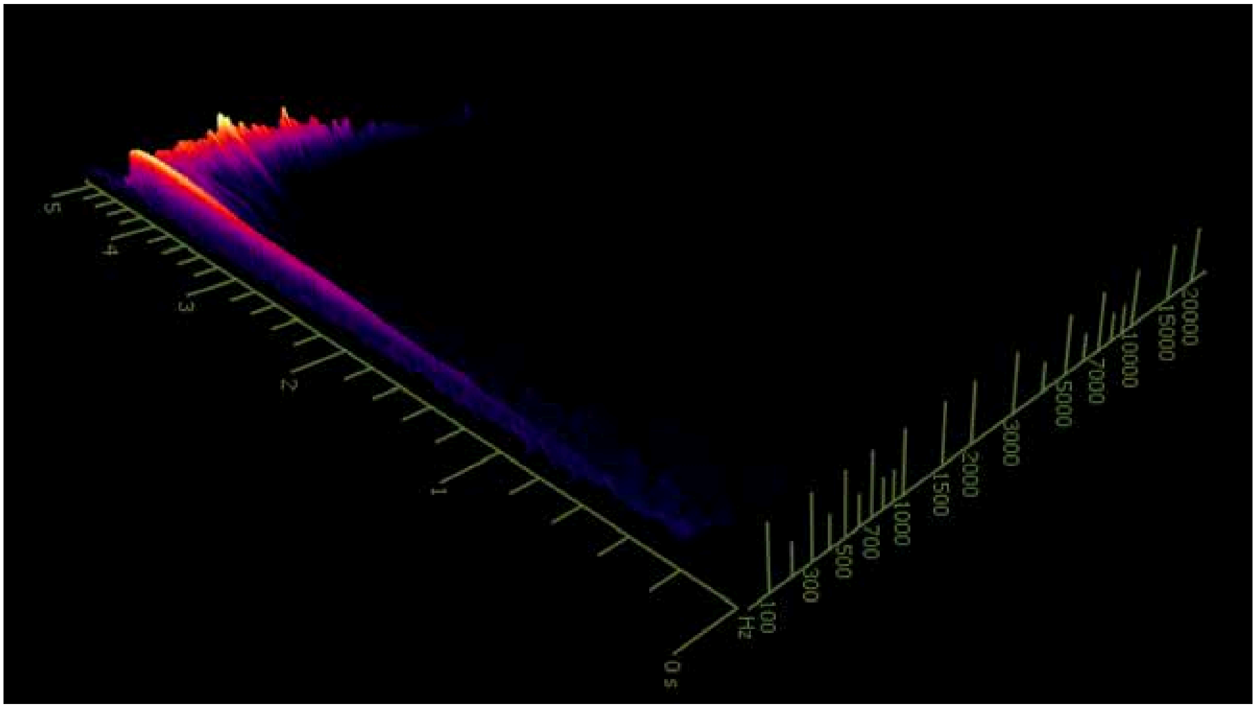
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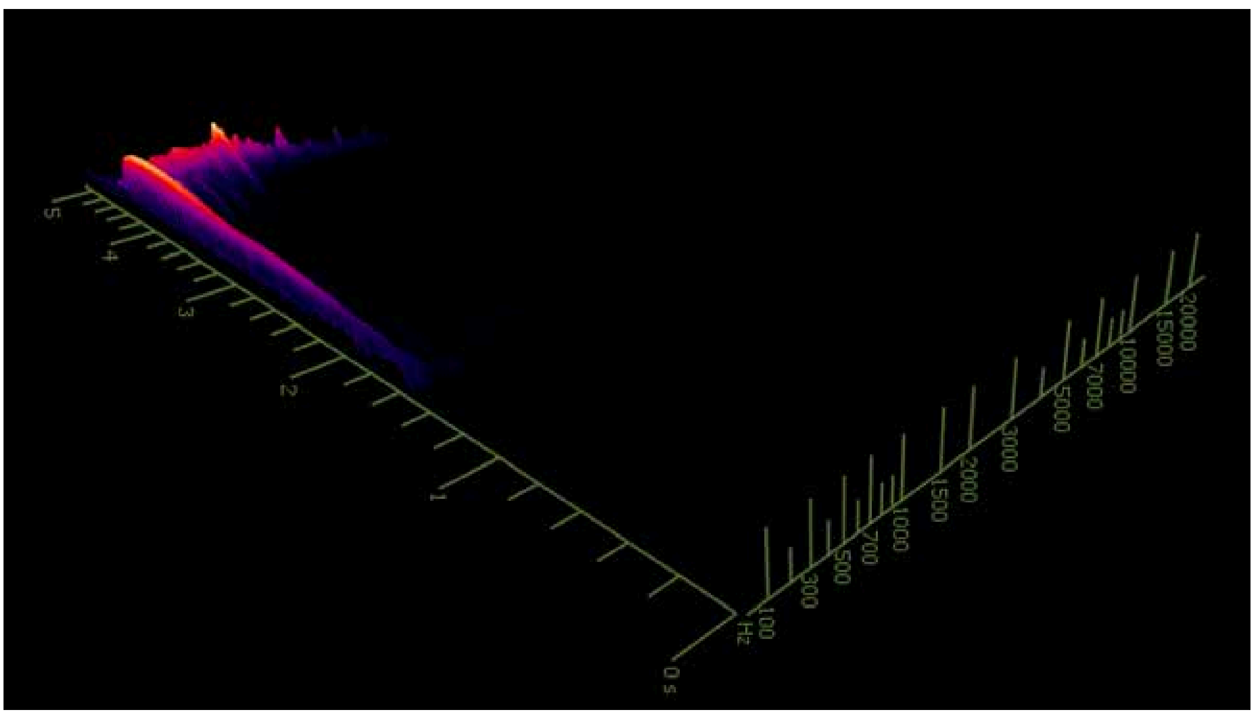
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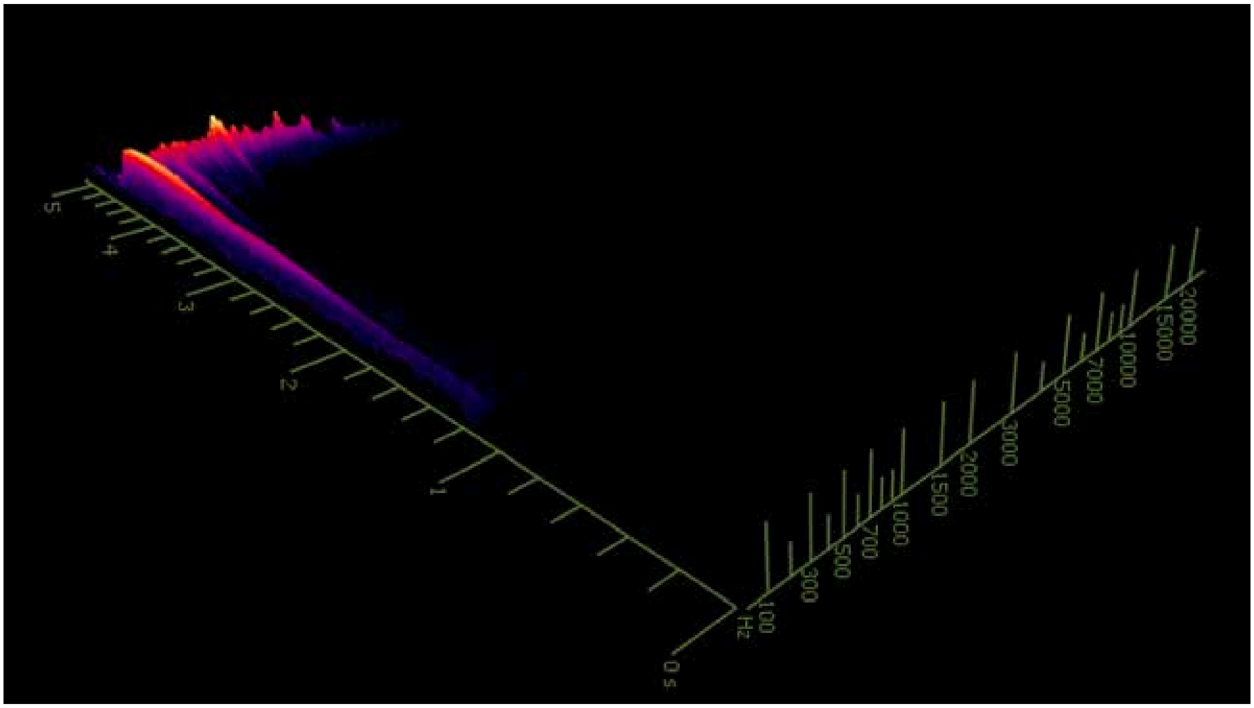
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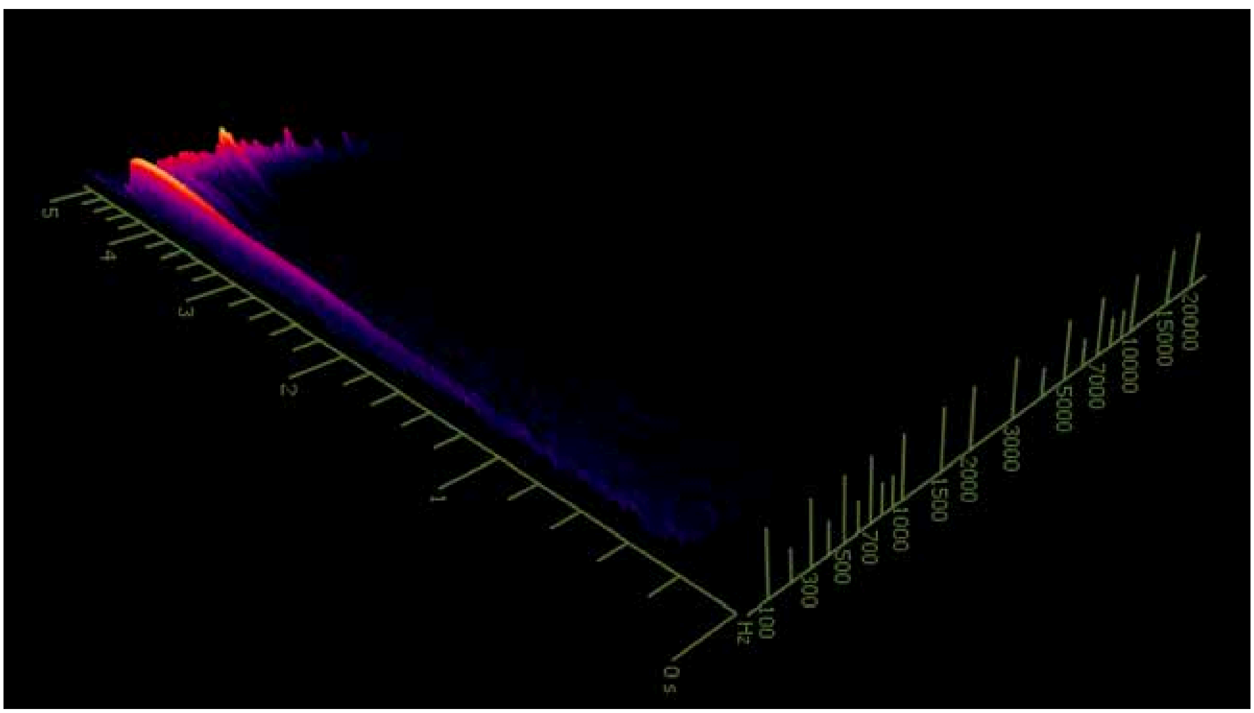
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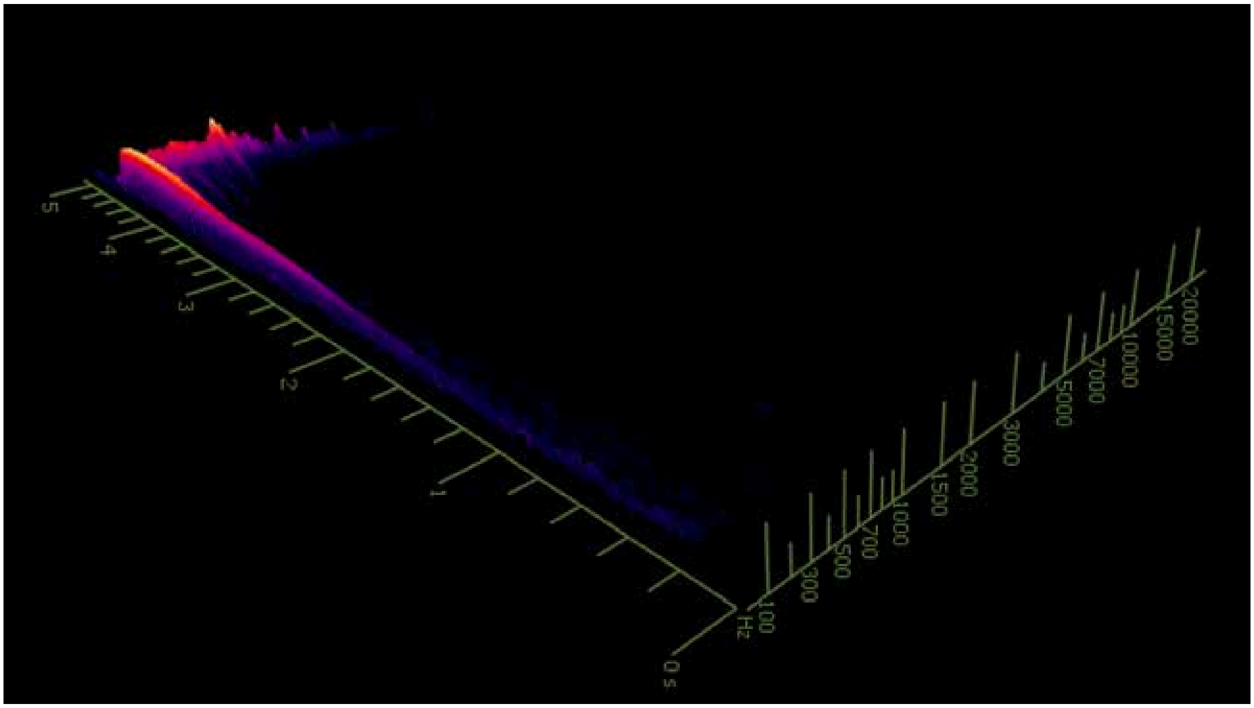
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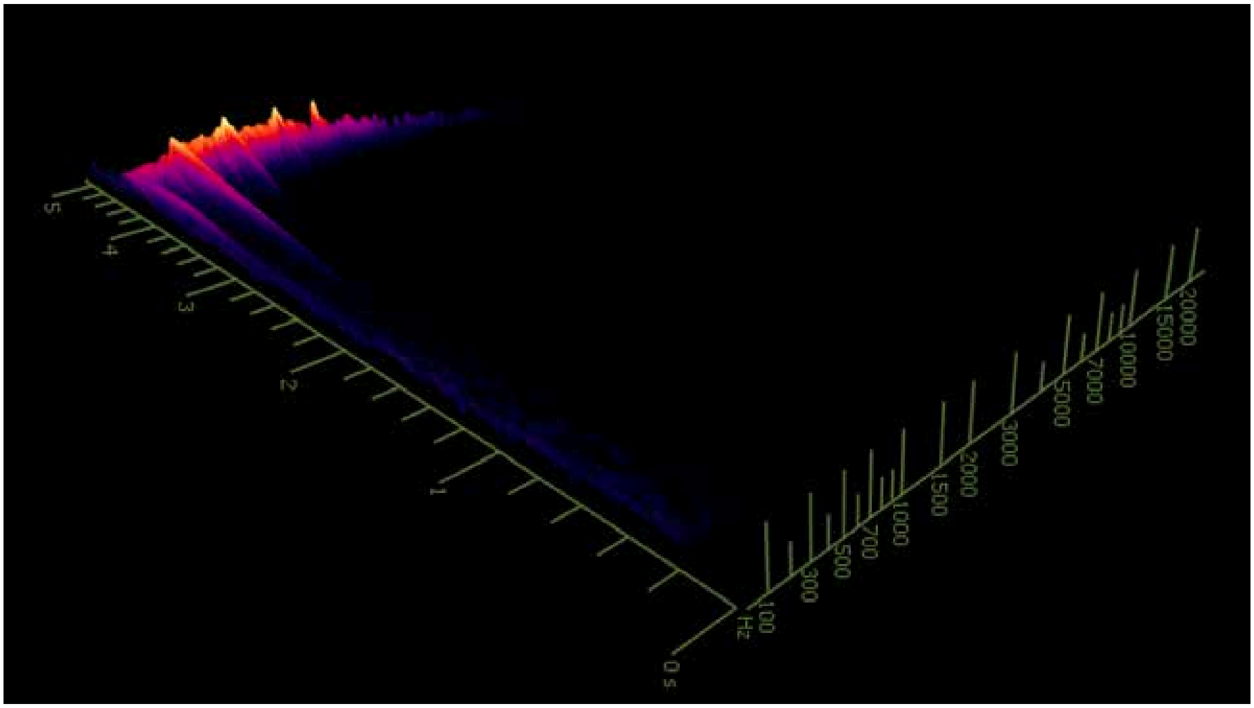

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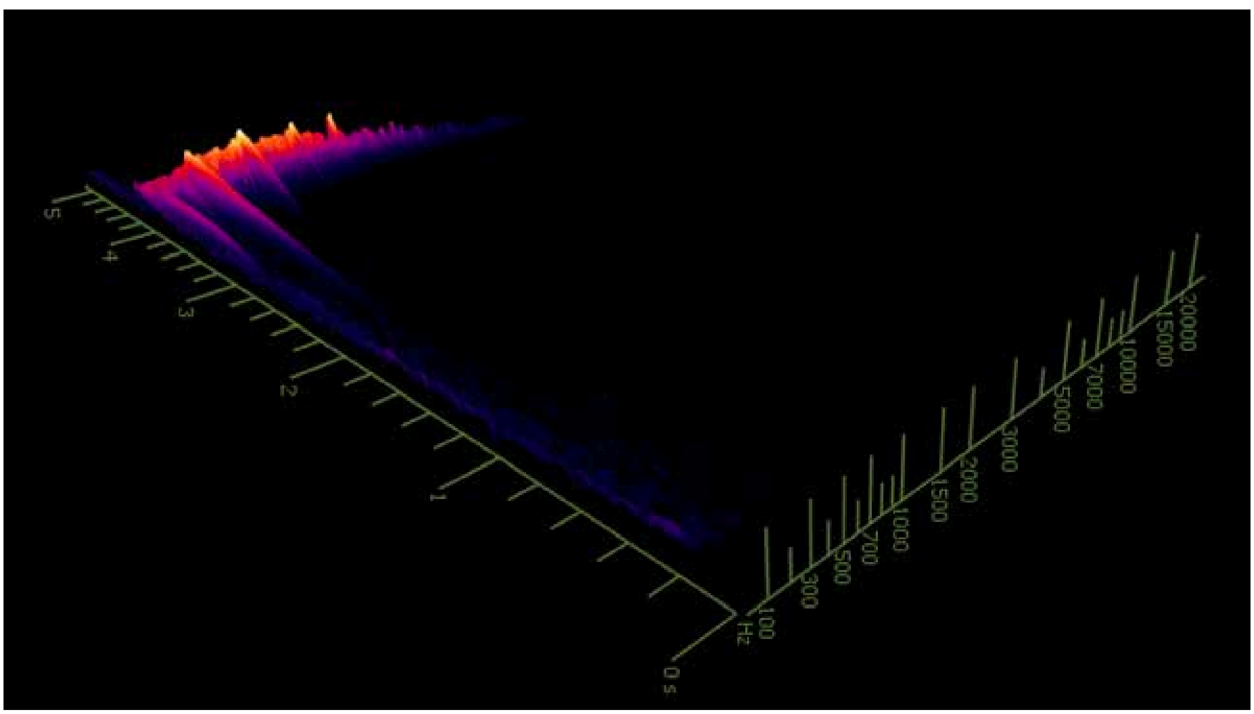

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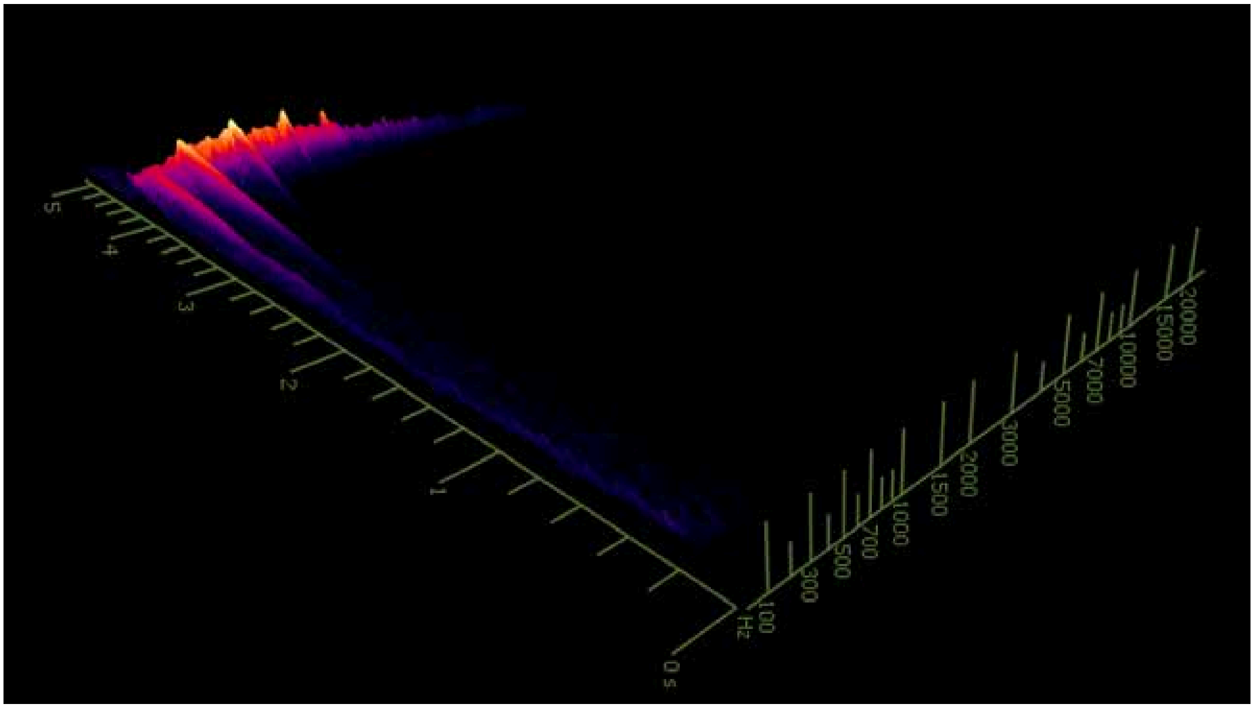

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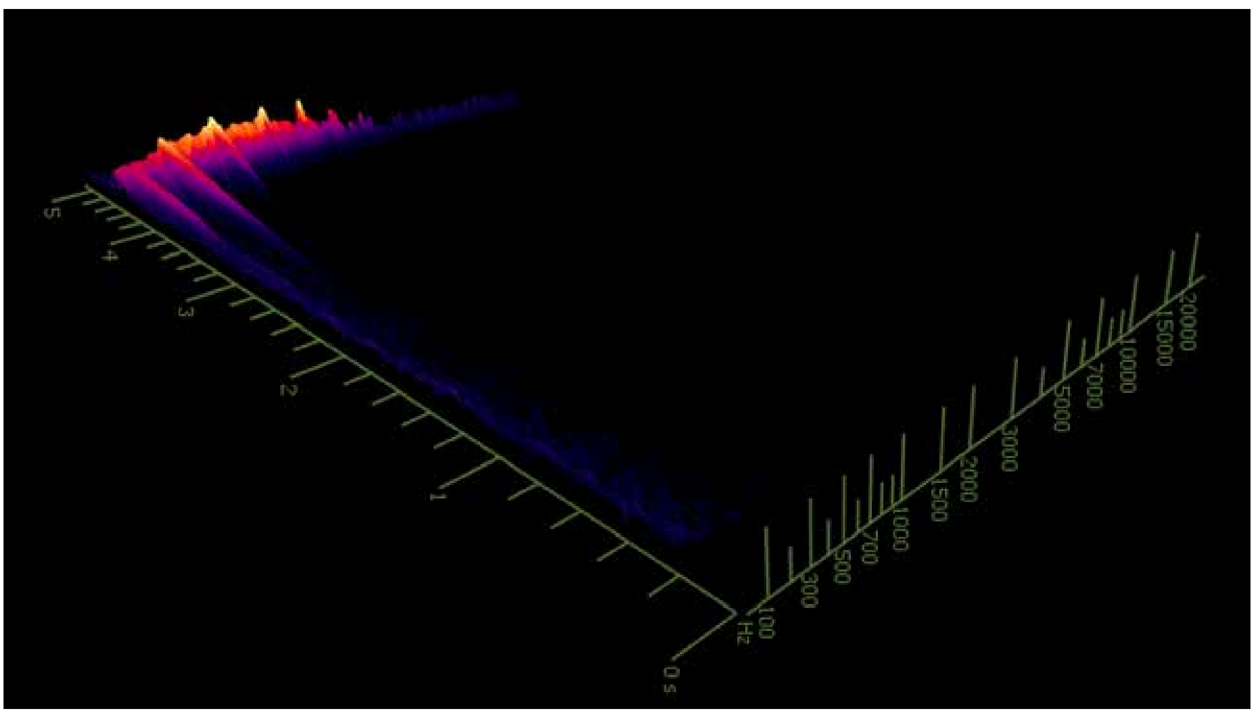

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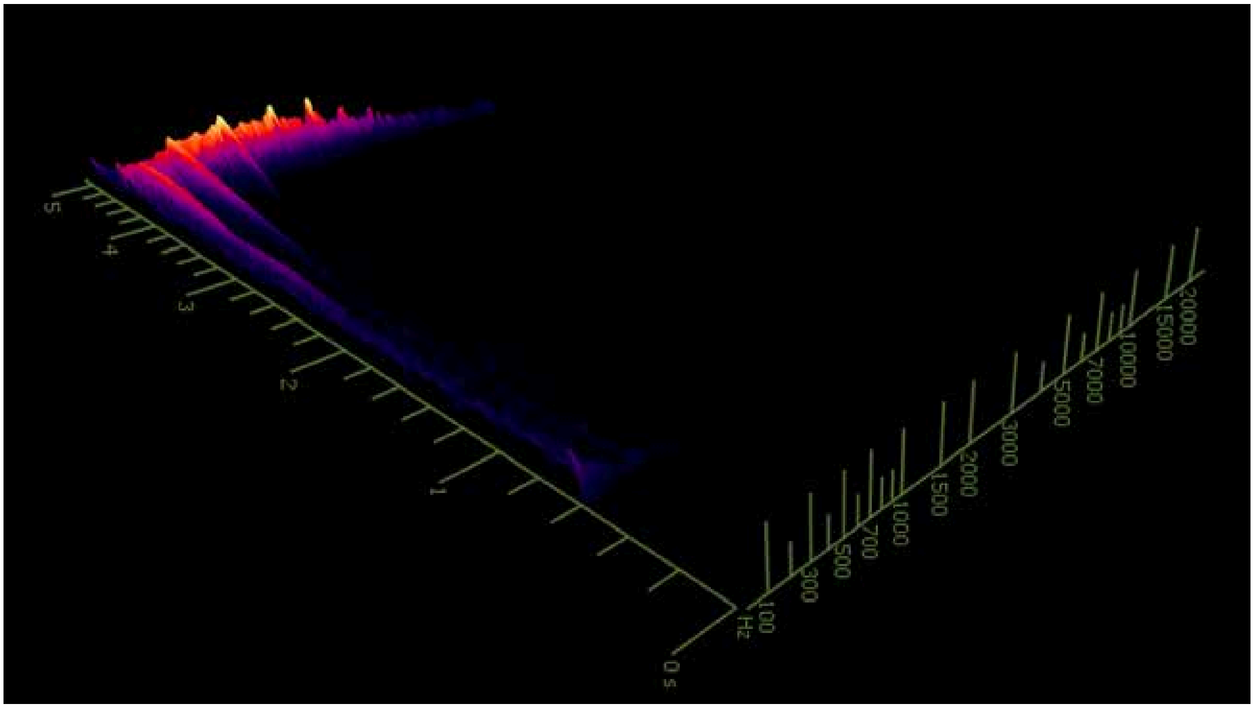
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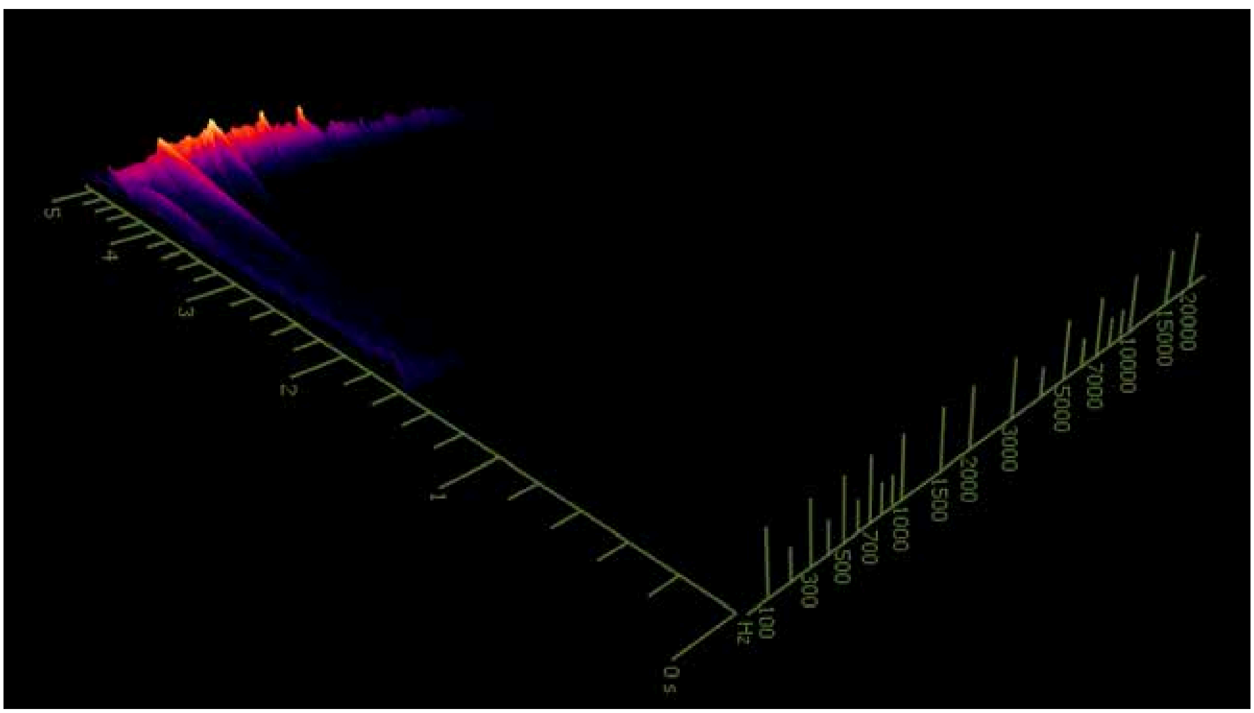
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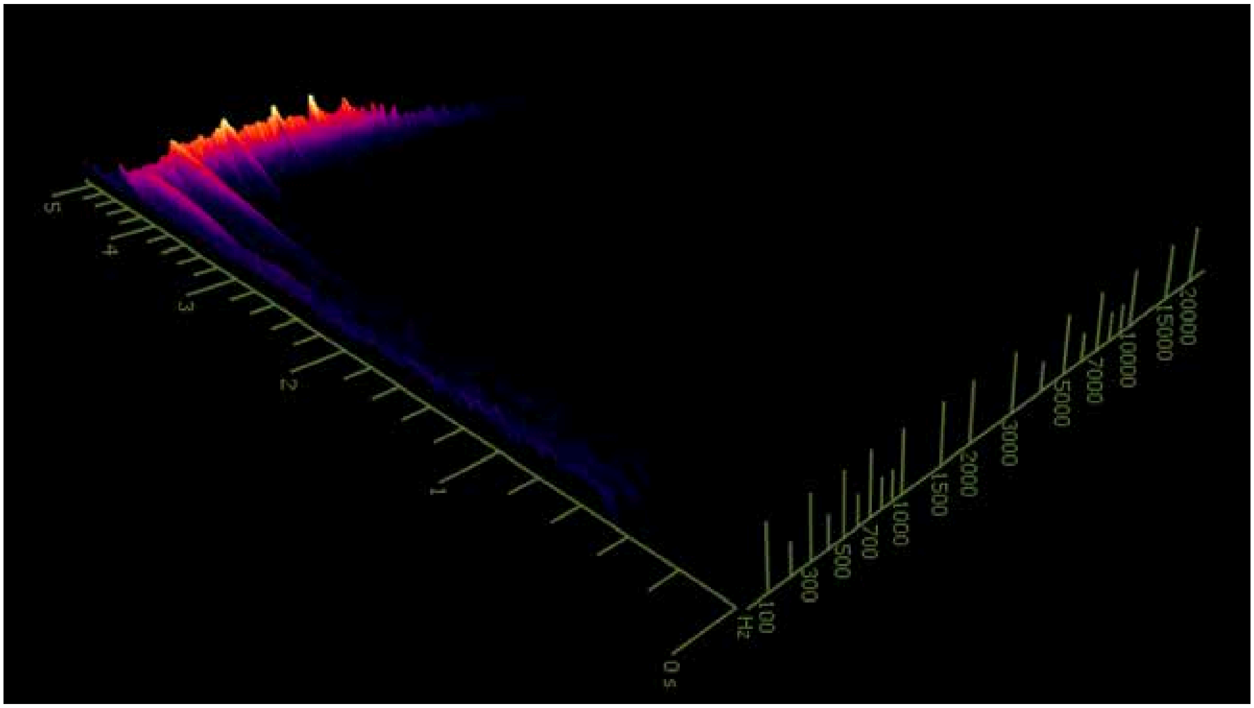
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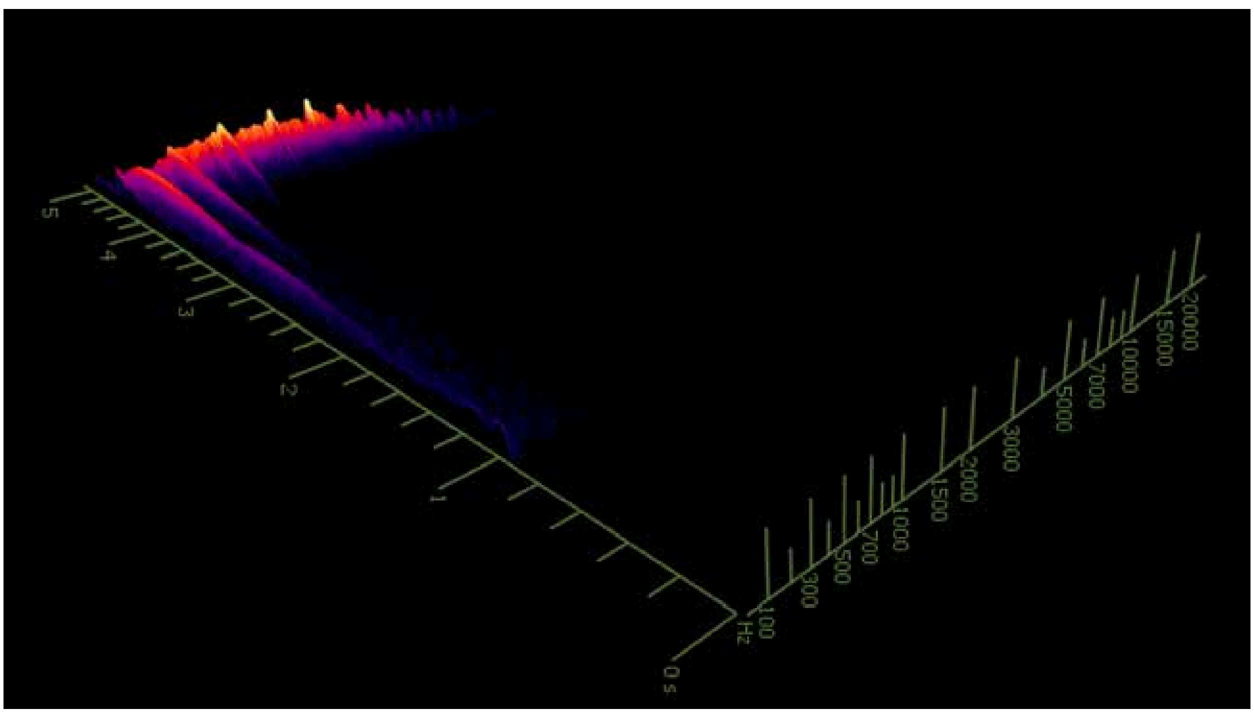
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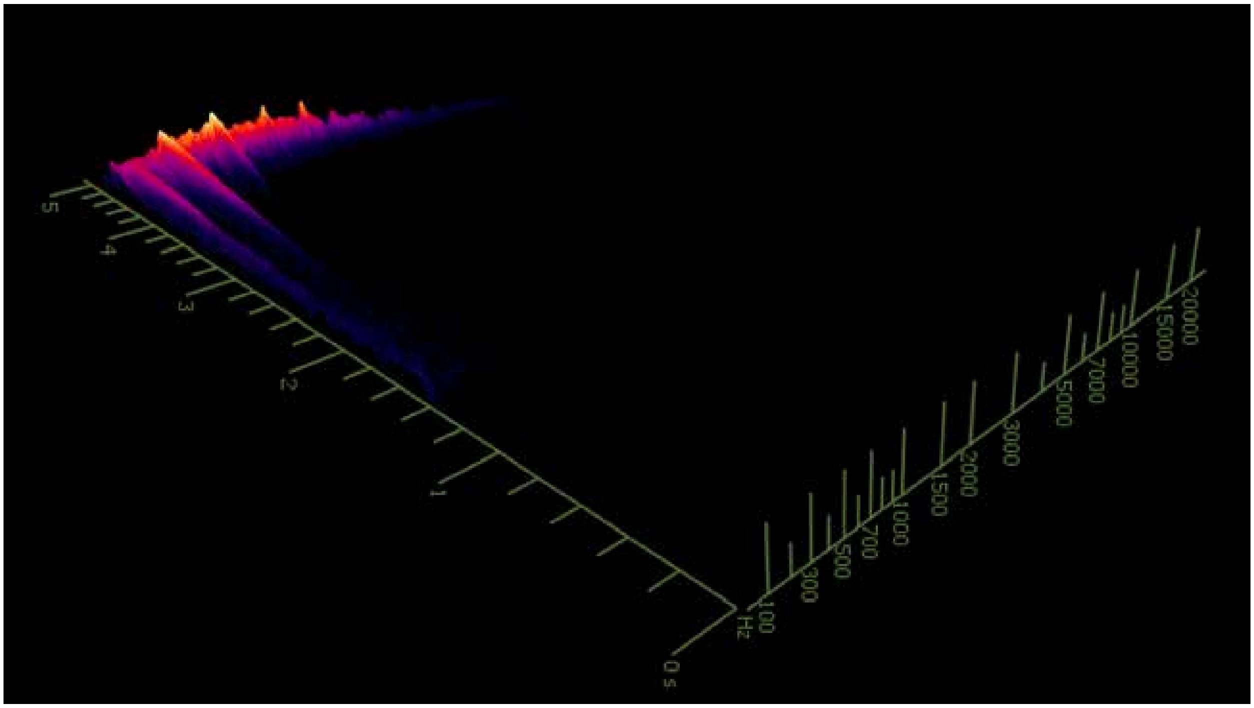
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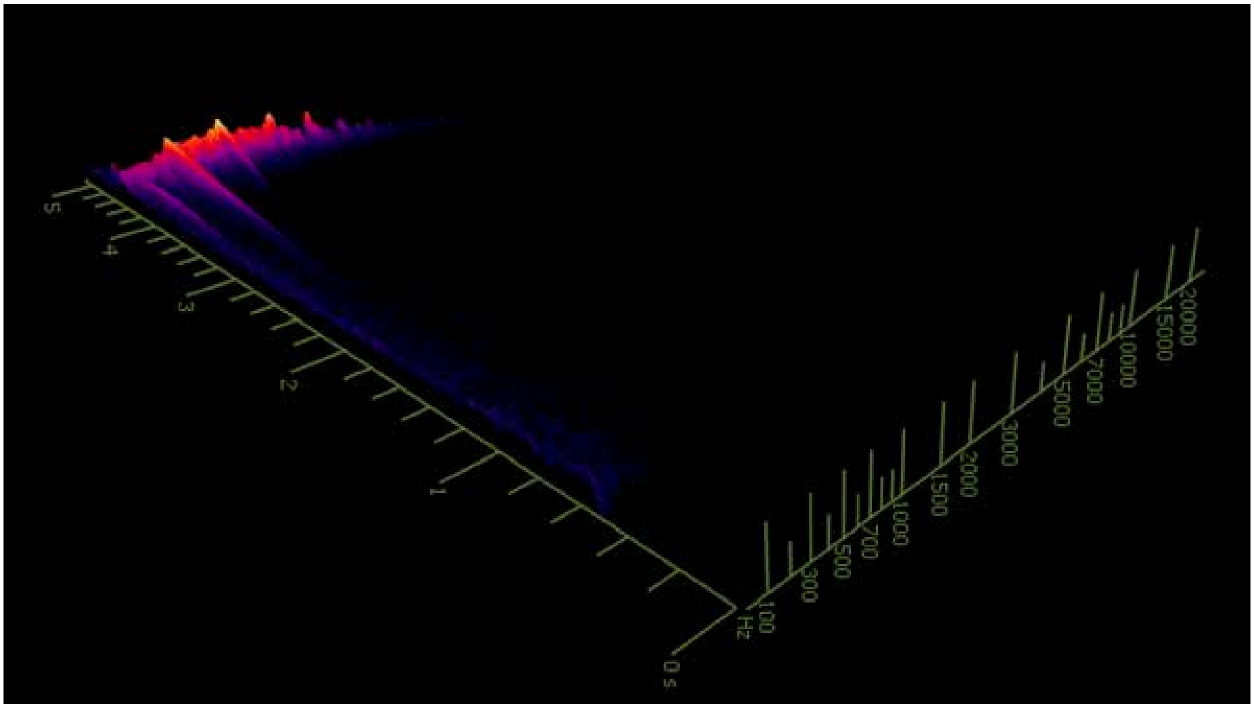

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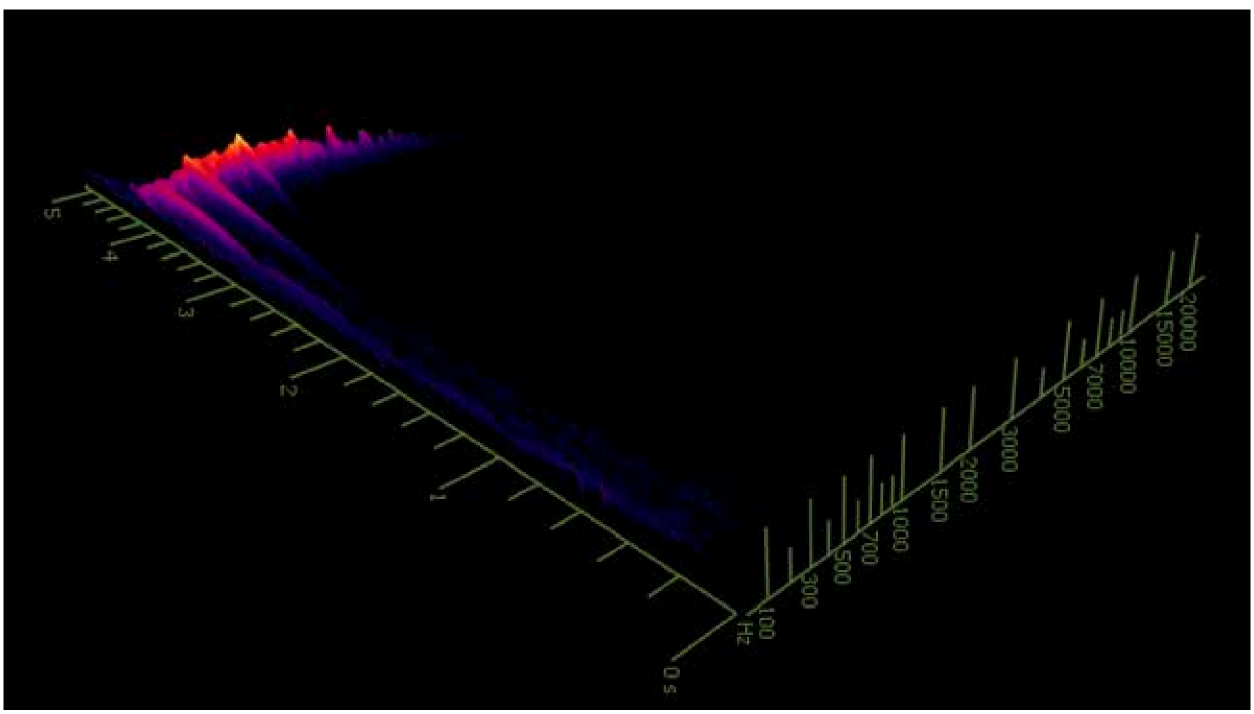

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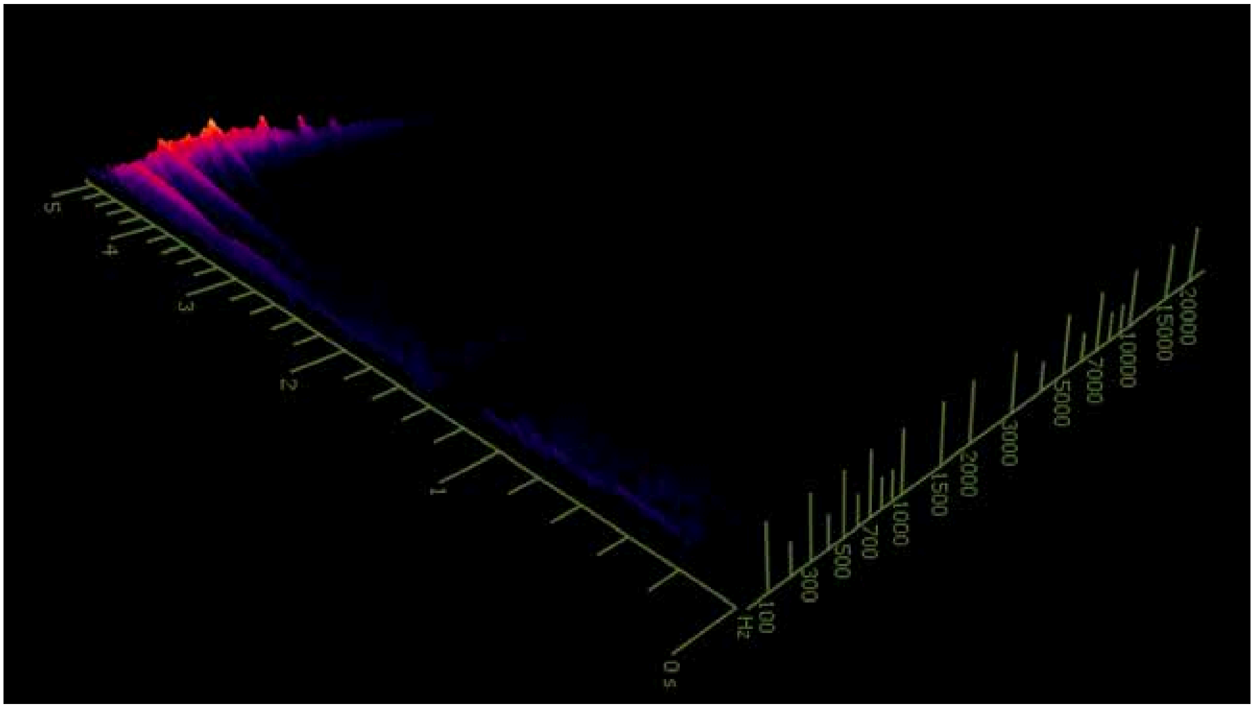

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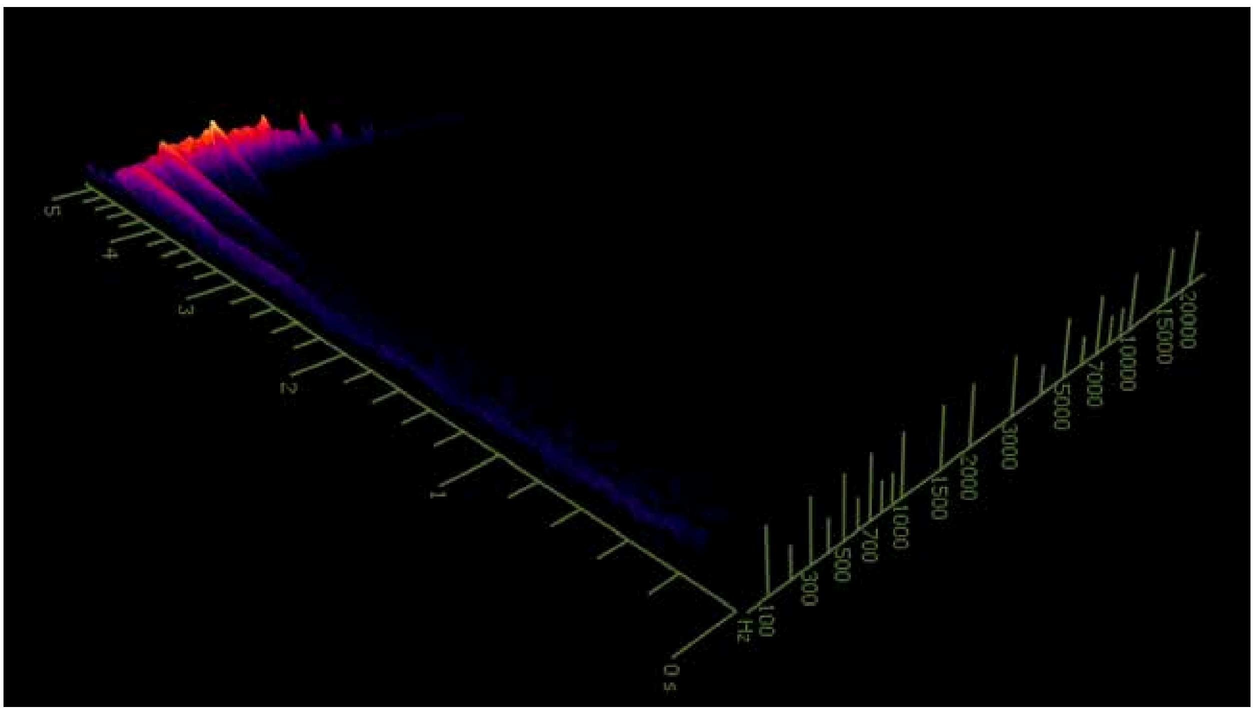

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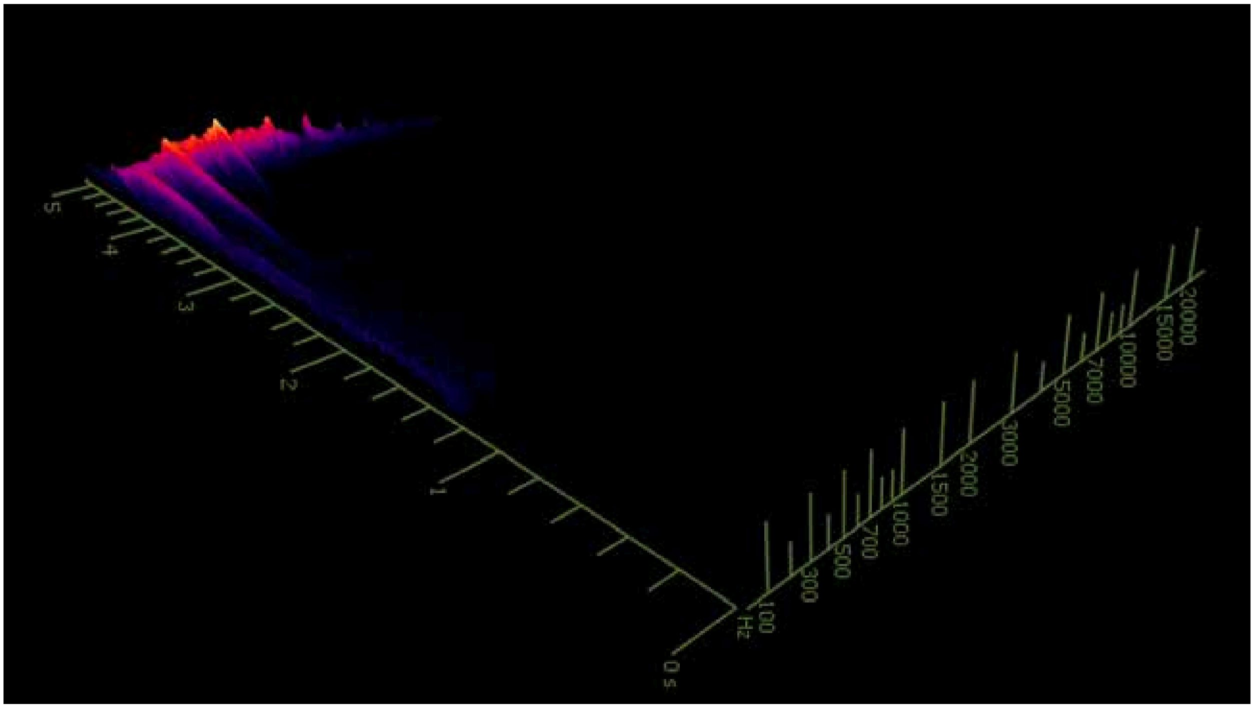
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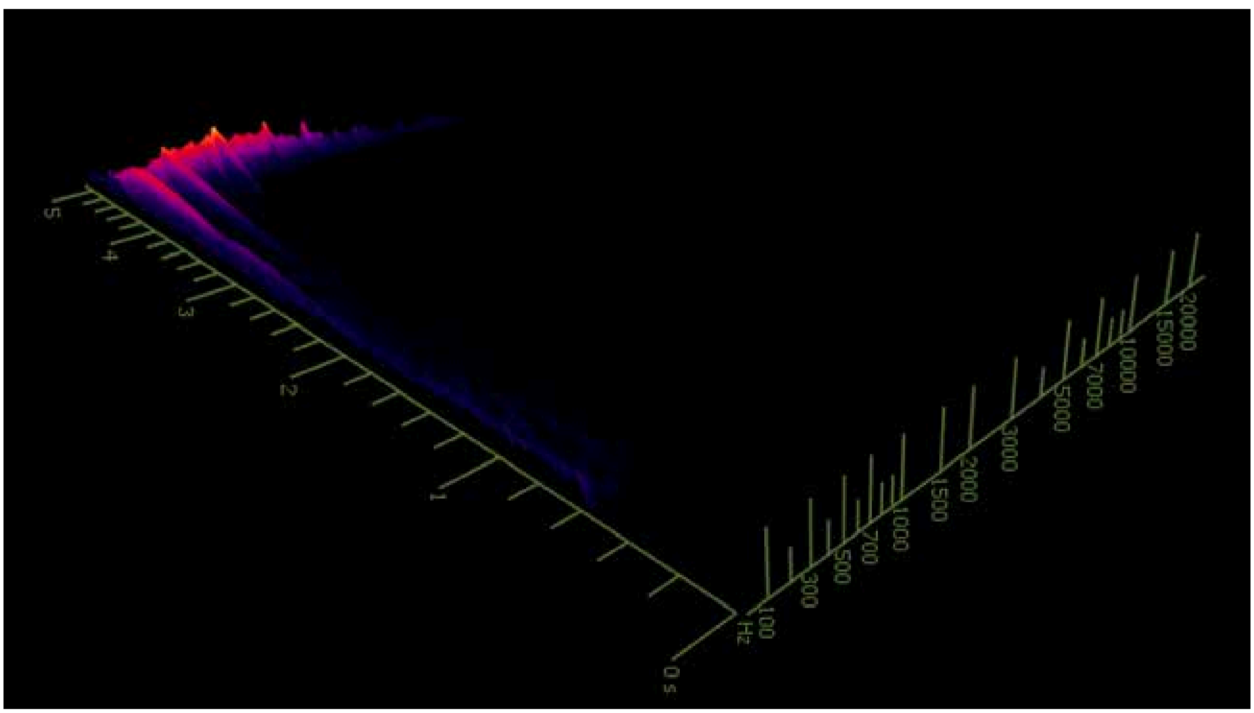
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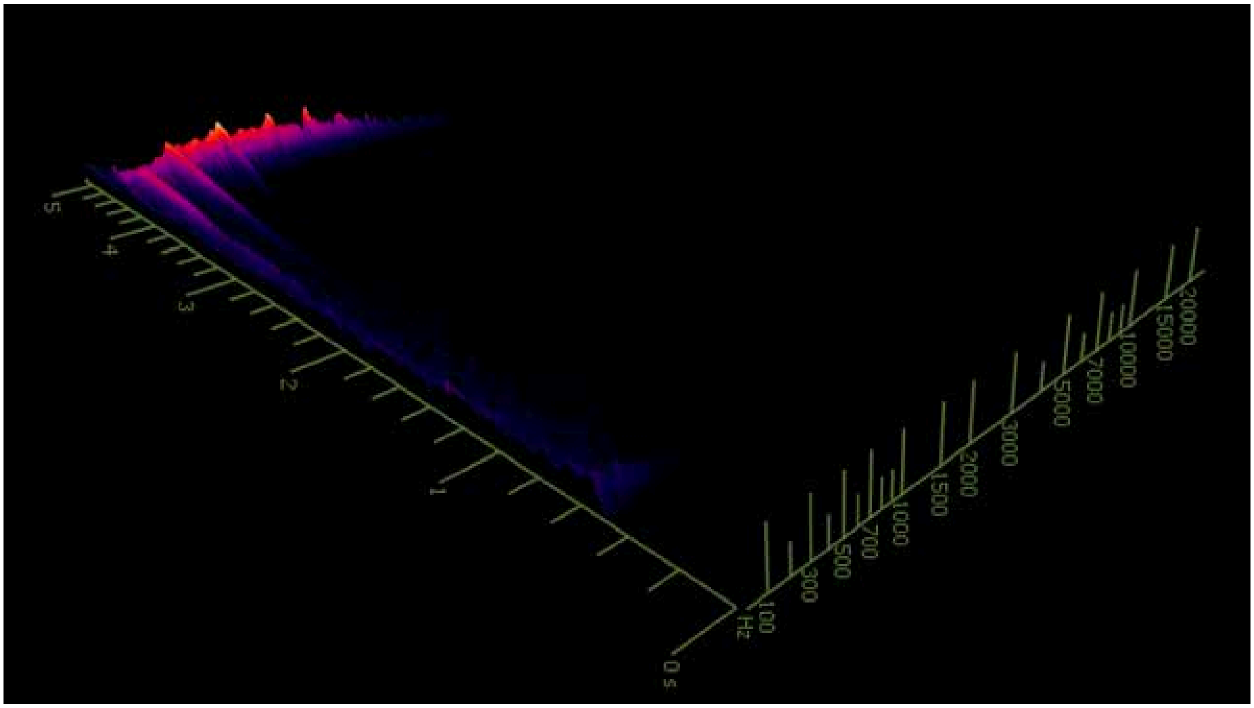
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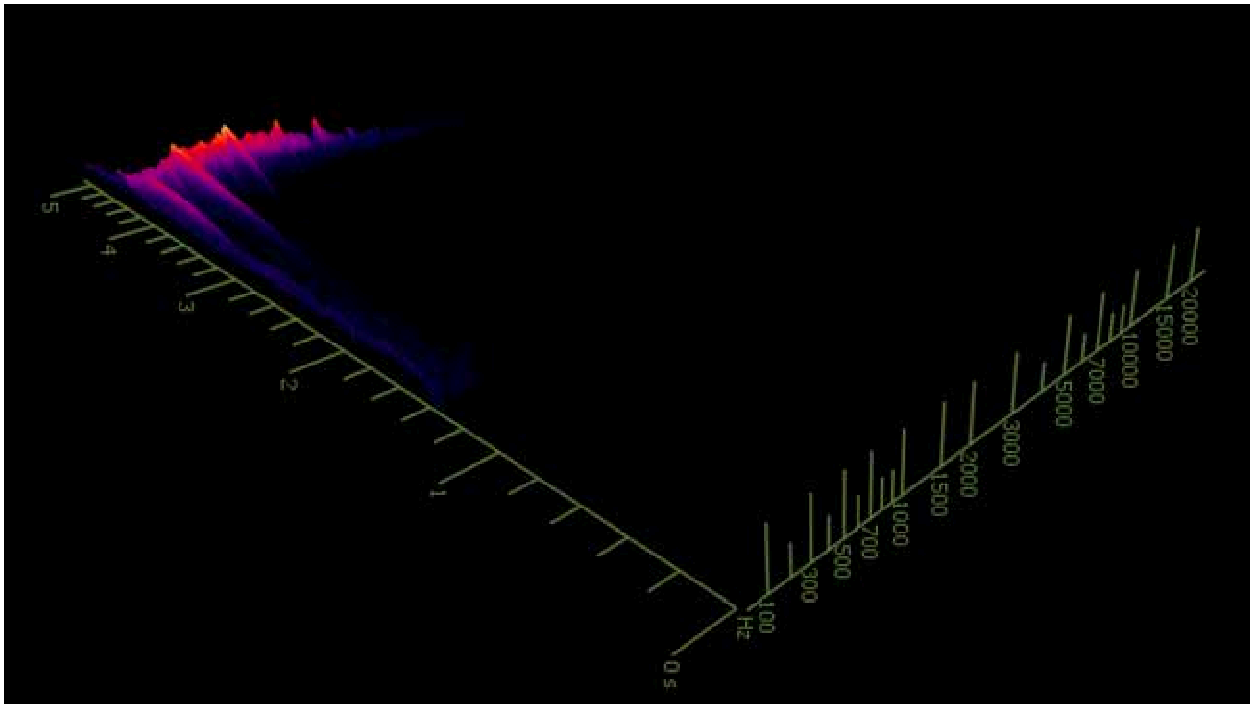
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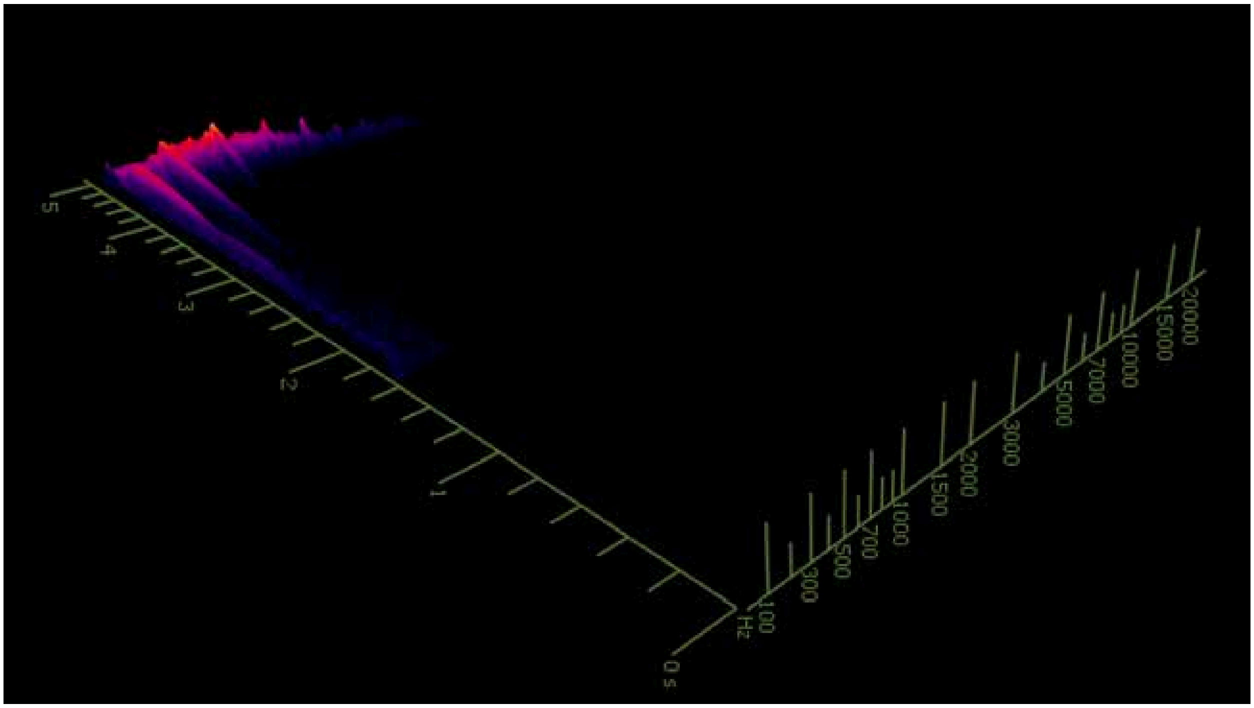
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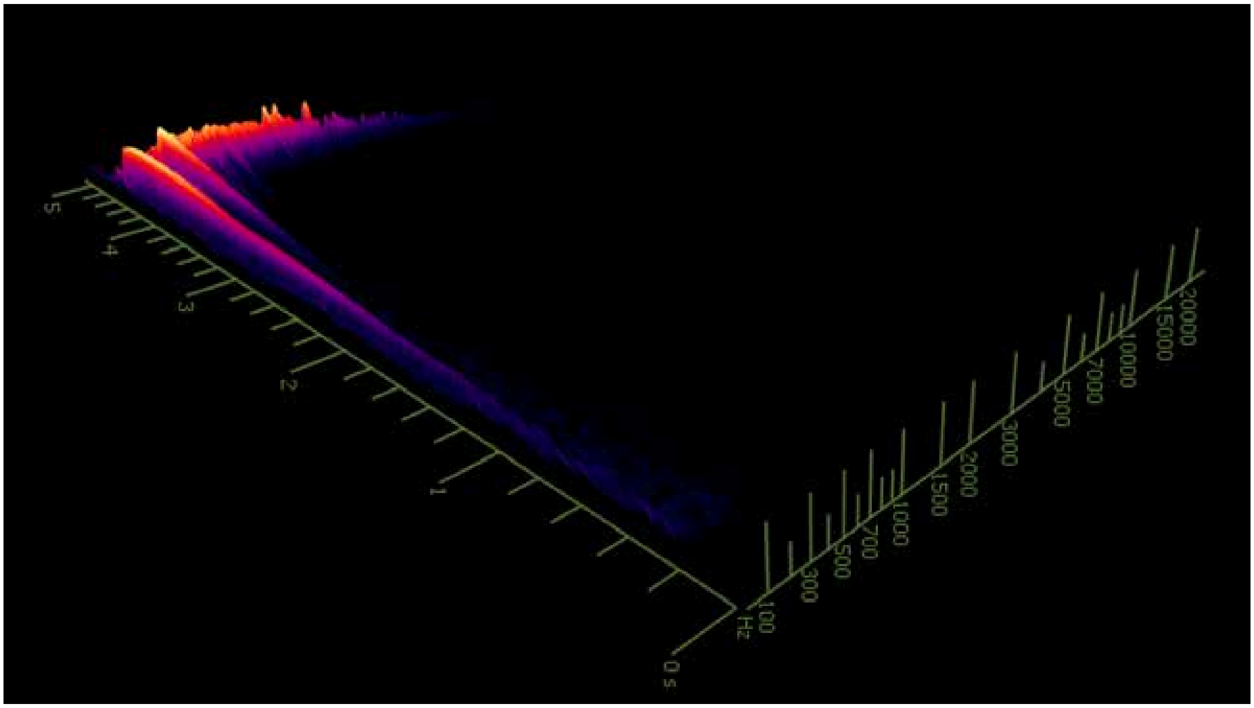
Fast Stroke, Just Off-Center



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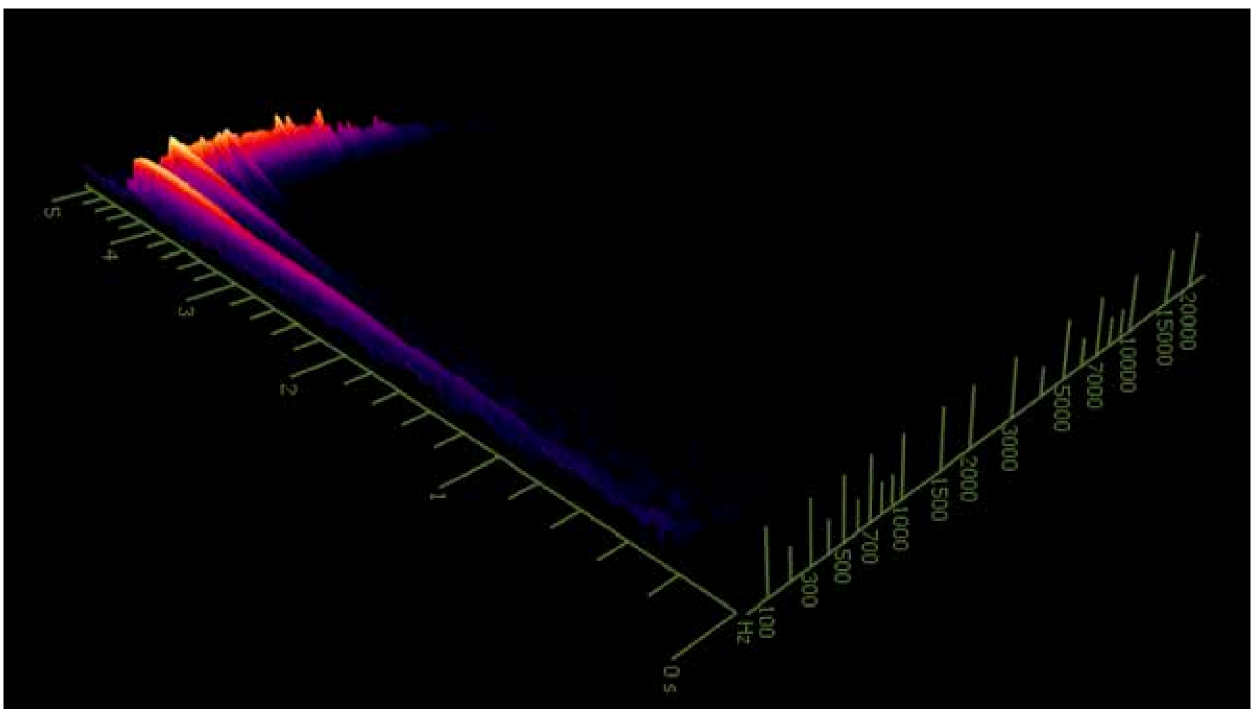

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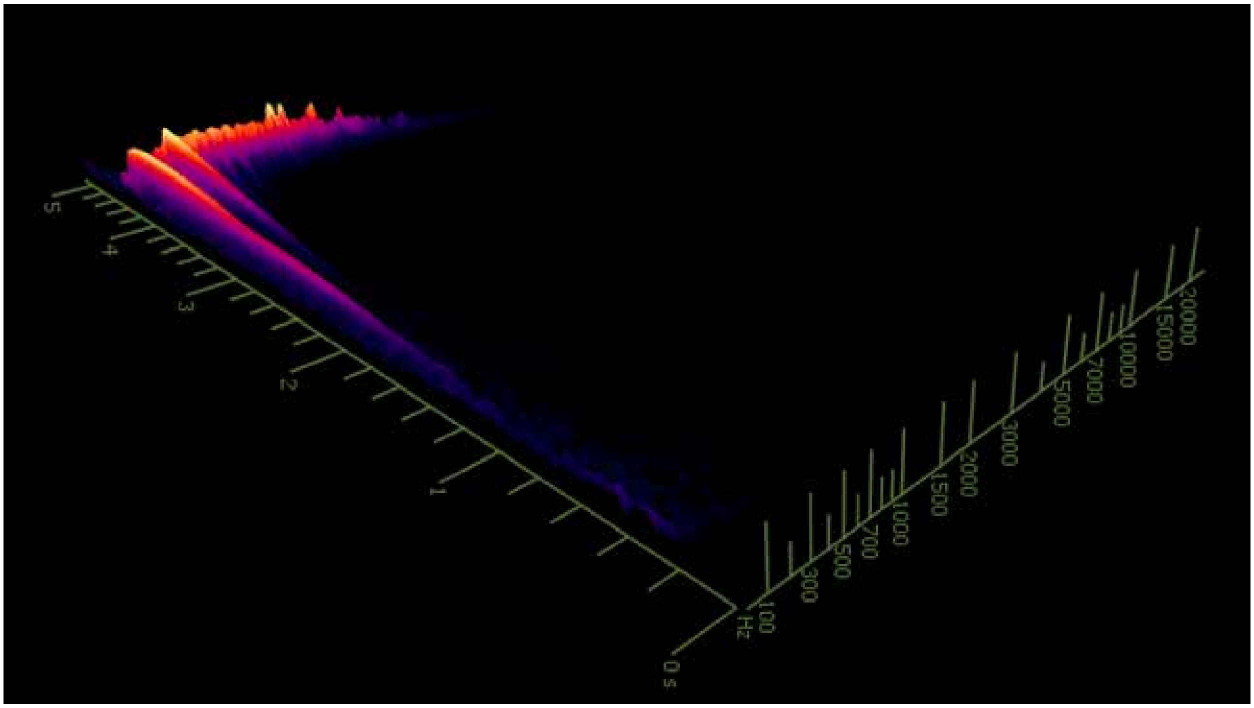

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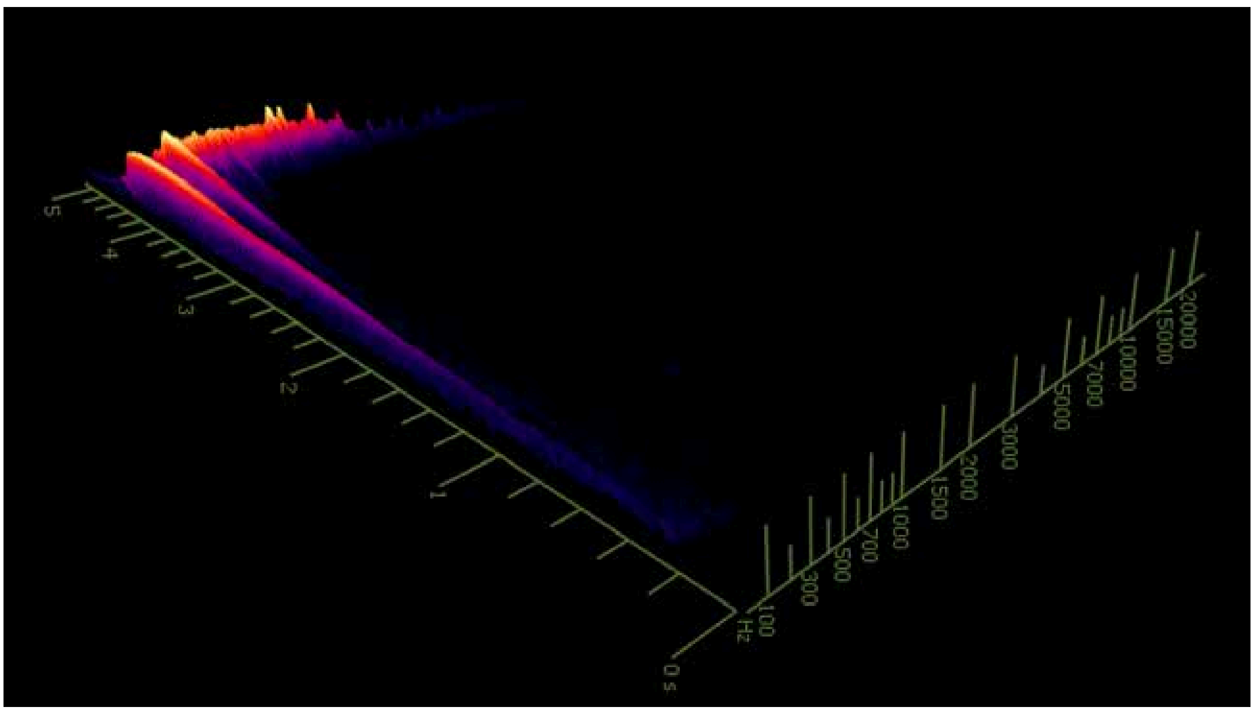

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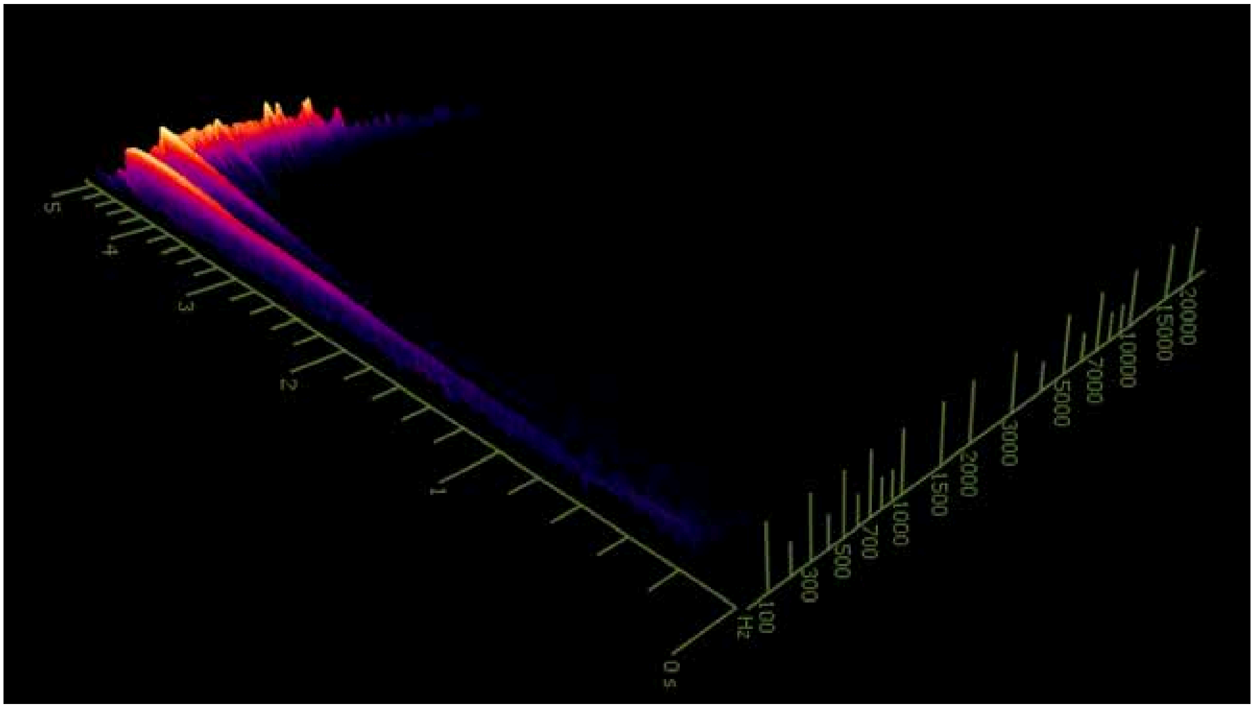

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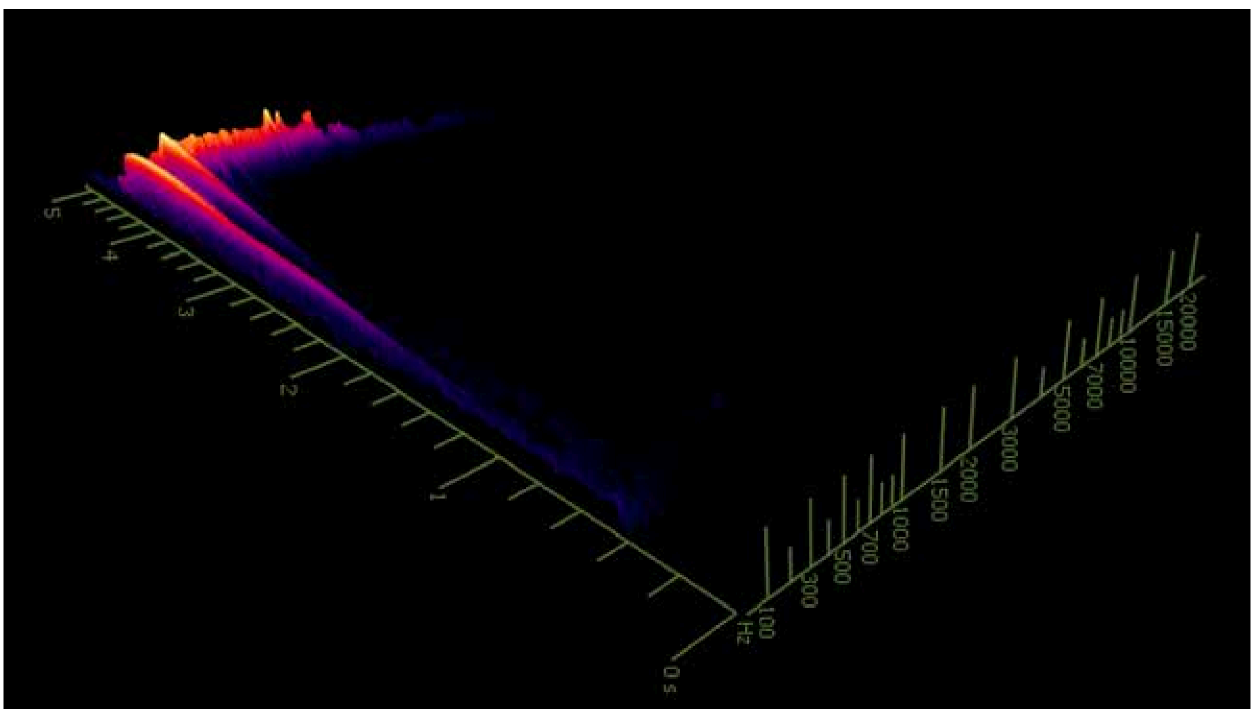

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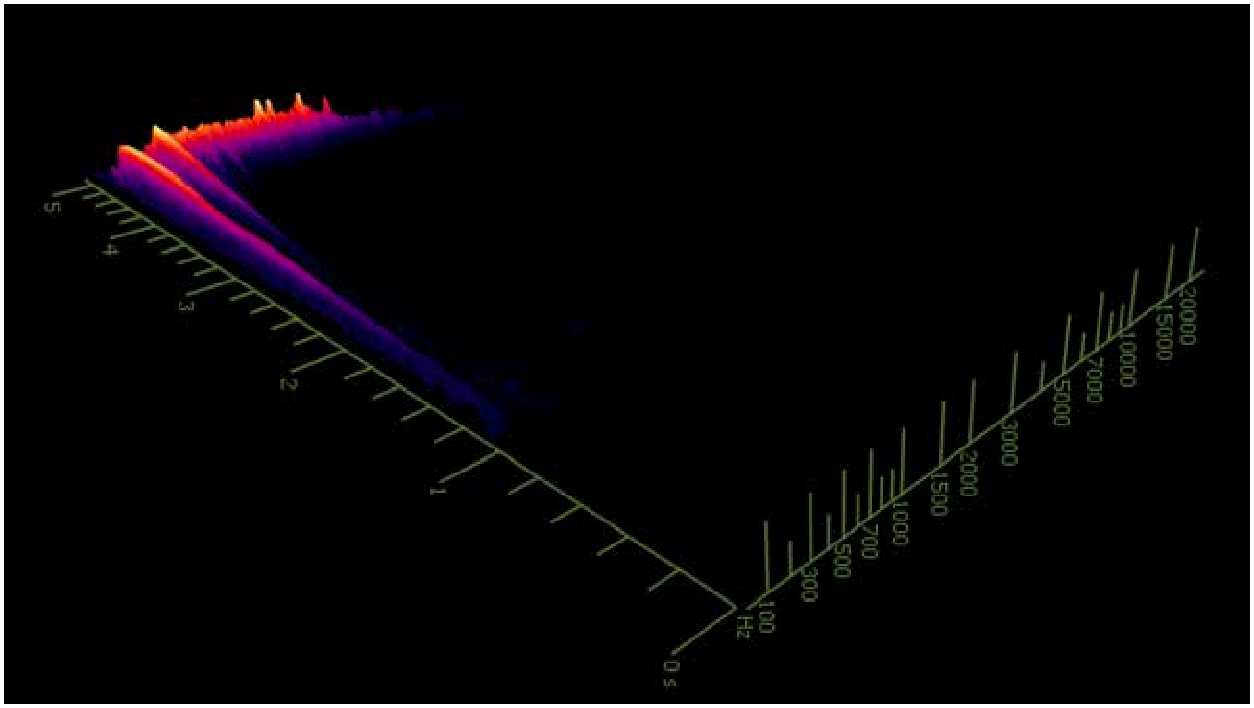
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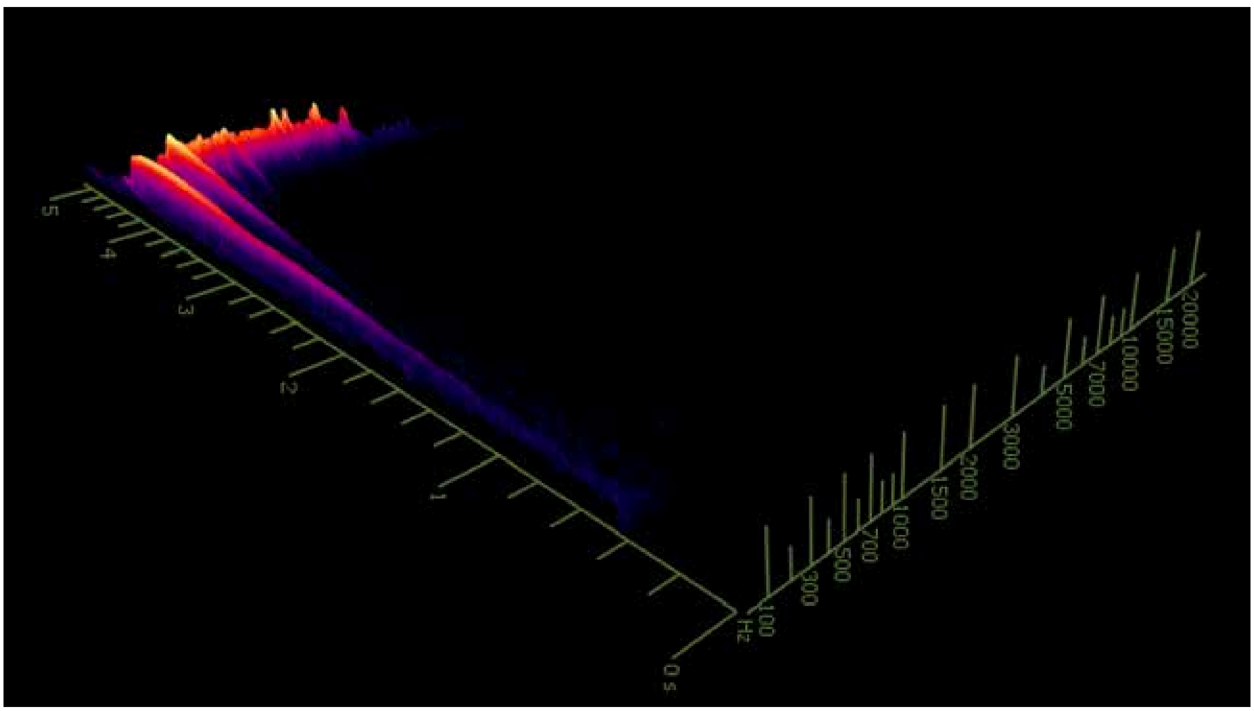
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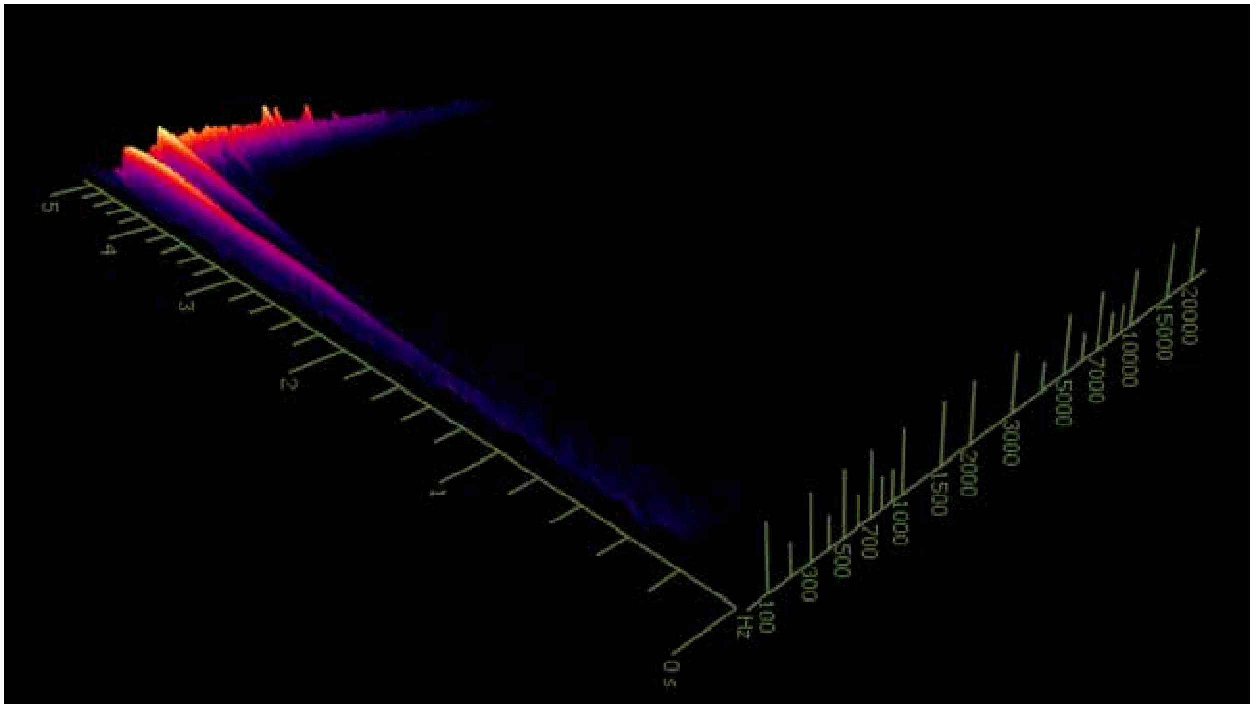
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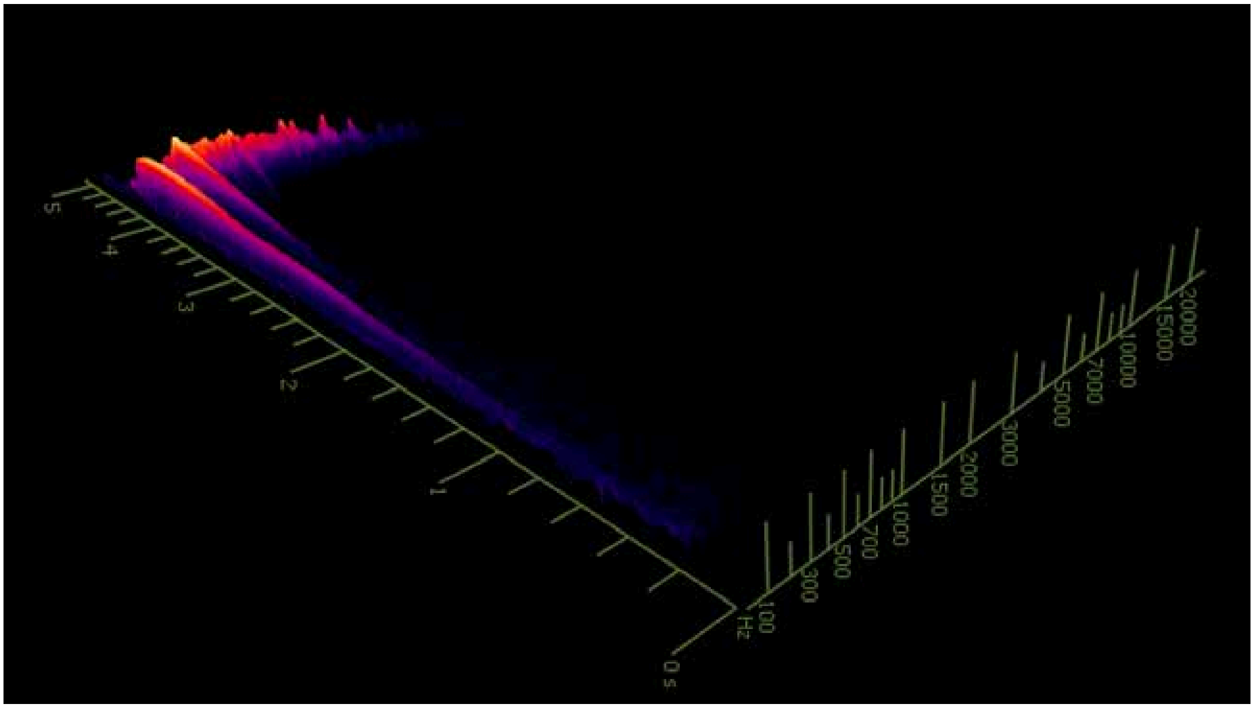
Slow Stroke, Just Off-Center



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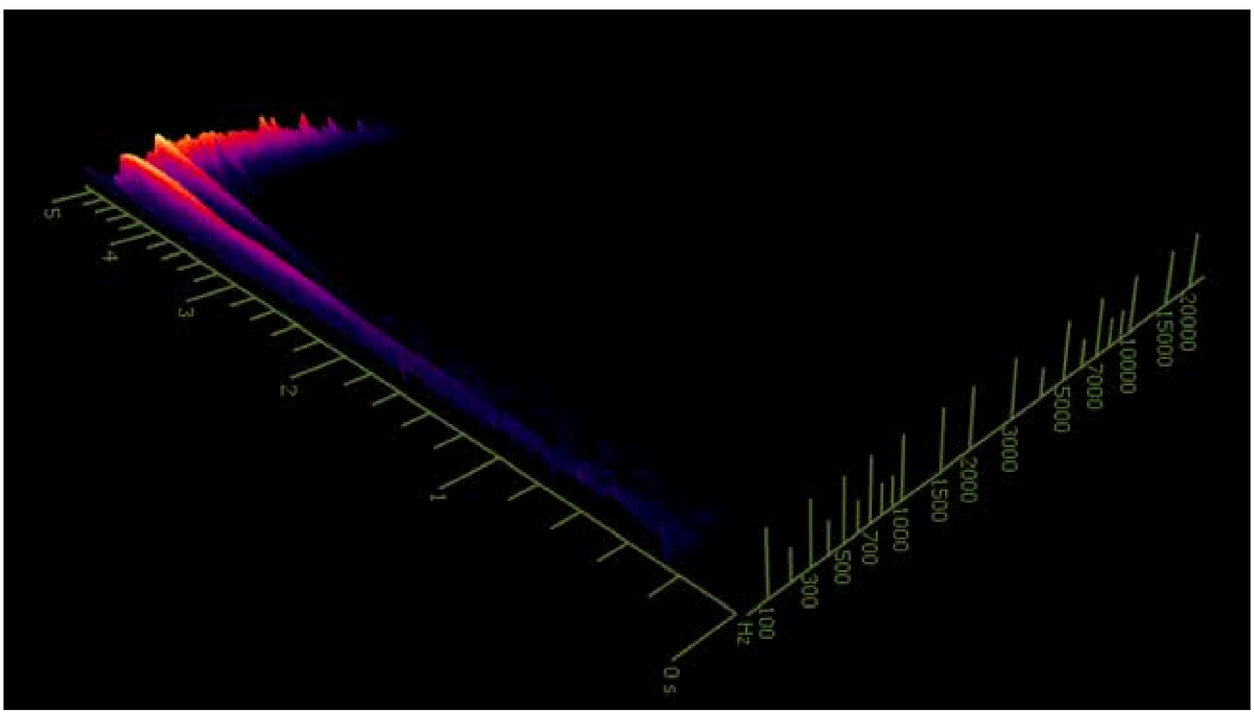

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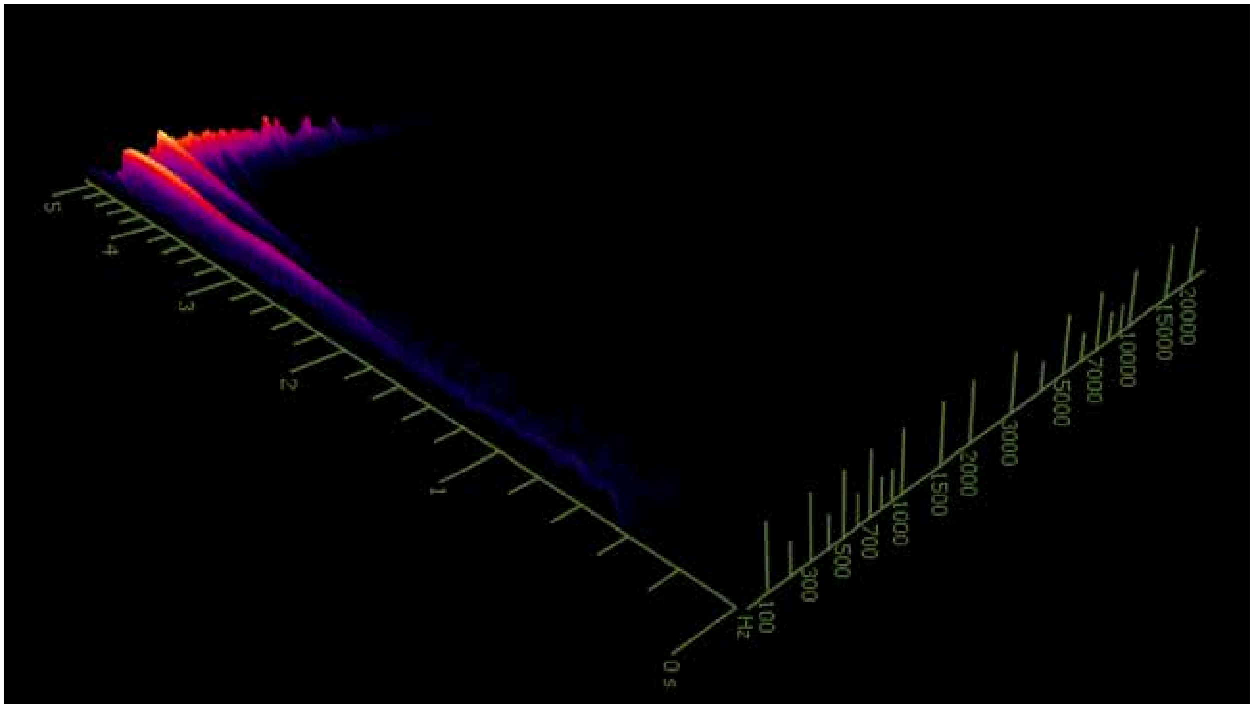

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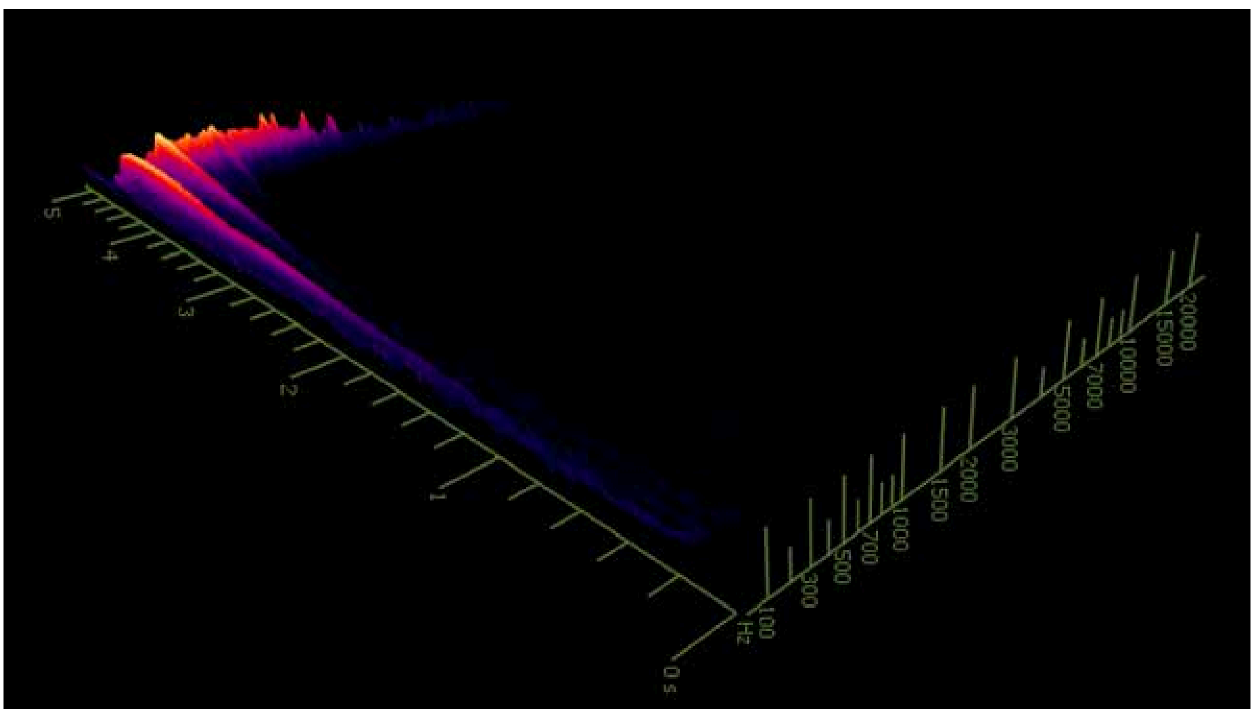

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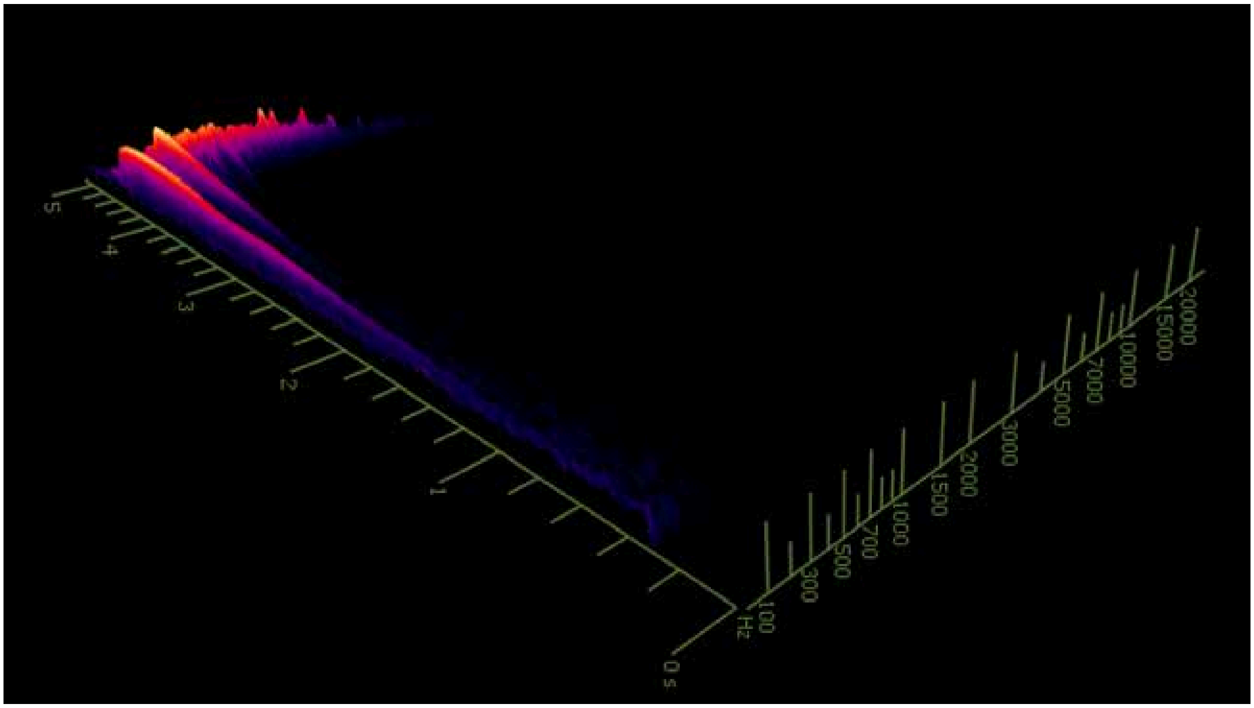

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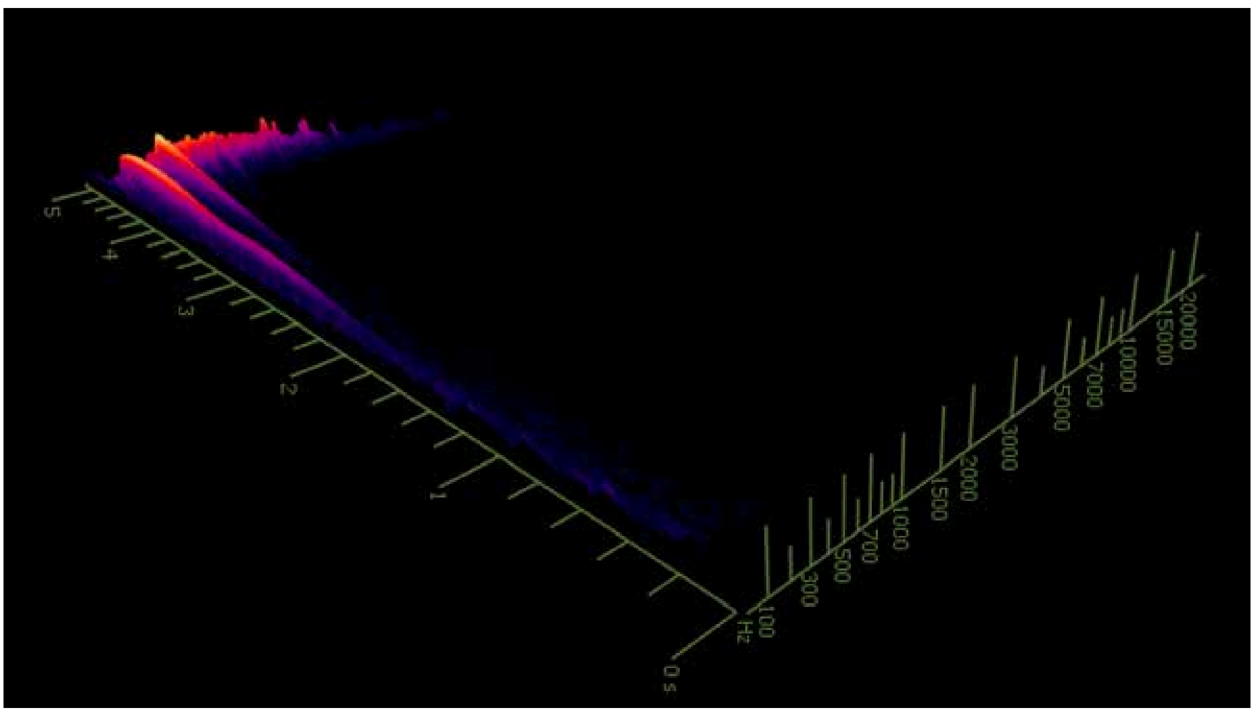

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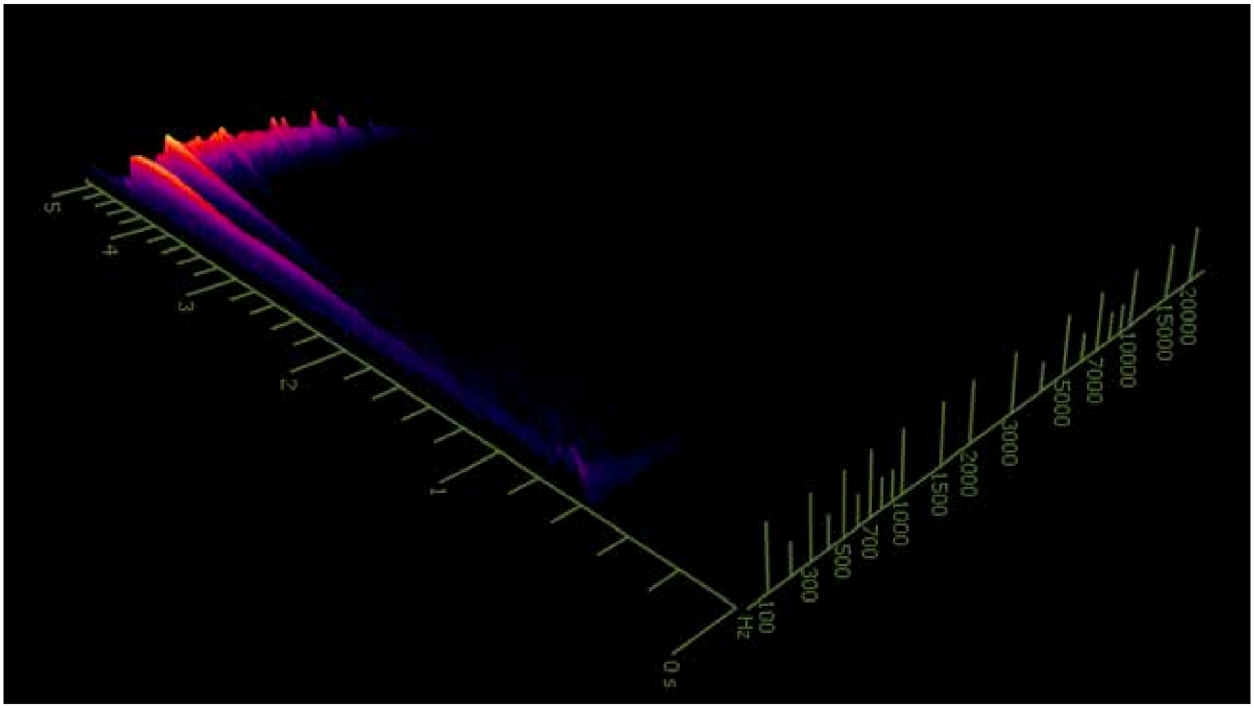
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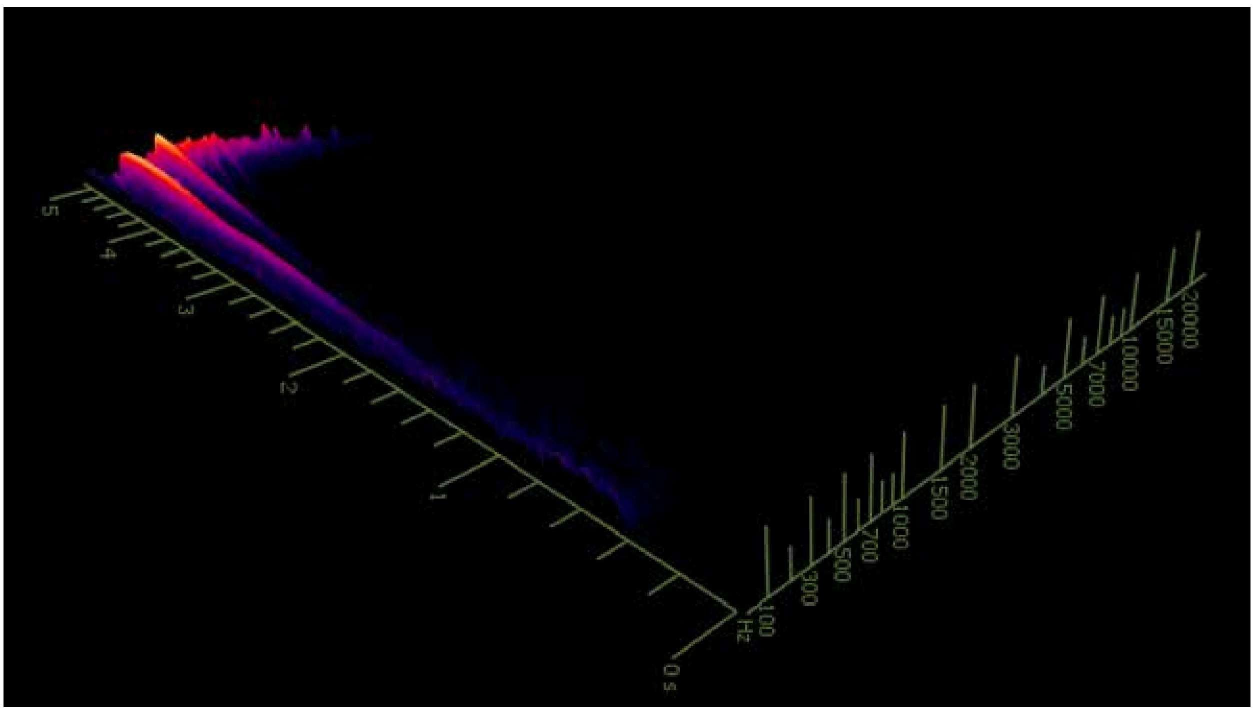
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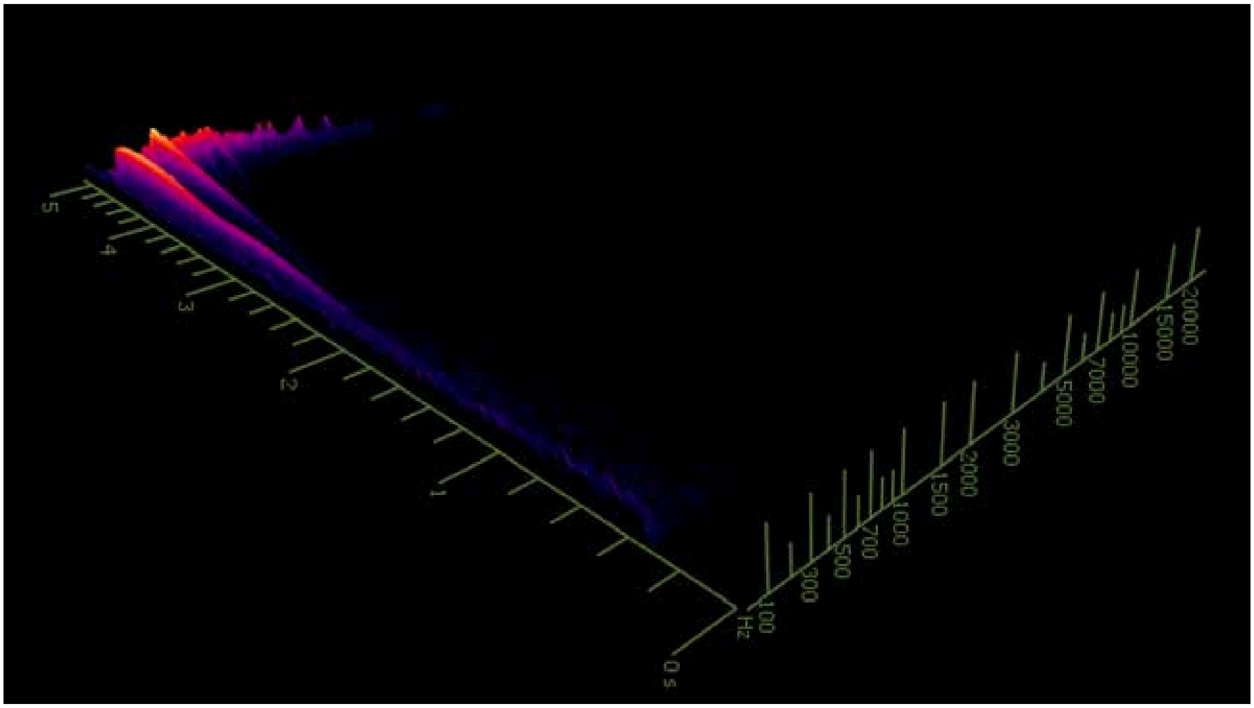
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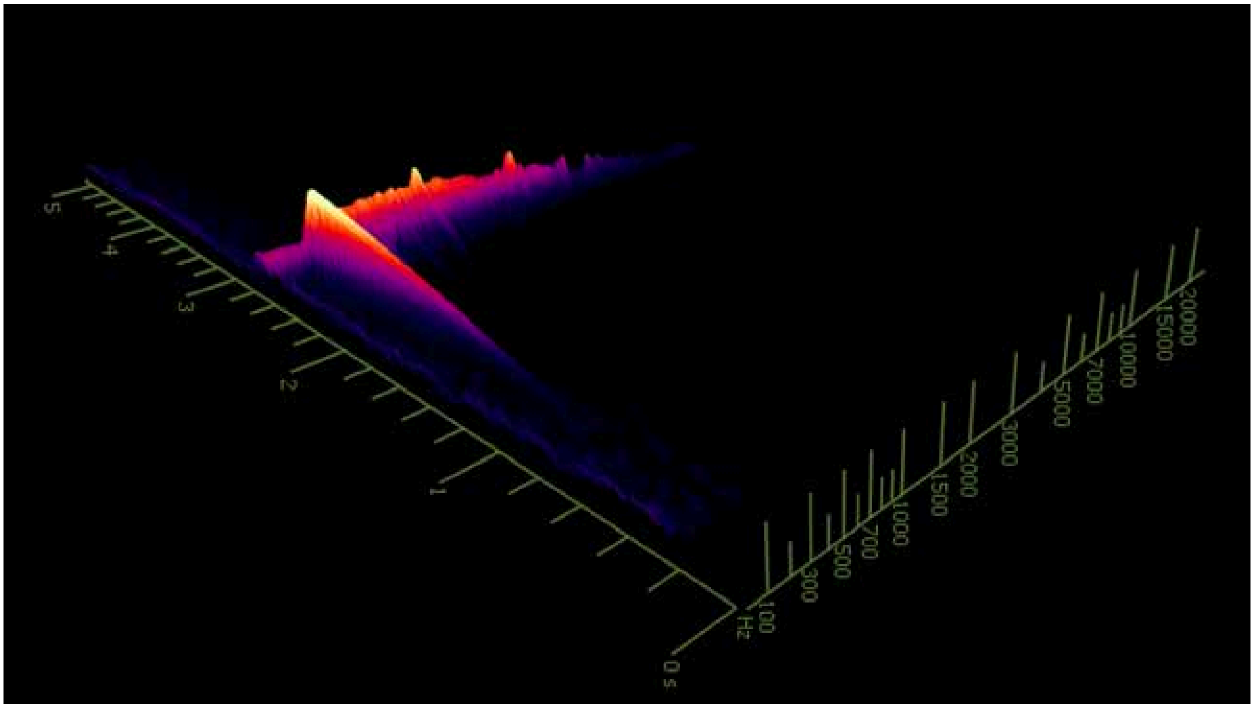
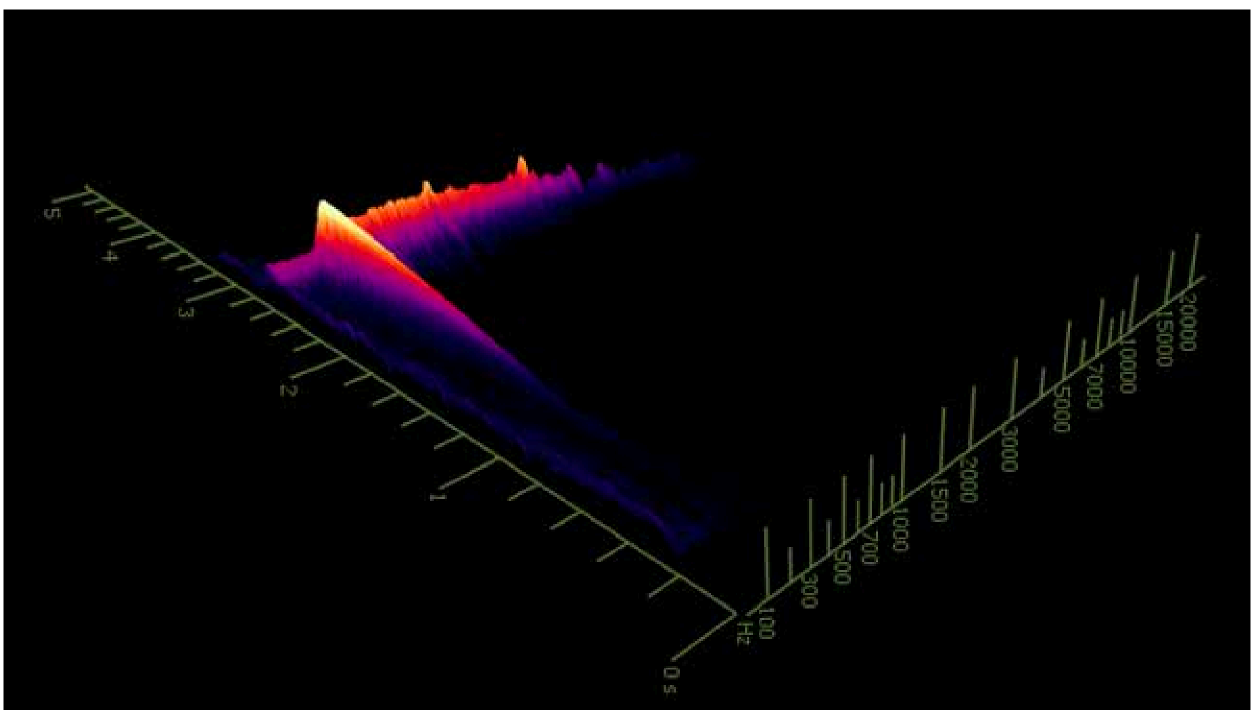
APPENDIX B

3D SPECTROGRAM IMAGES, BAR E_4

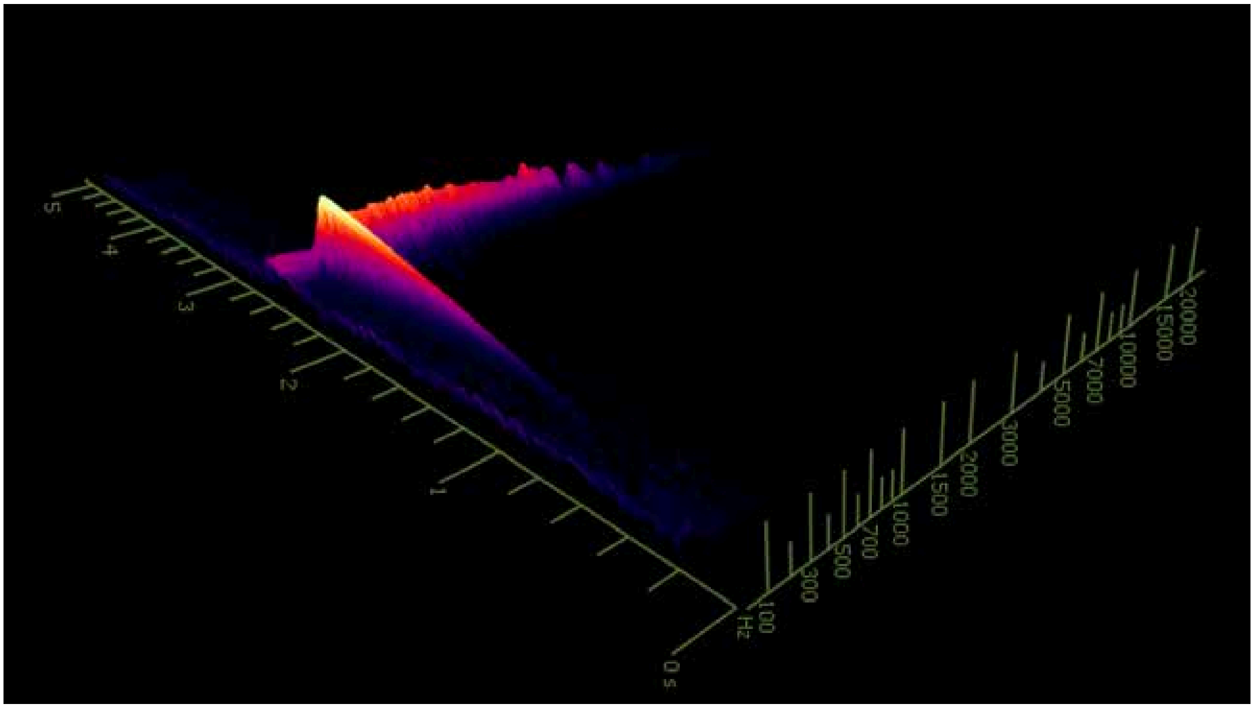
Fast Stroke, Center of the Bar



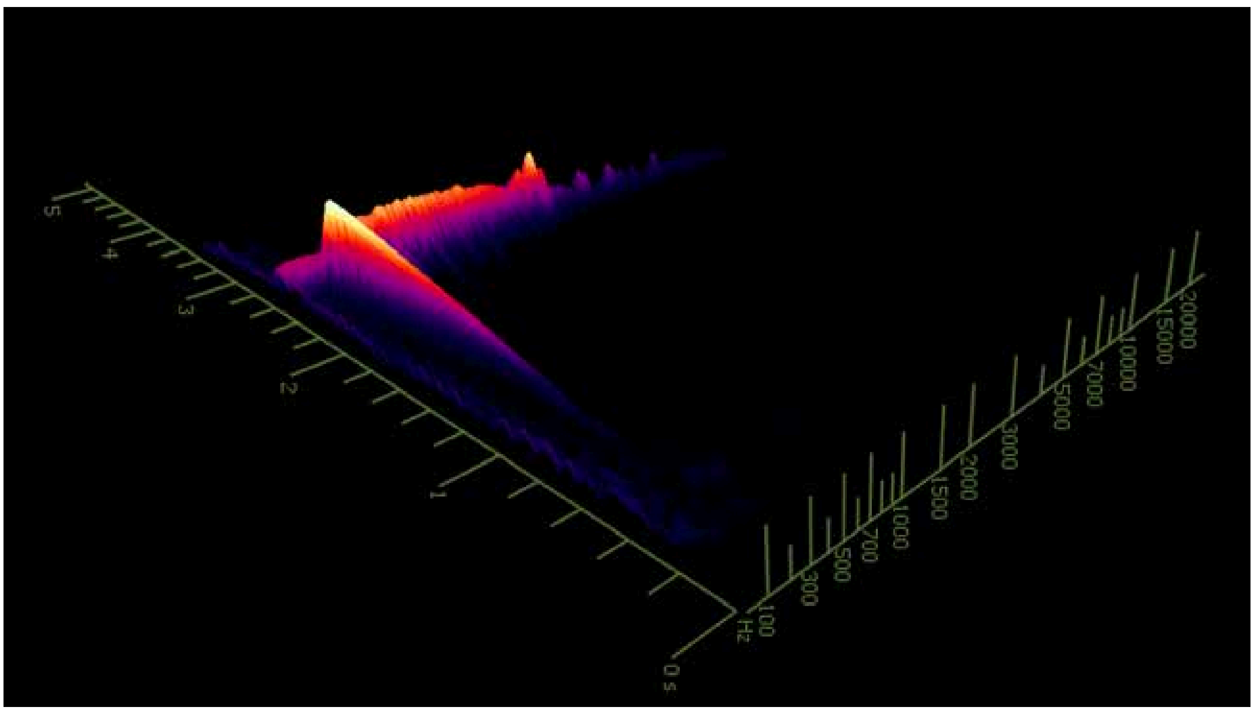
IP 3106 B



IP 3106



Weighted IP 3106 B



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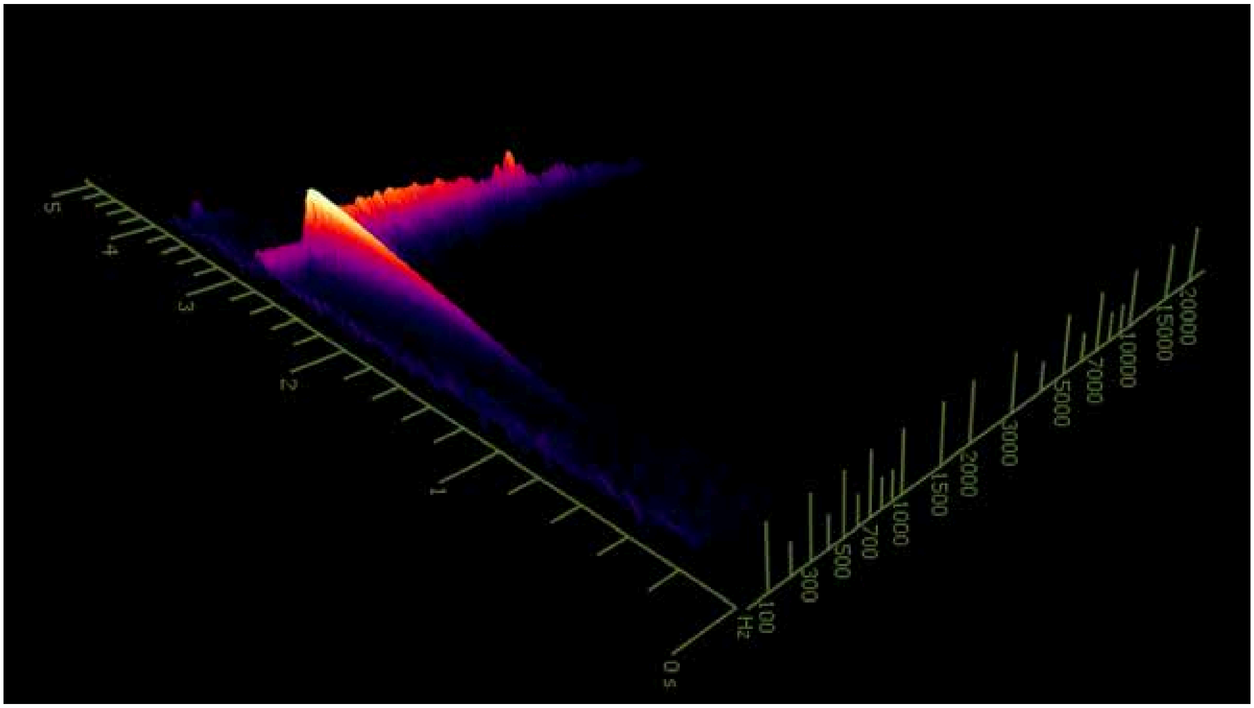
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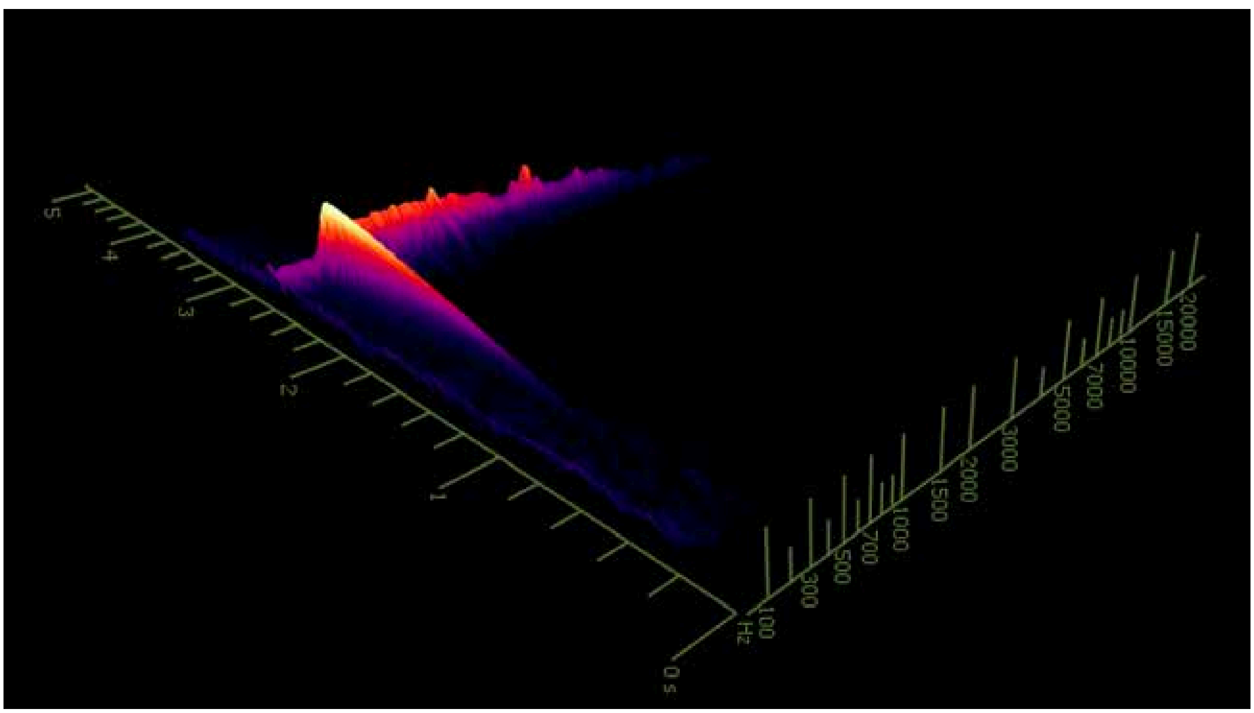
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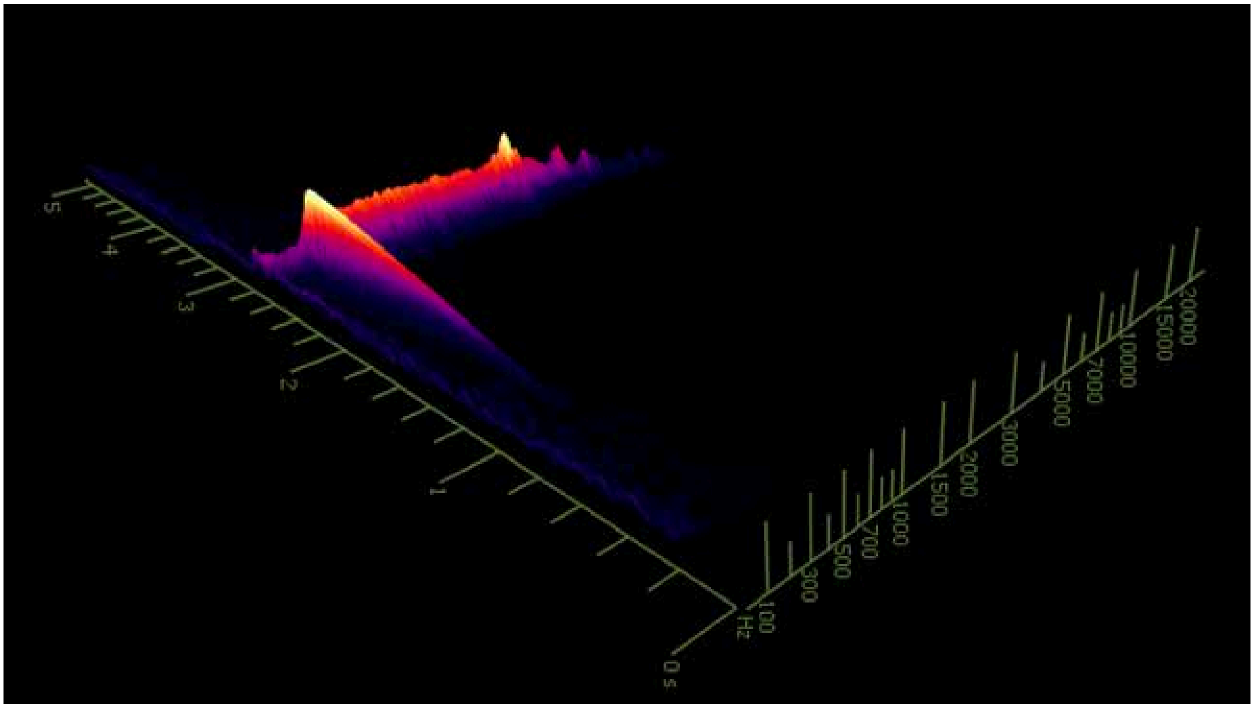
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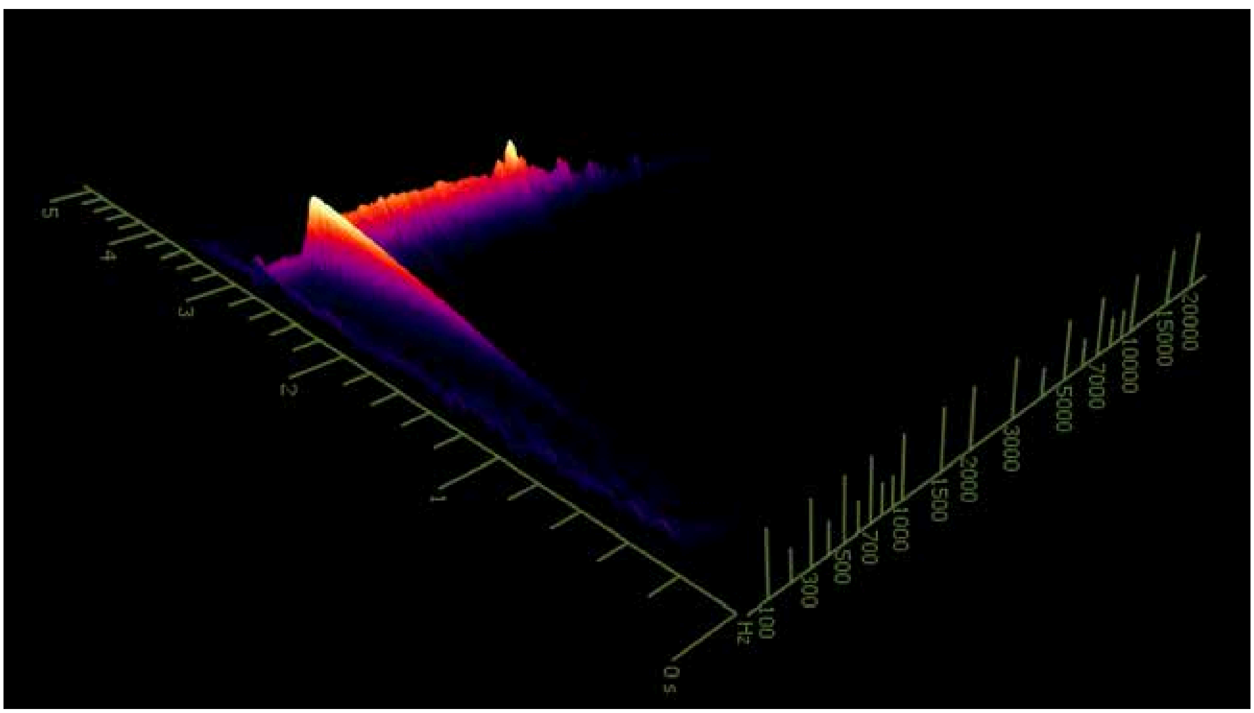
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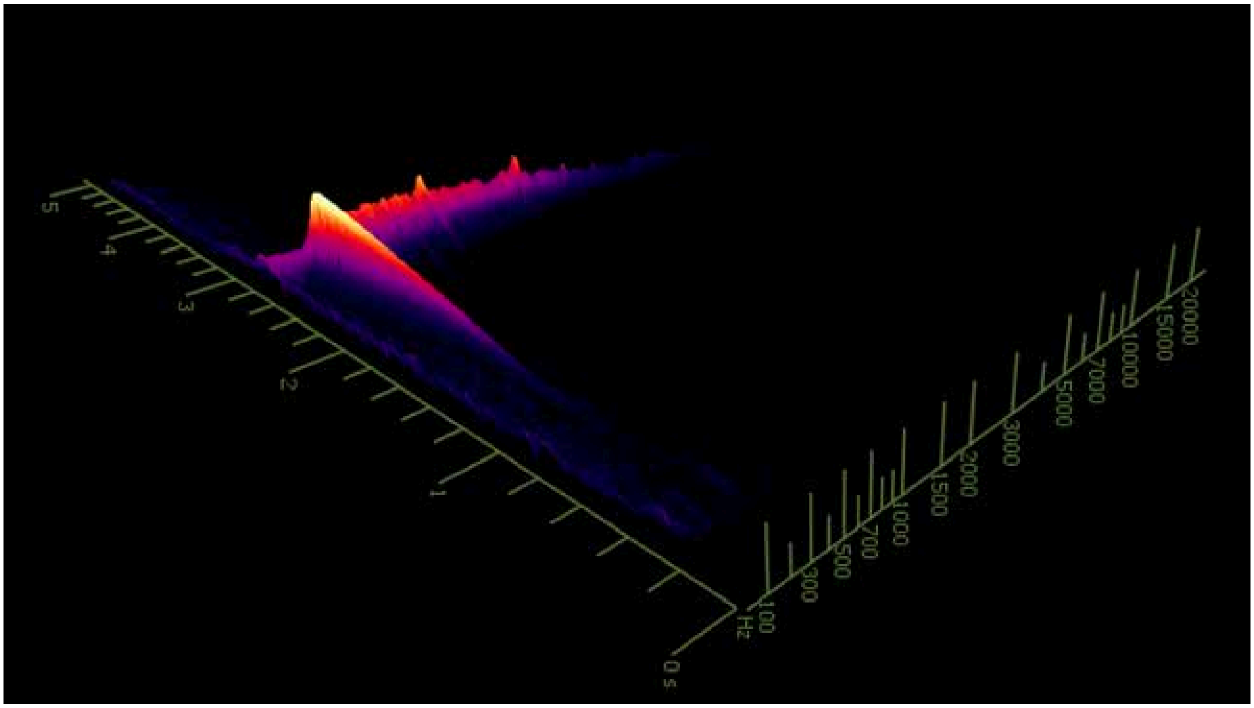

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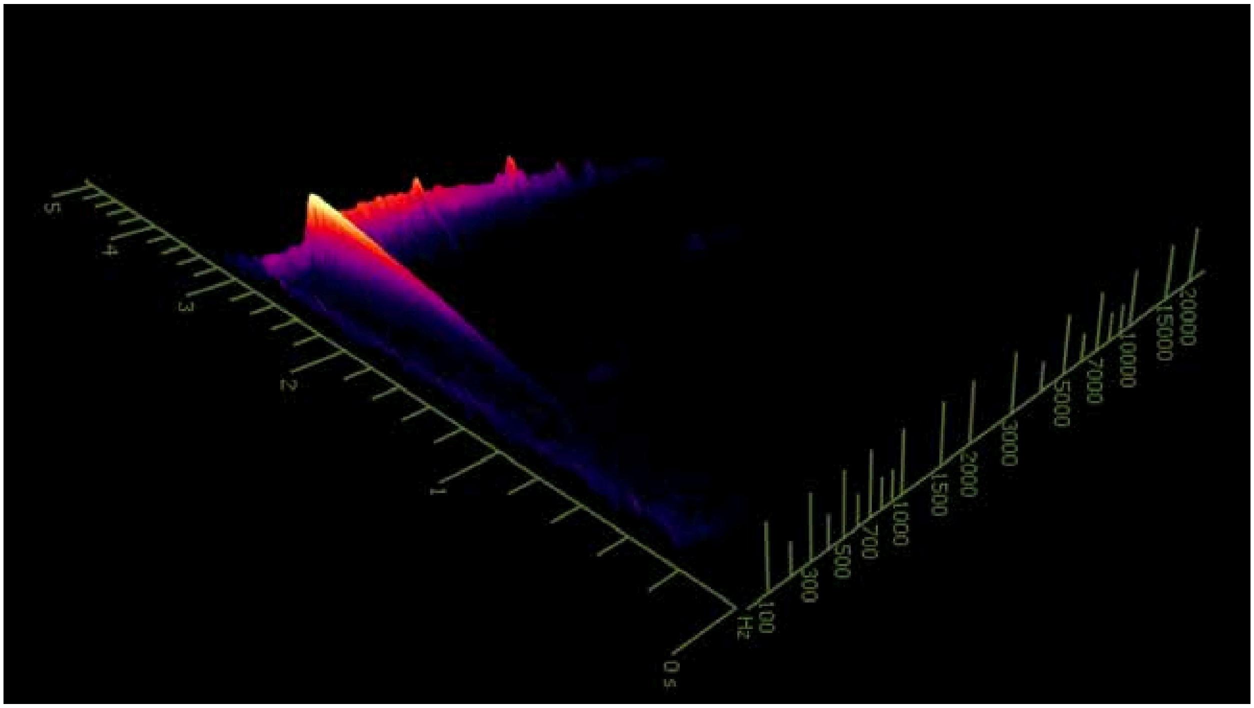
Slow Stroke, Center of the Bar



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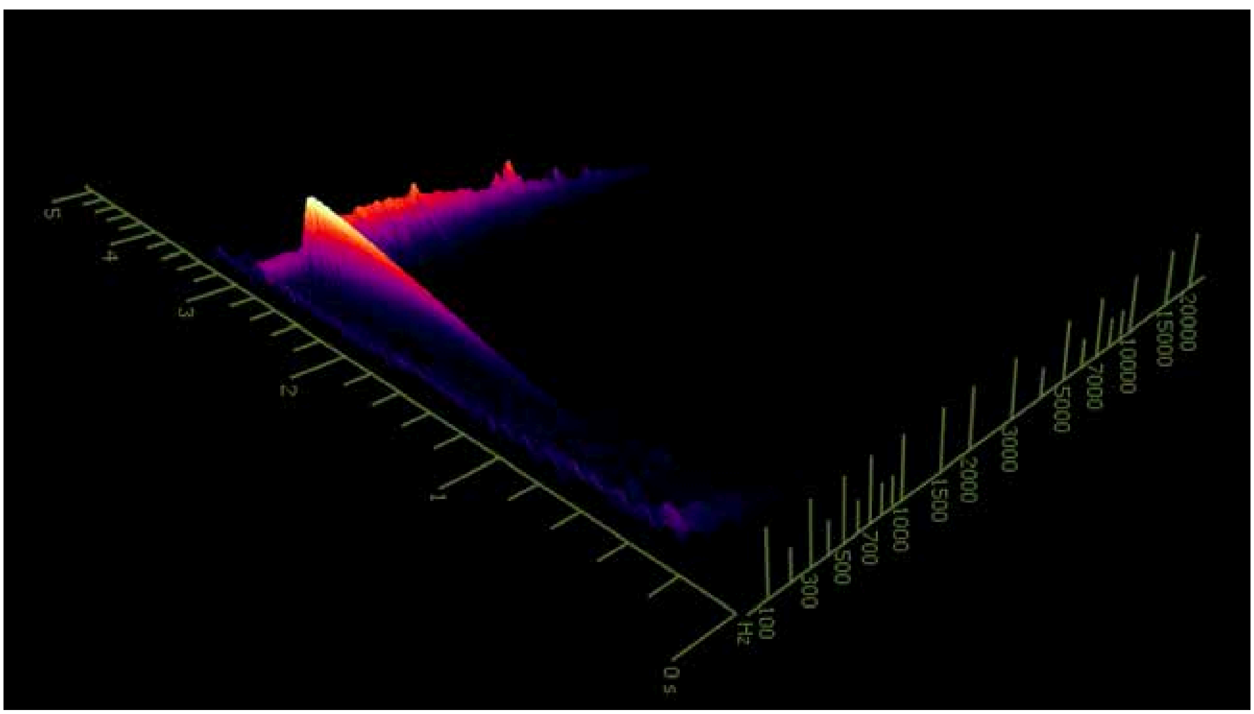
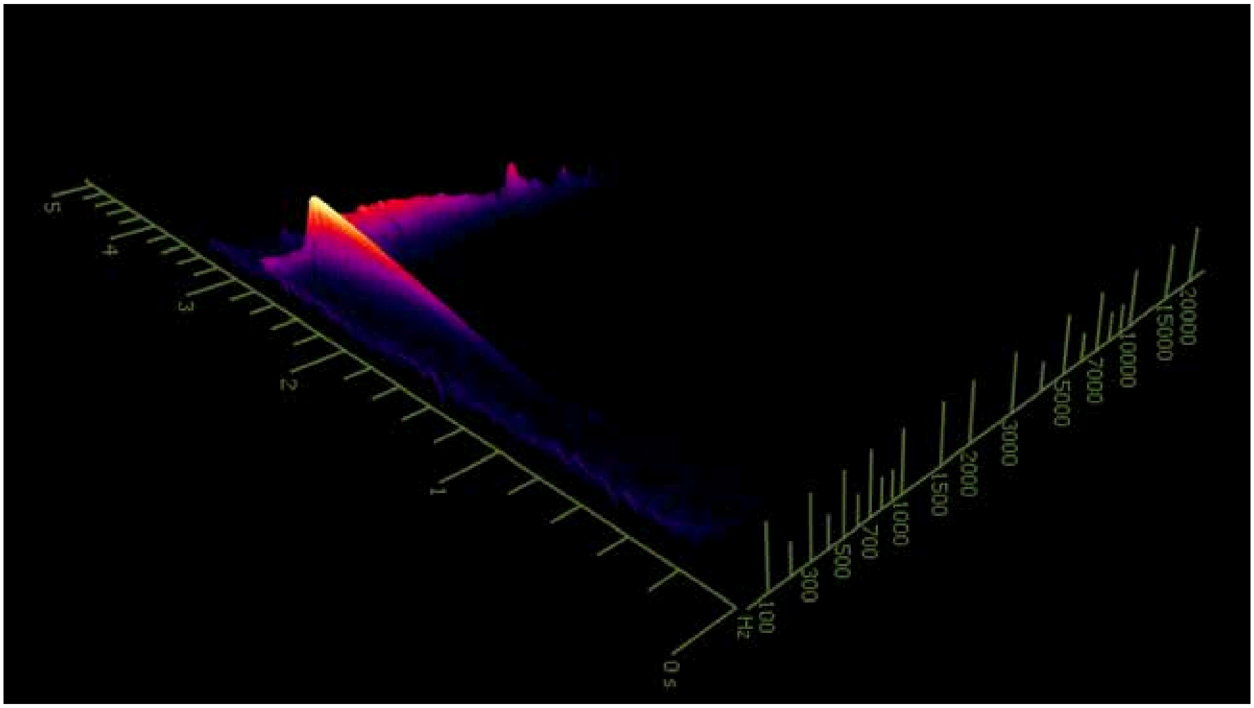


IP 3106



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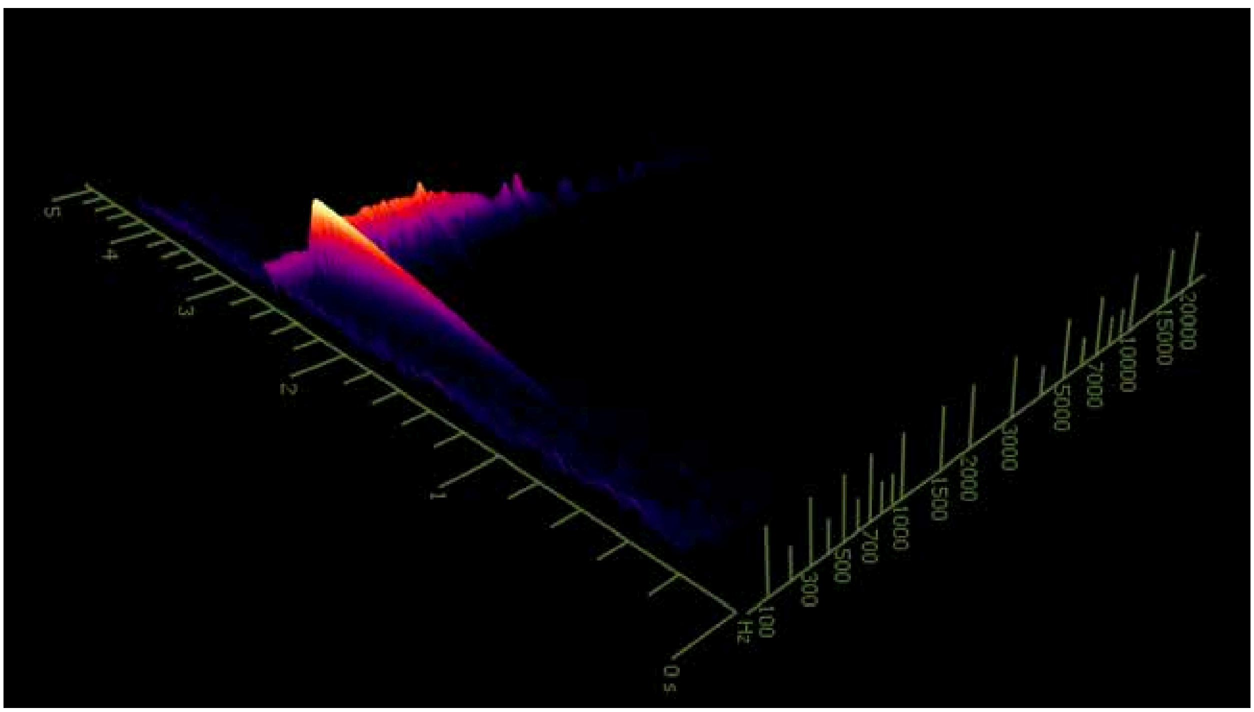

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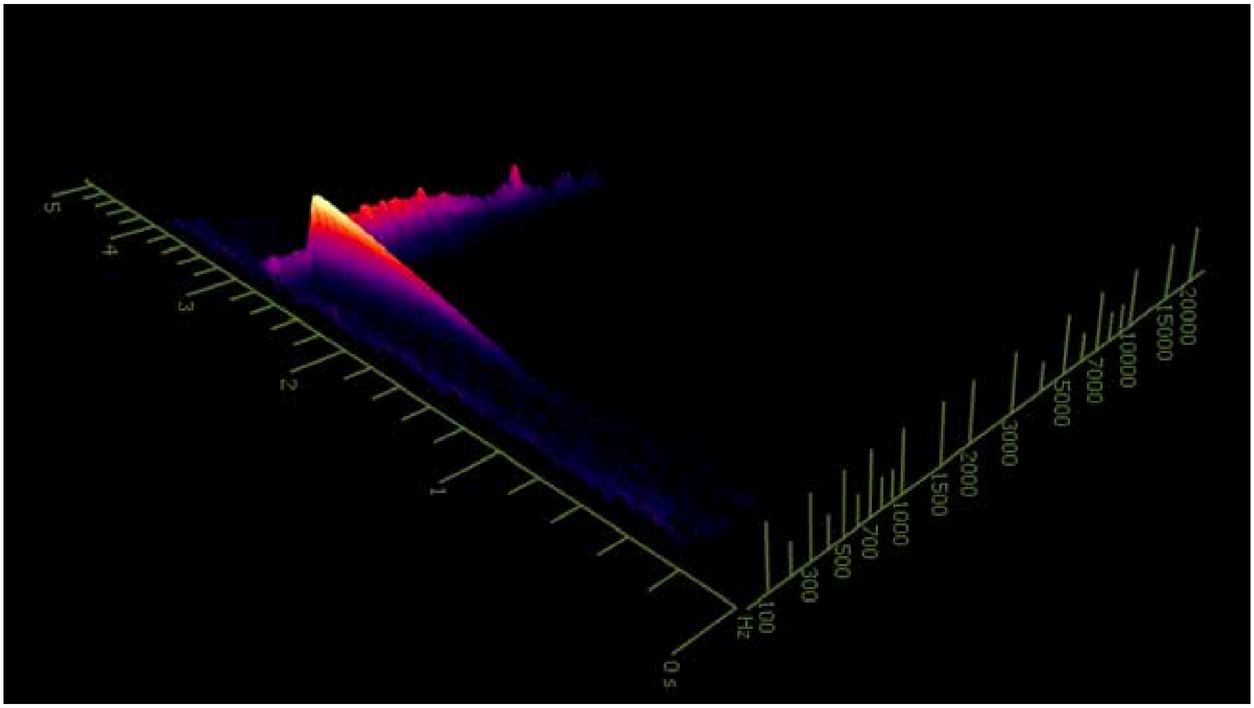

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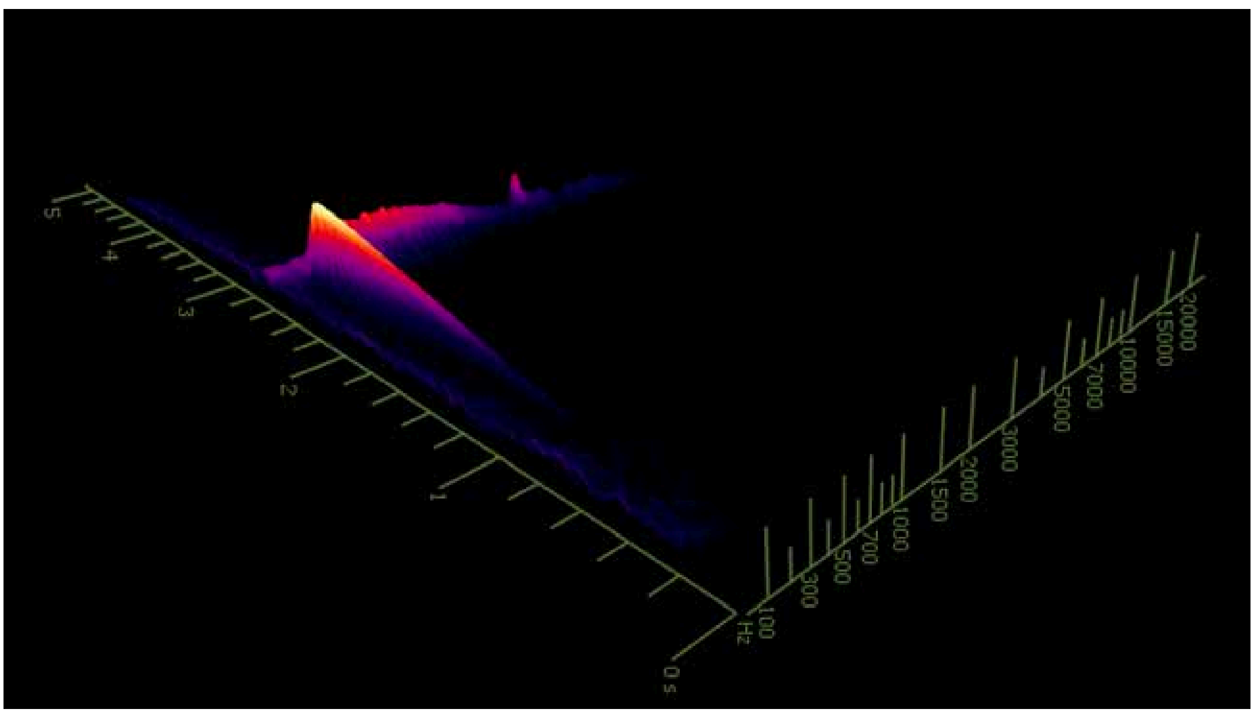

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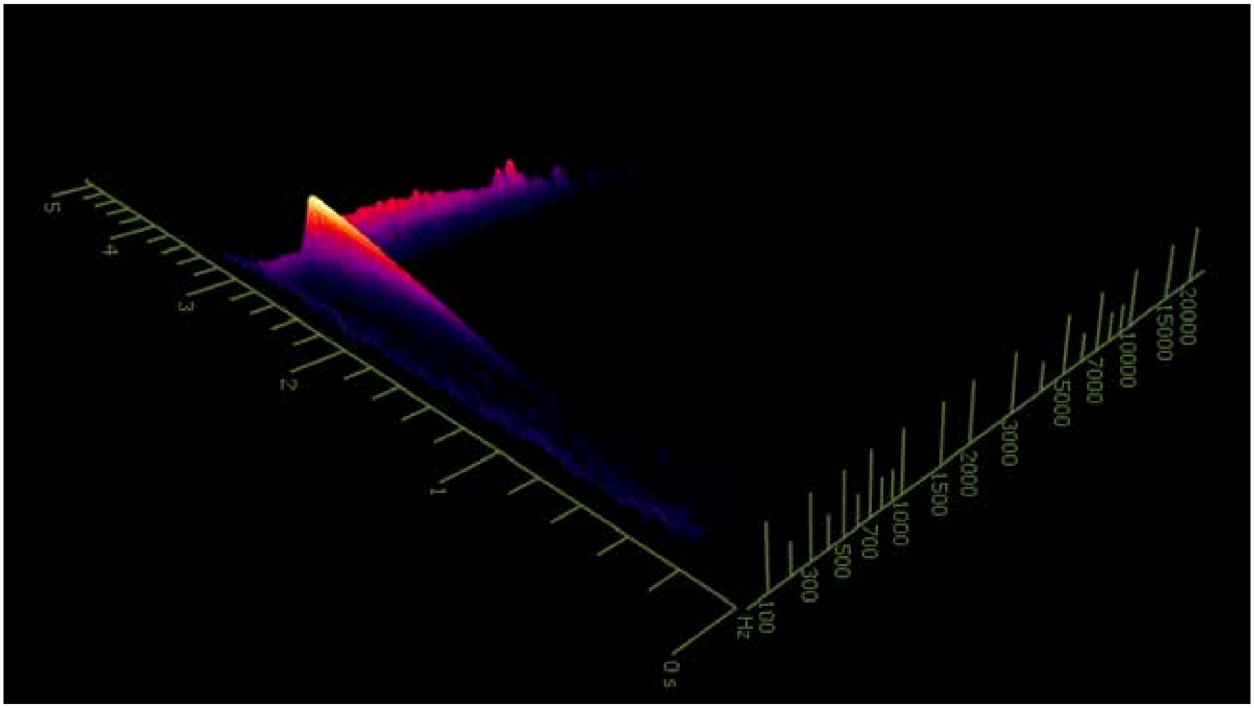
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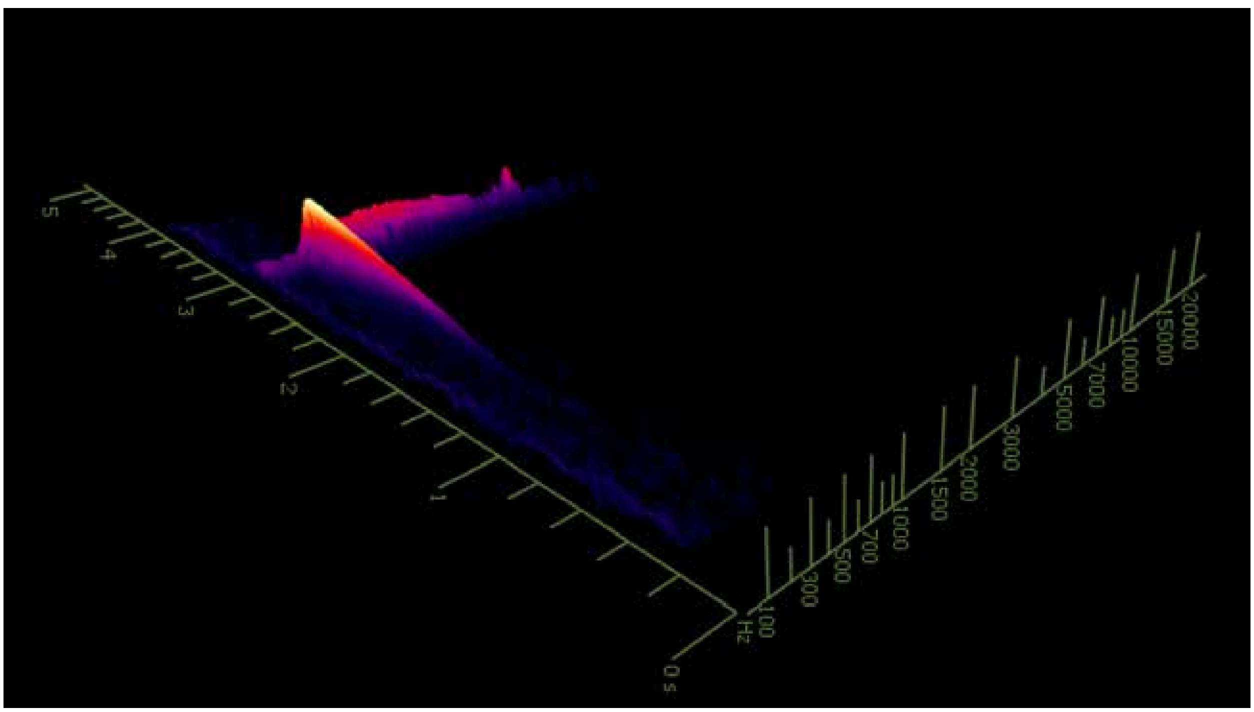
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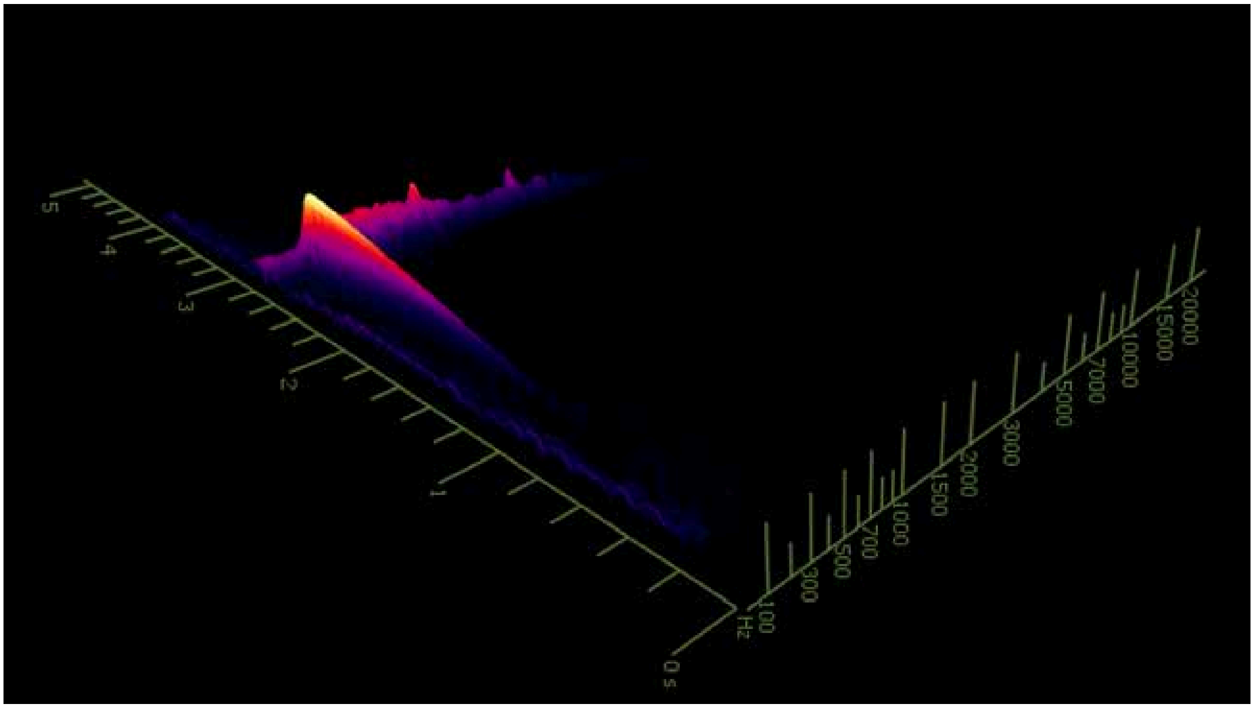
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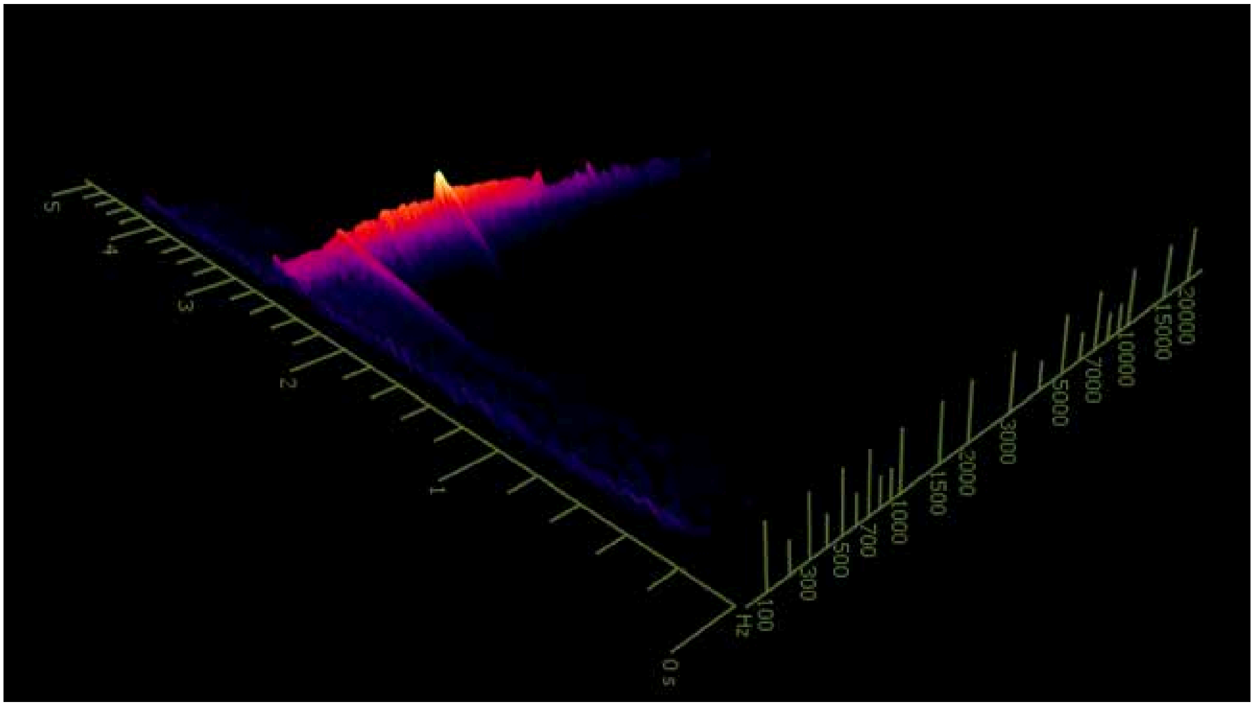
Fast Stroke, Node



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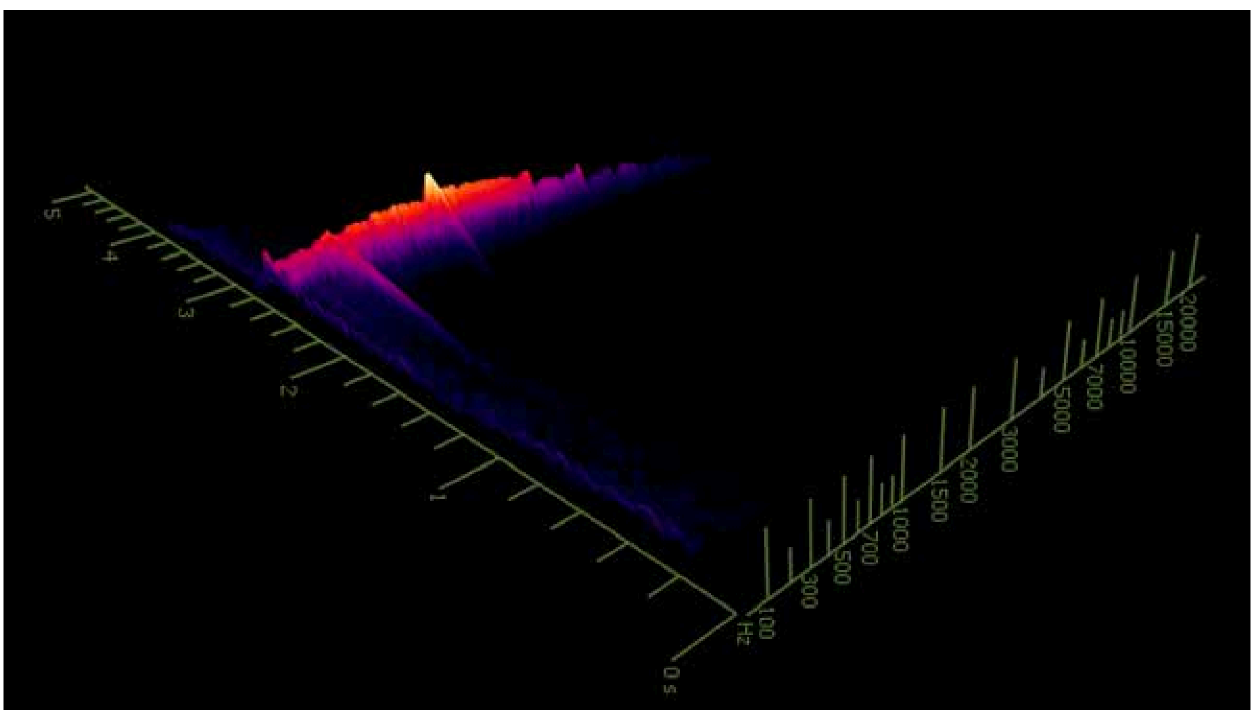

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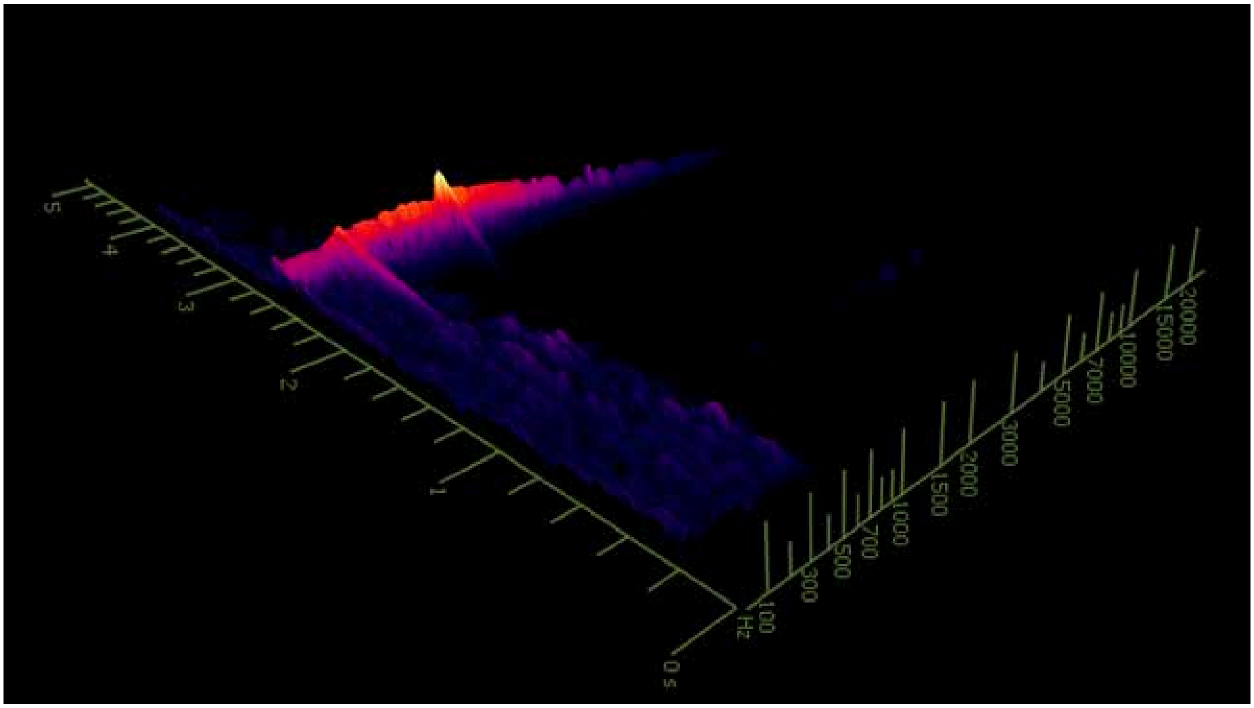

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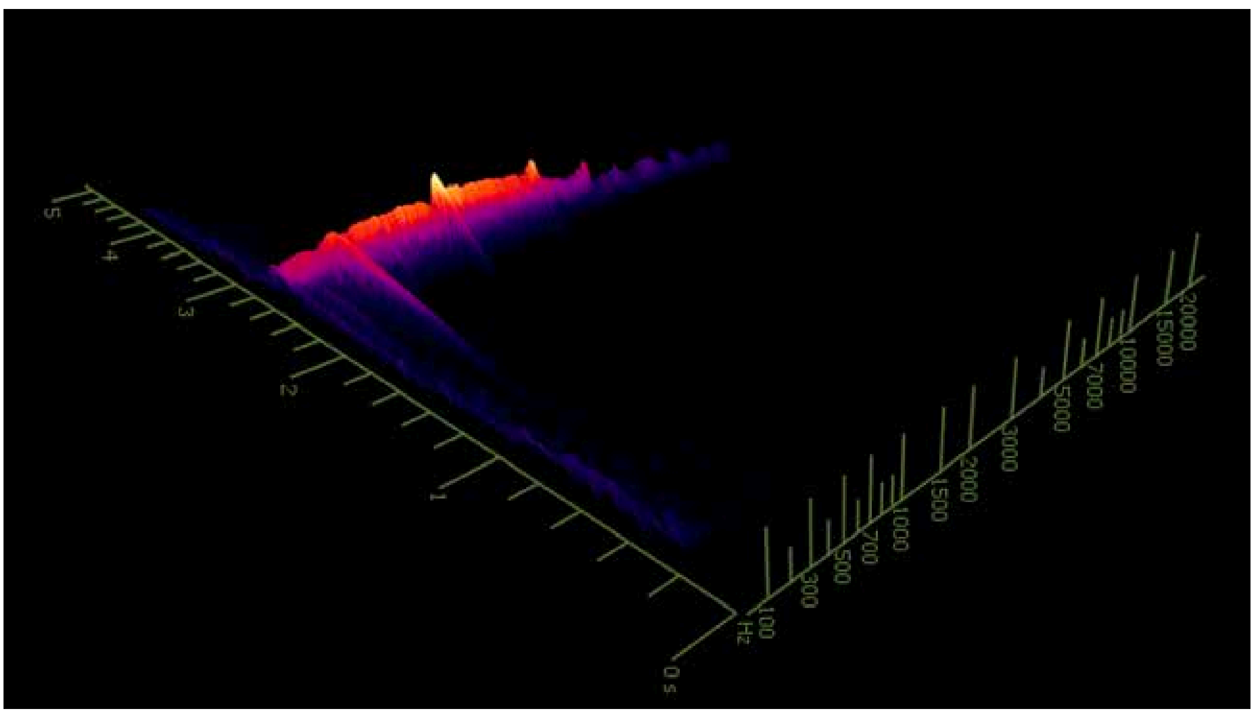

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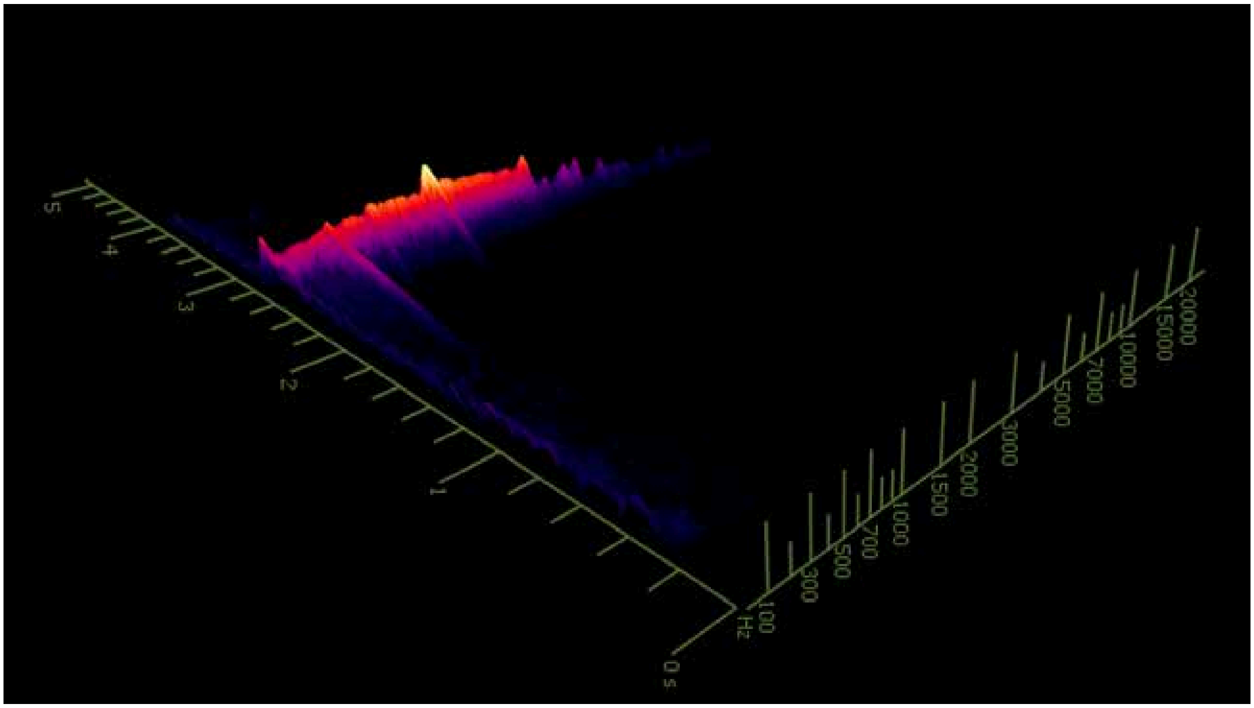
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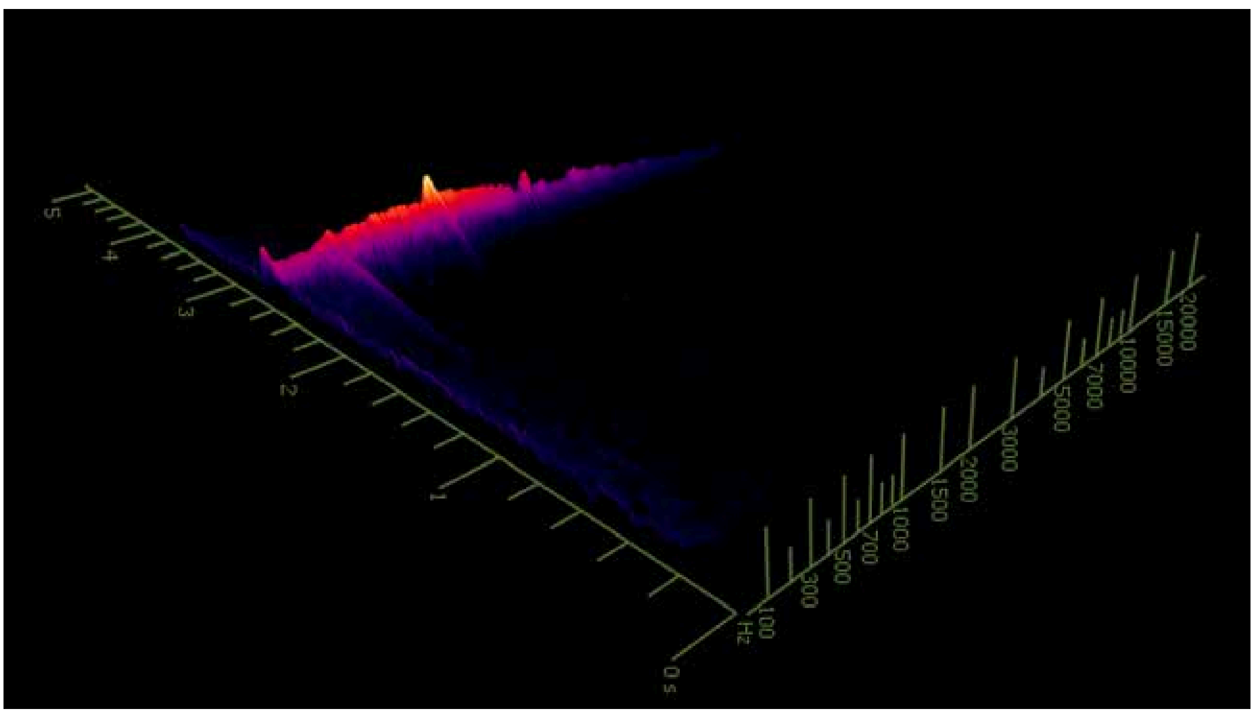
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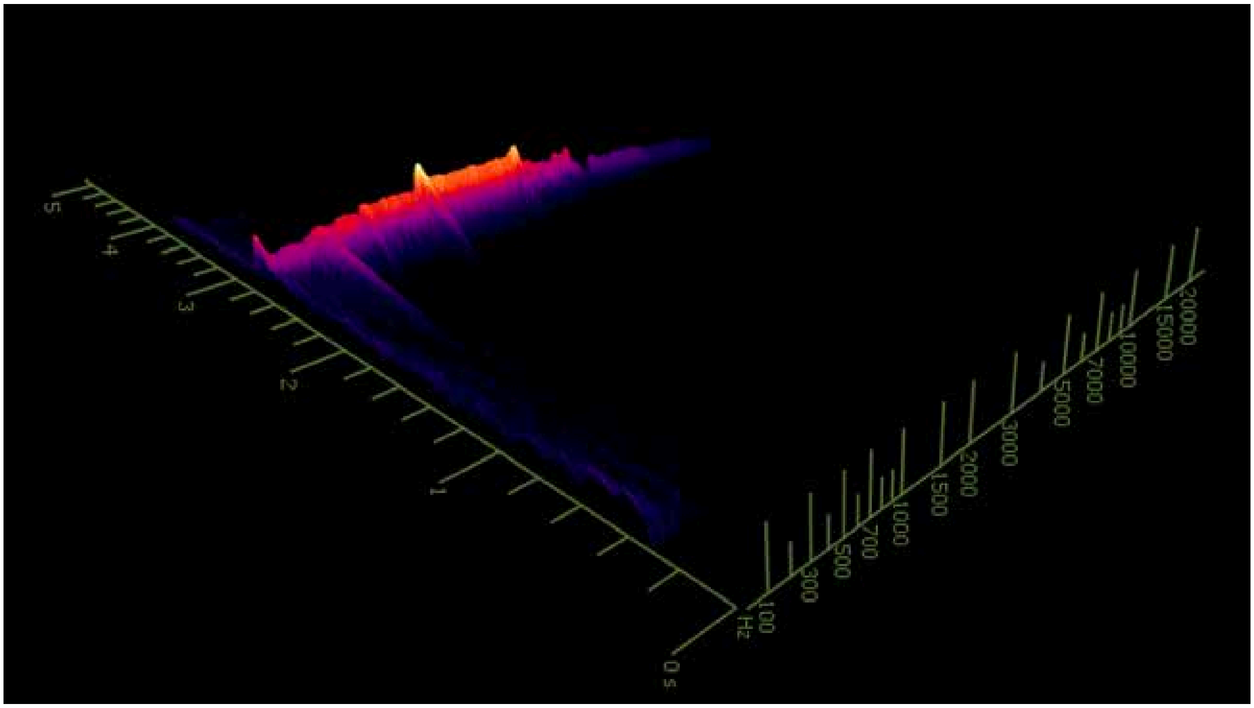

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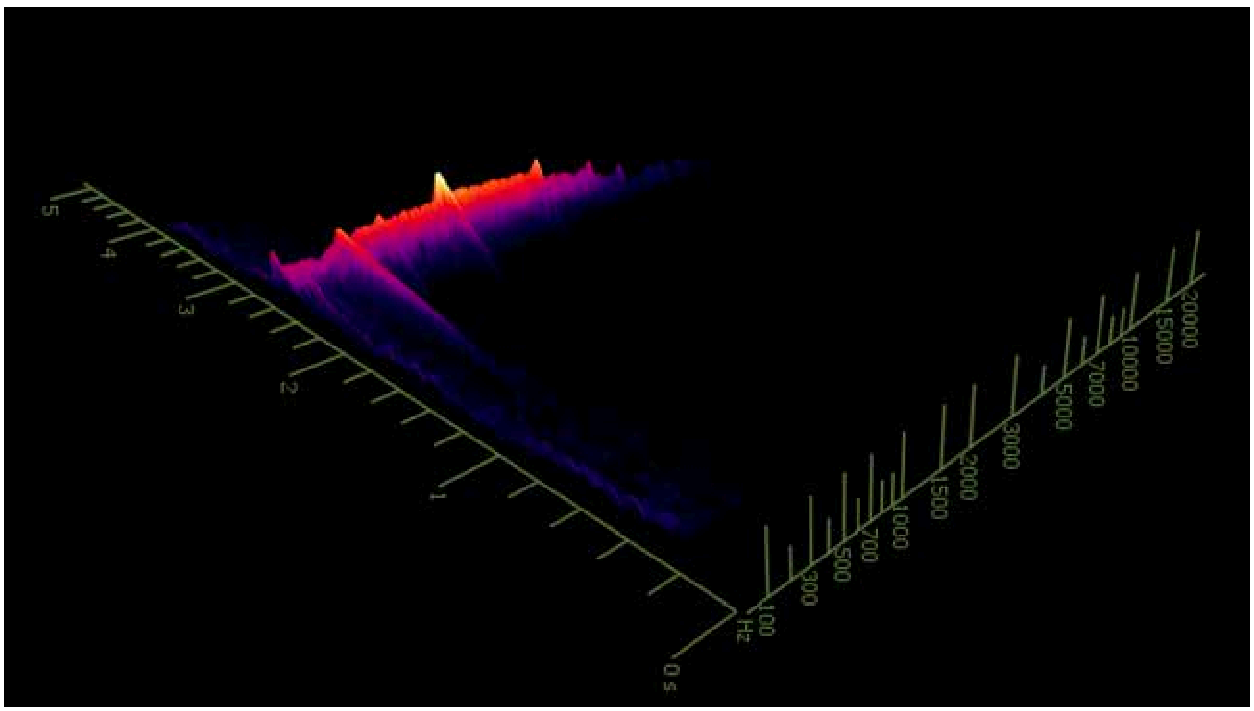

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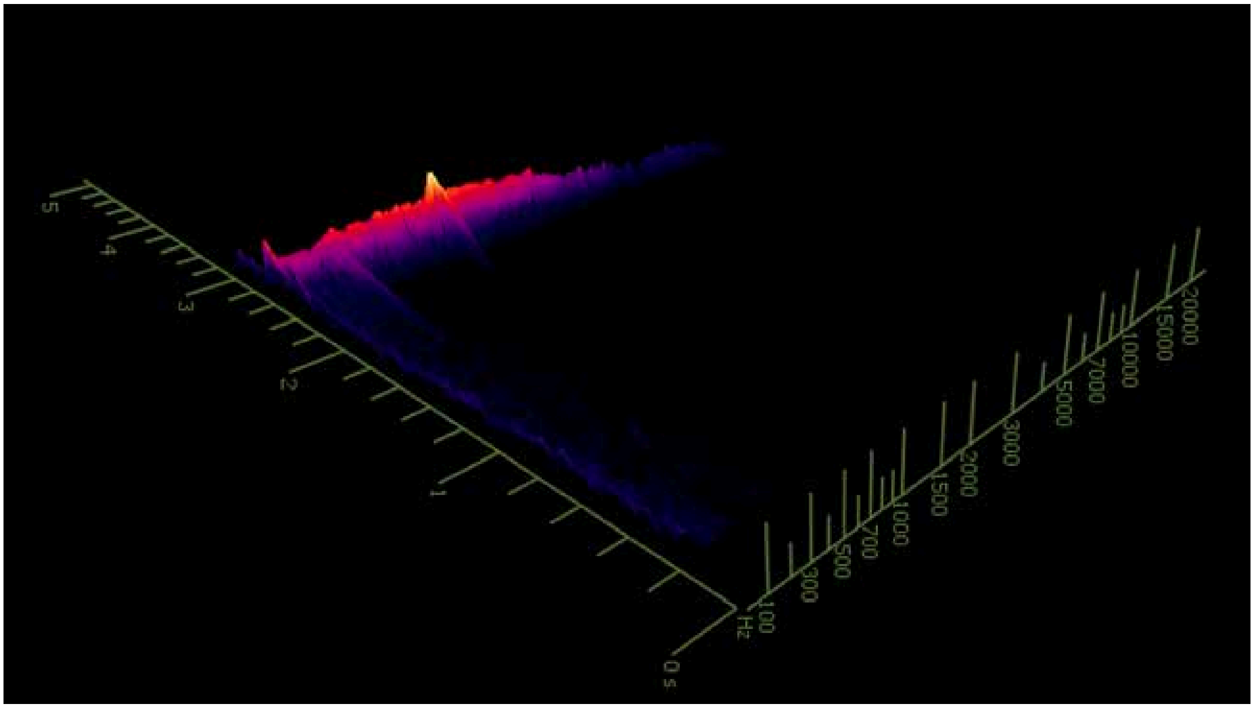

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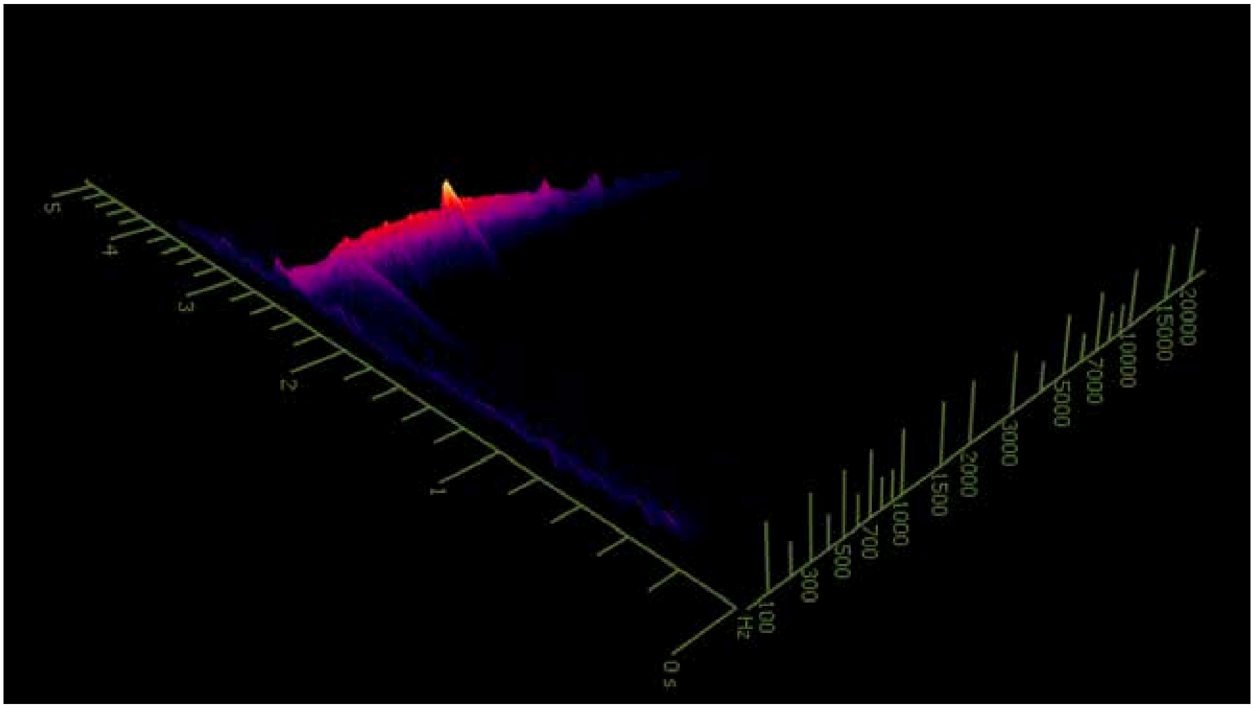
Slow Stroke, Node



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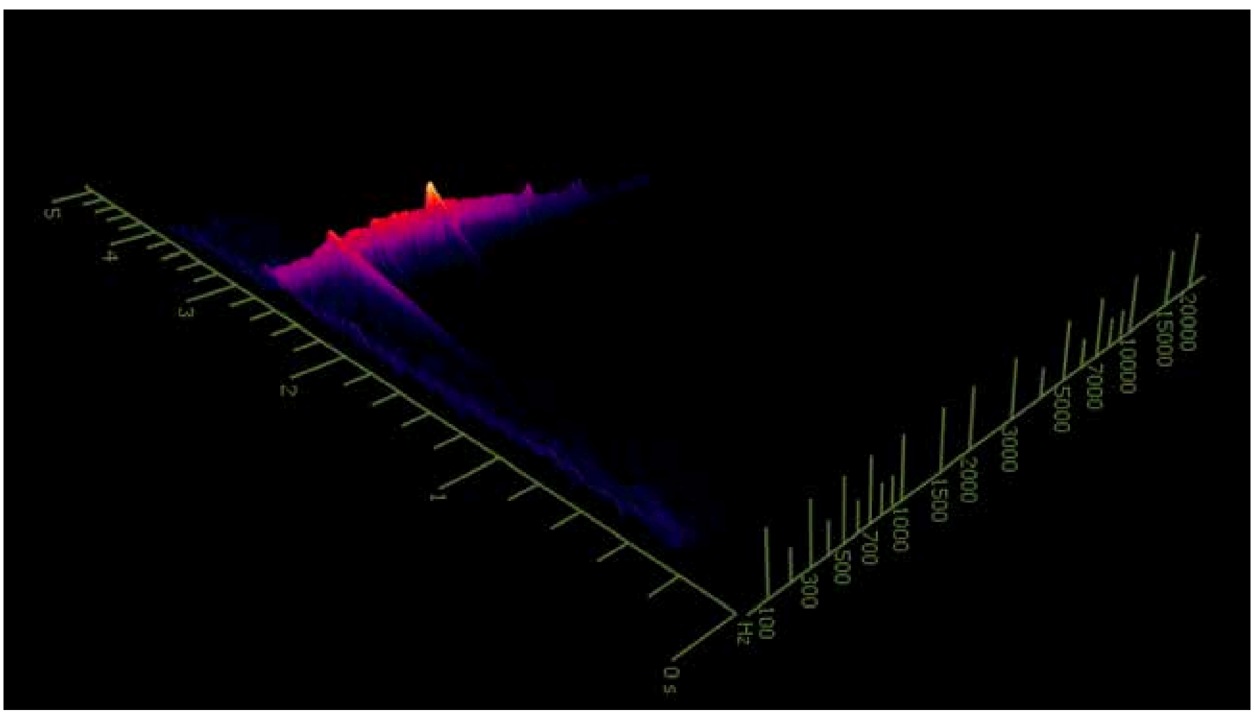

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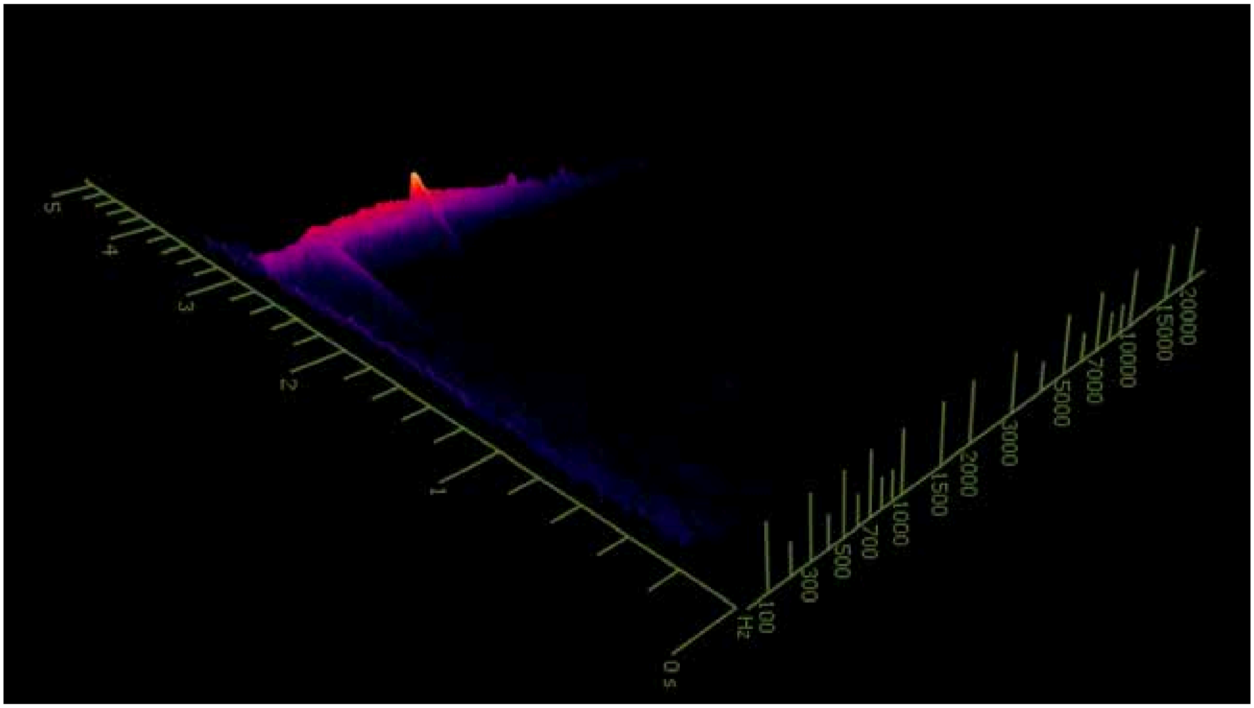

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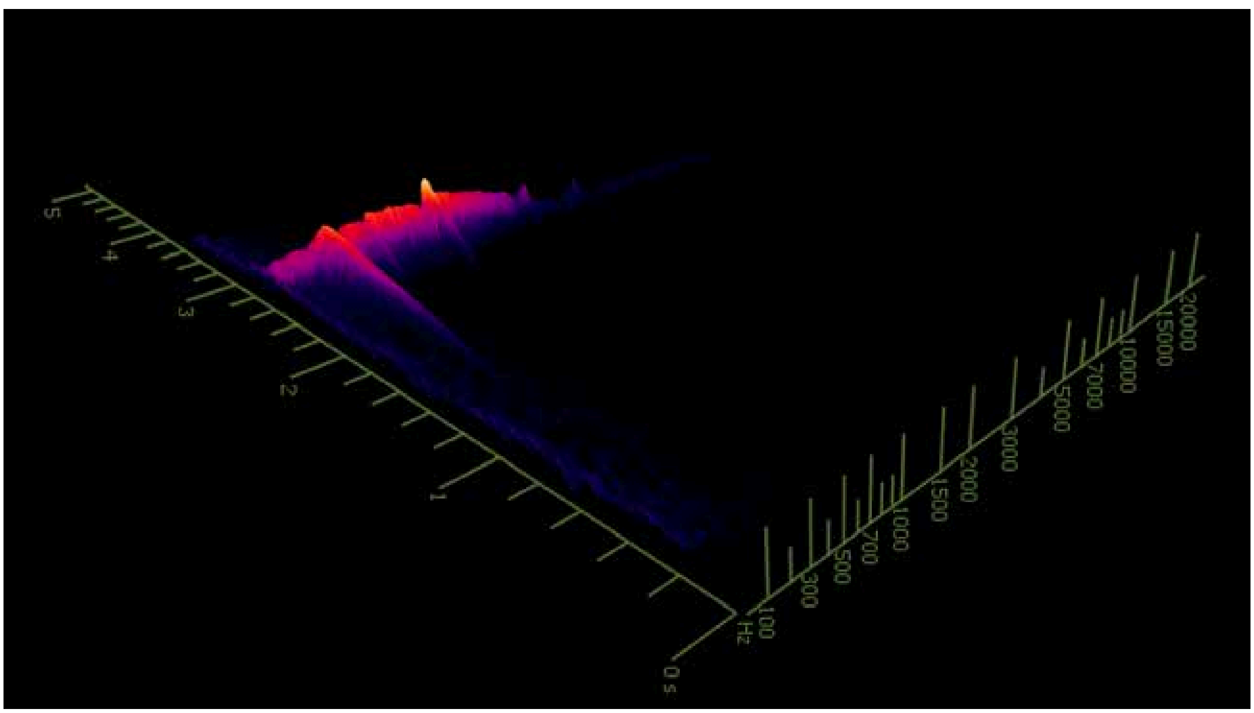

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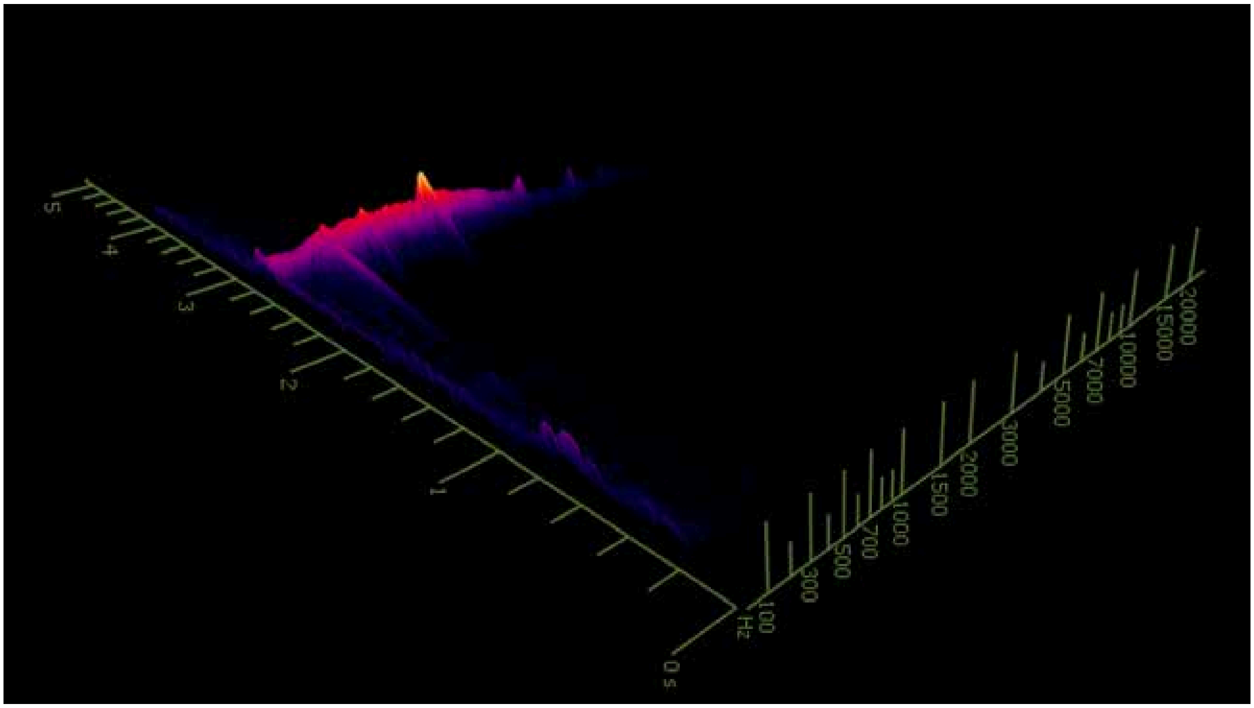
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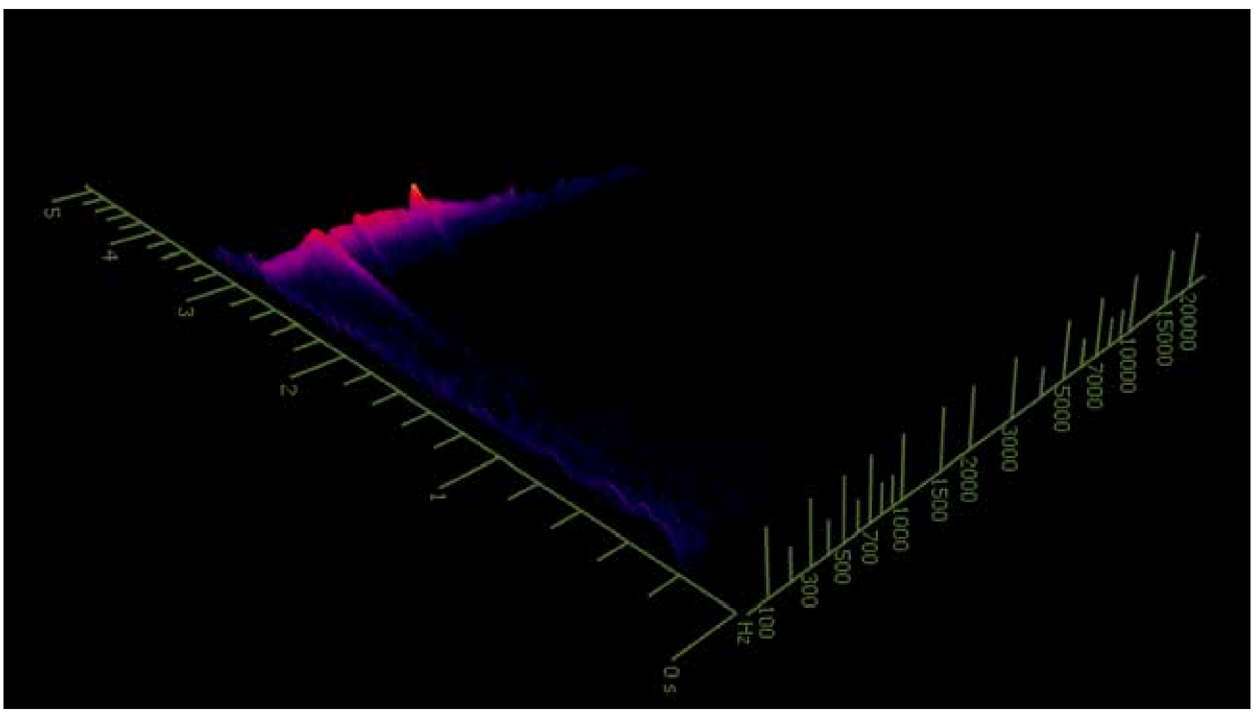
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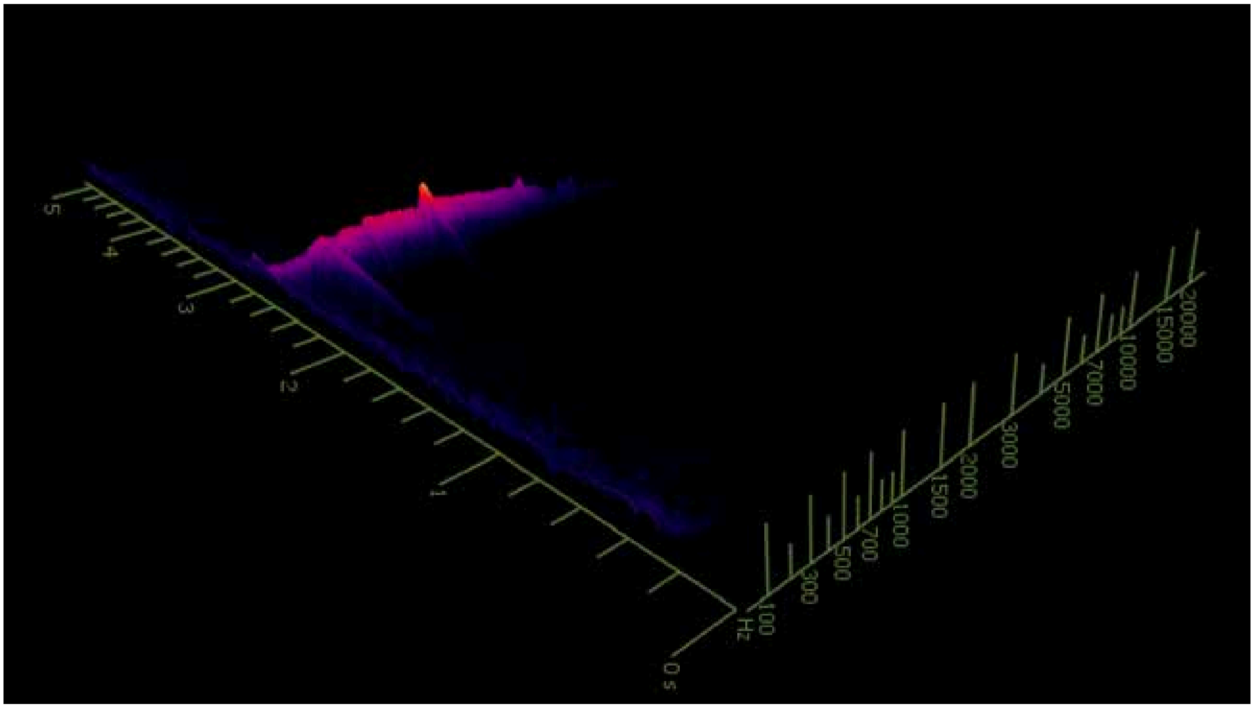
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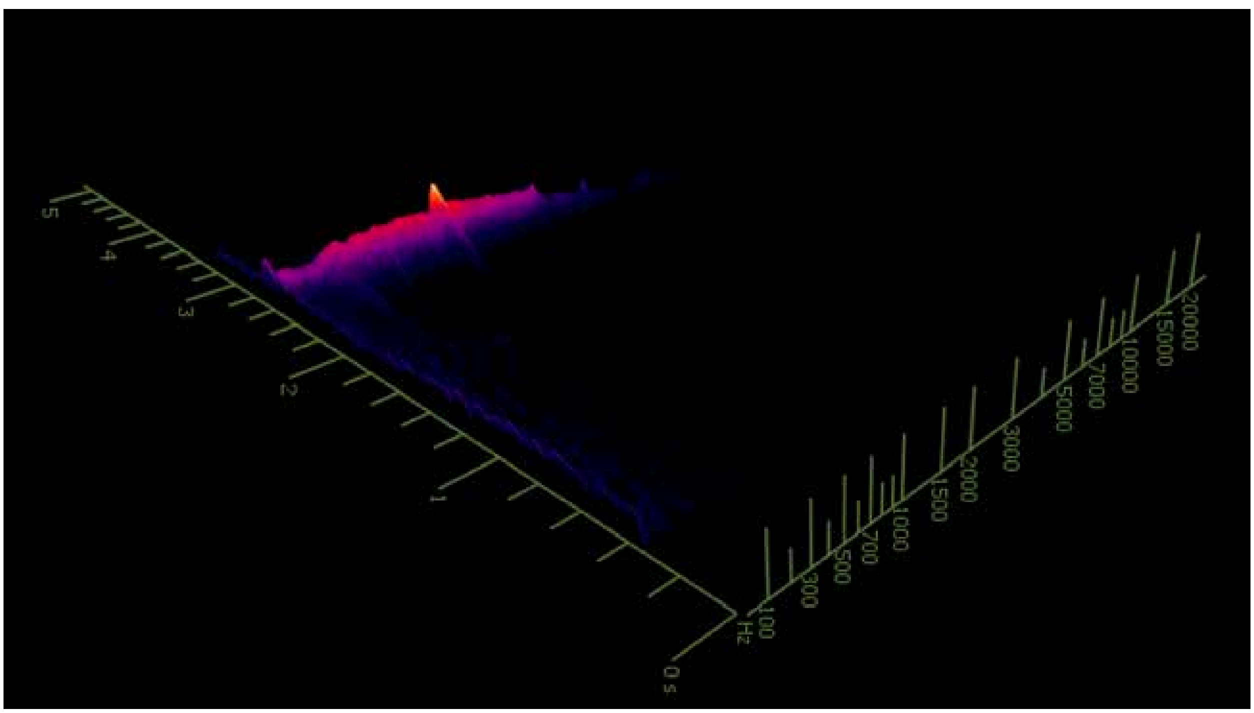
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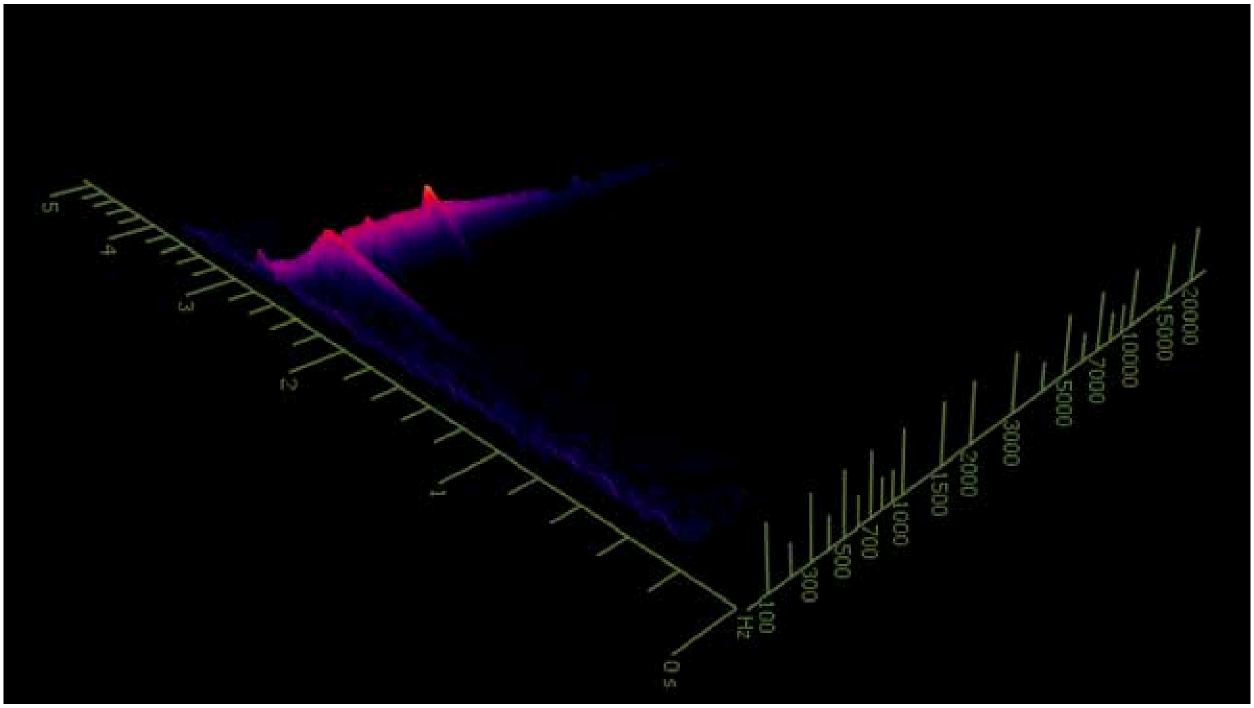

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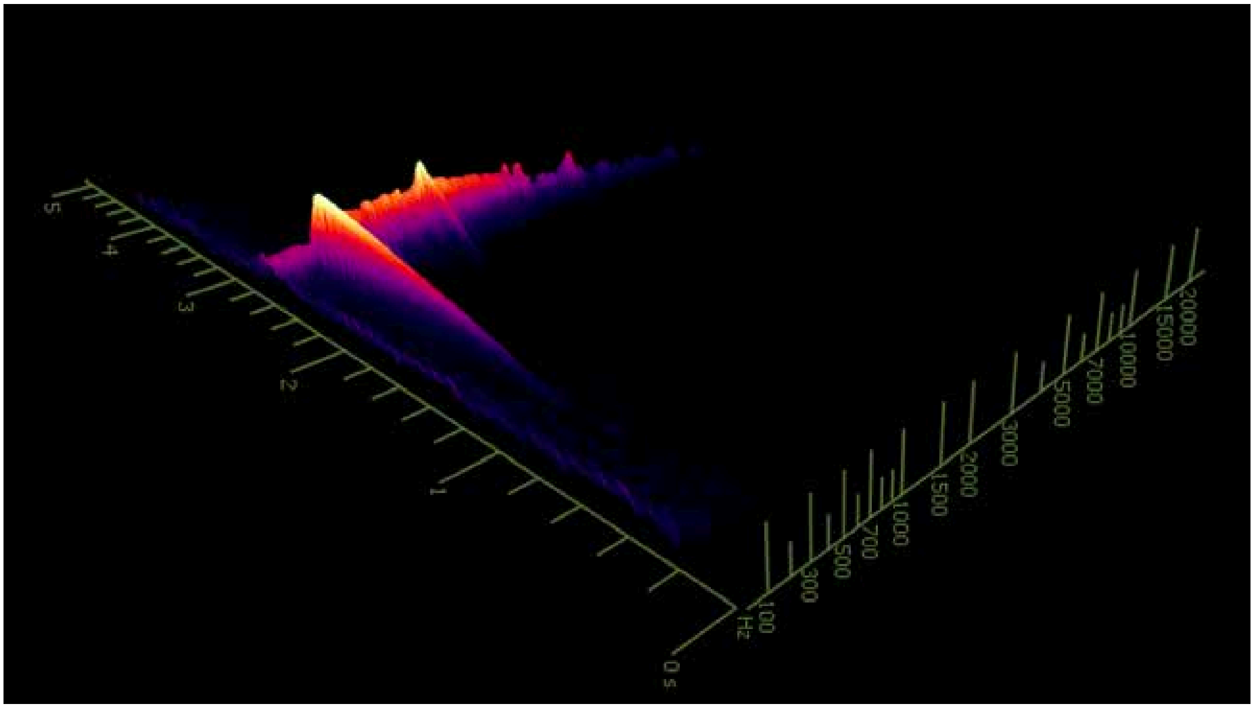
Fast Stroke, Just Off-Center



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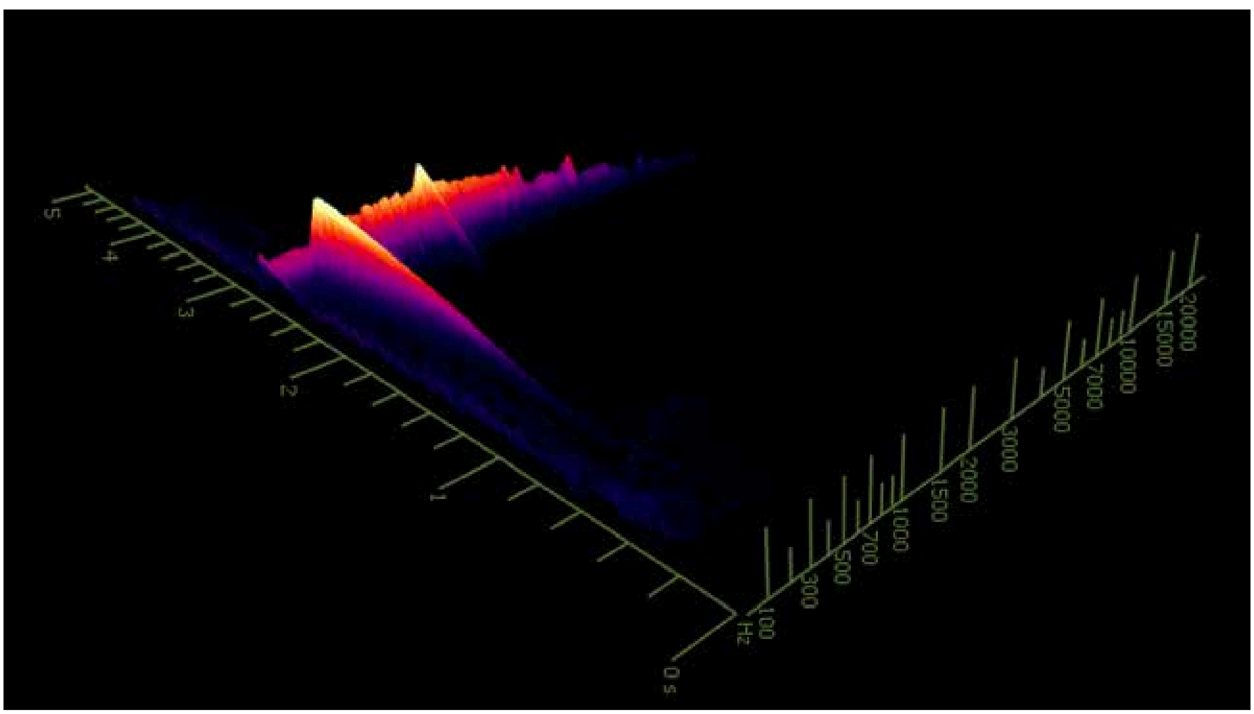
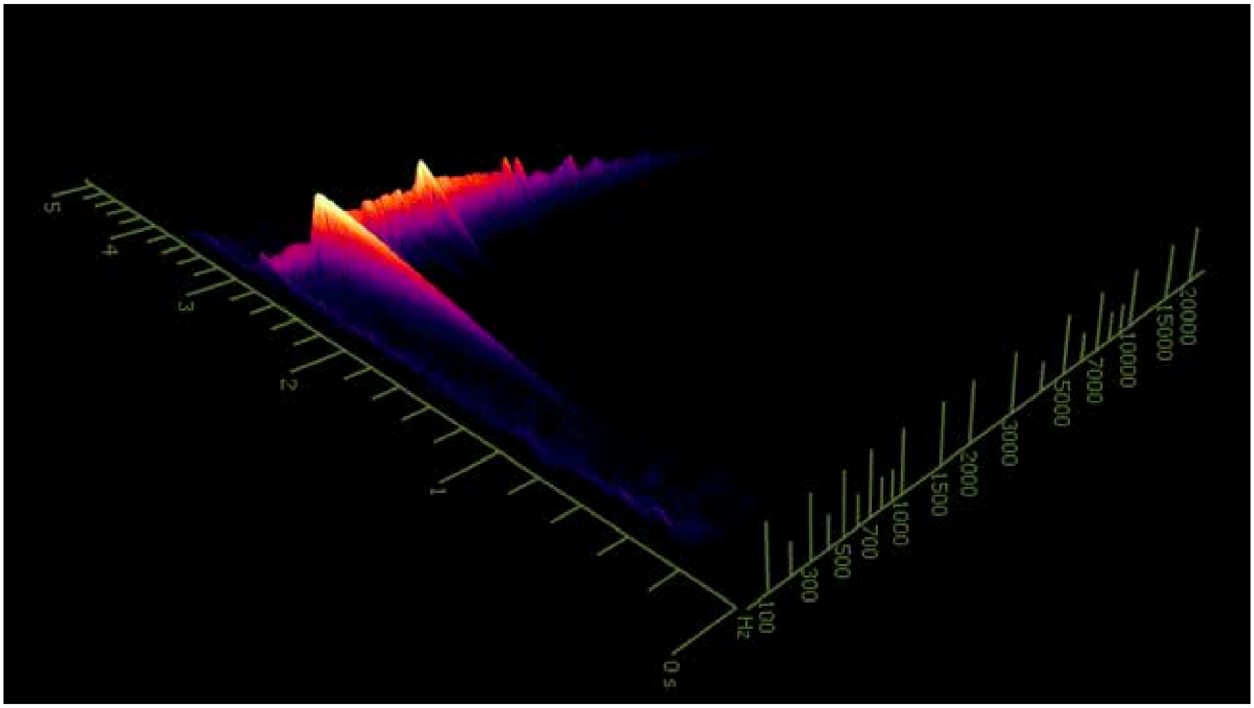


IP 3106



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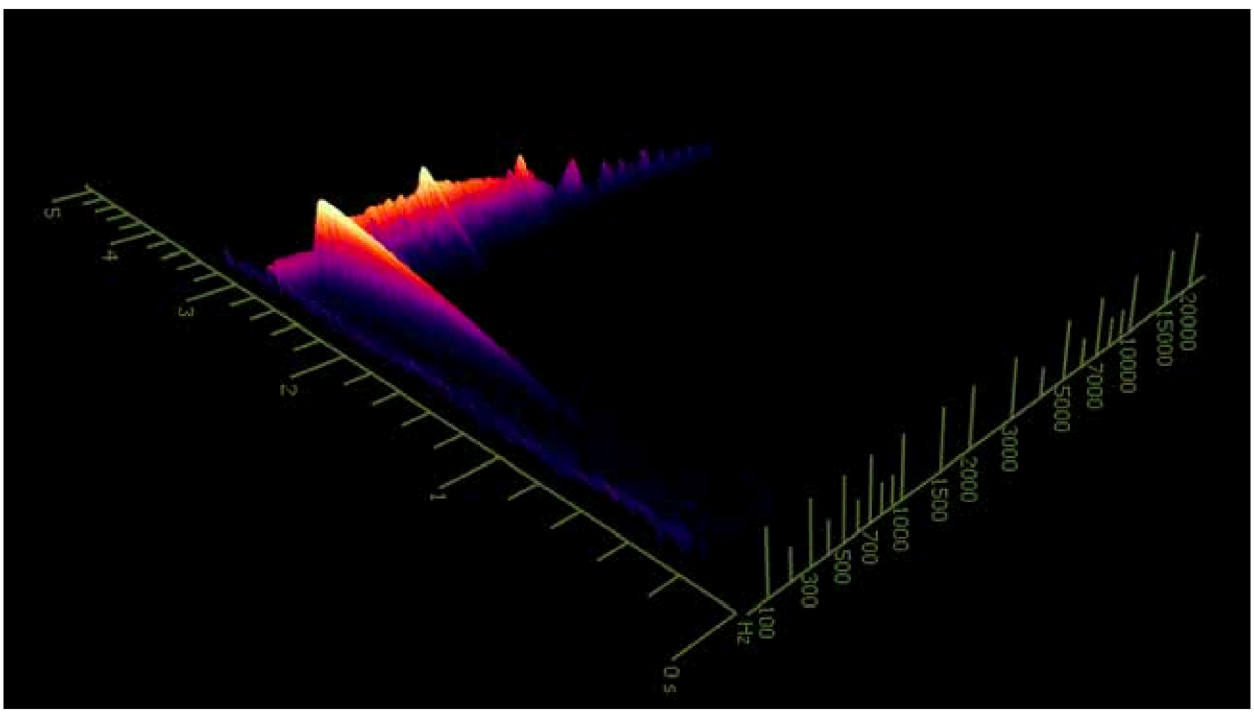

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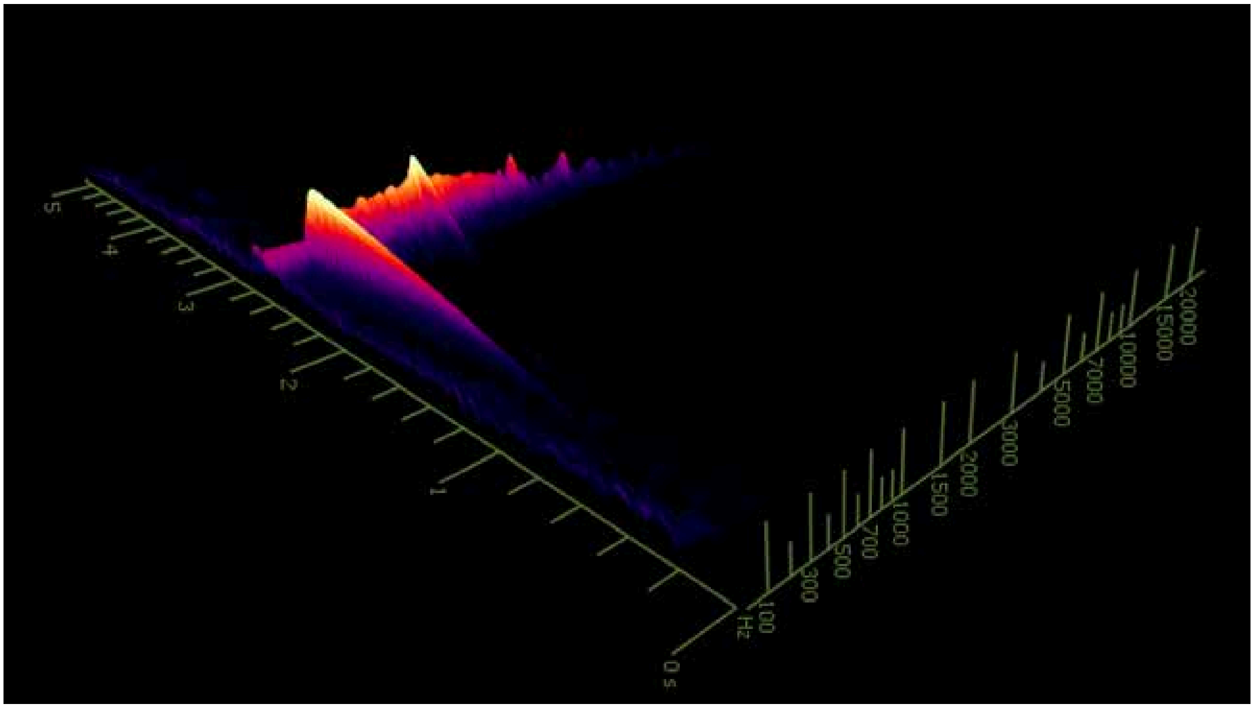
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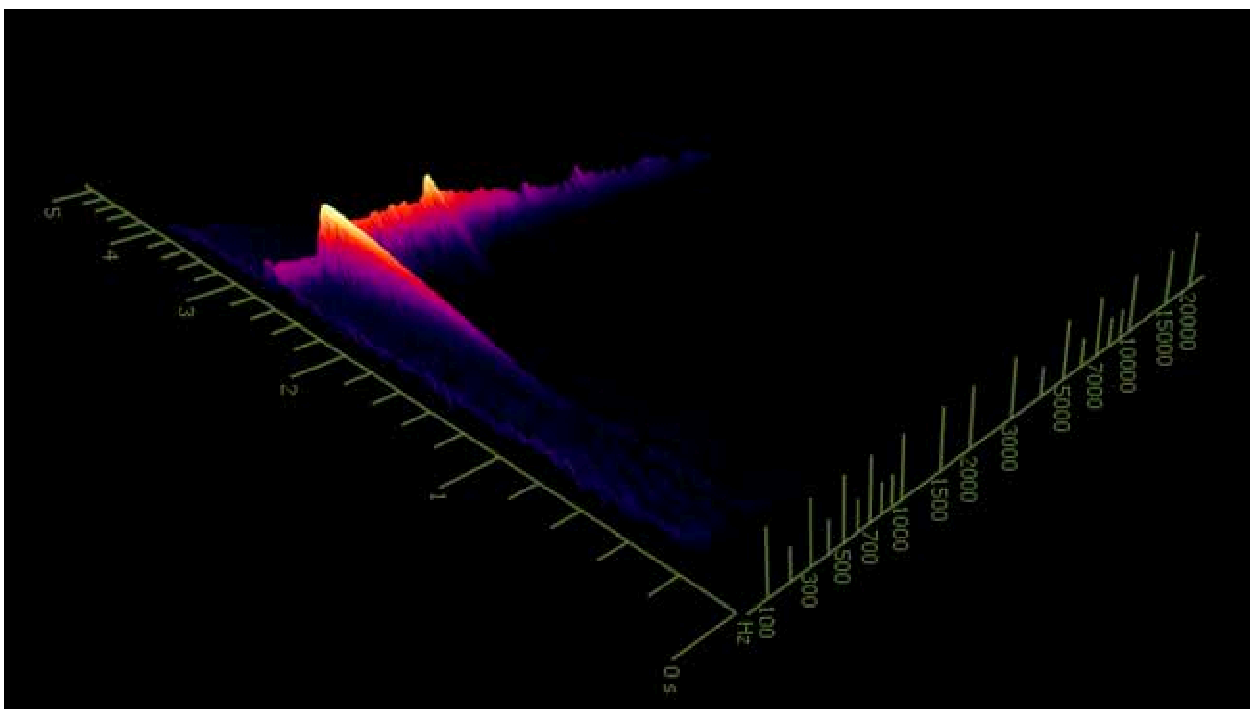
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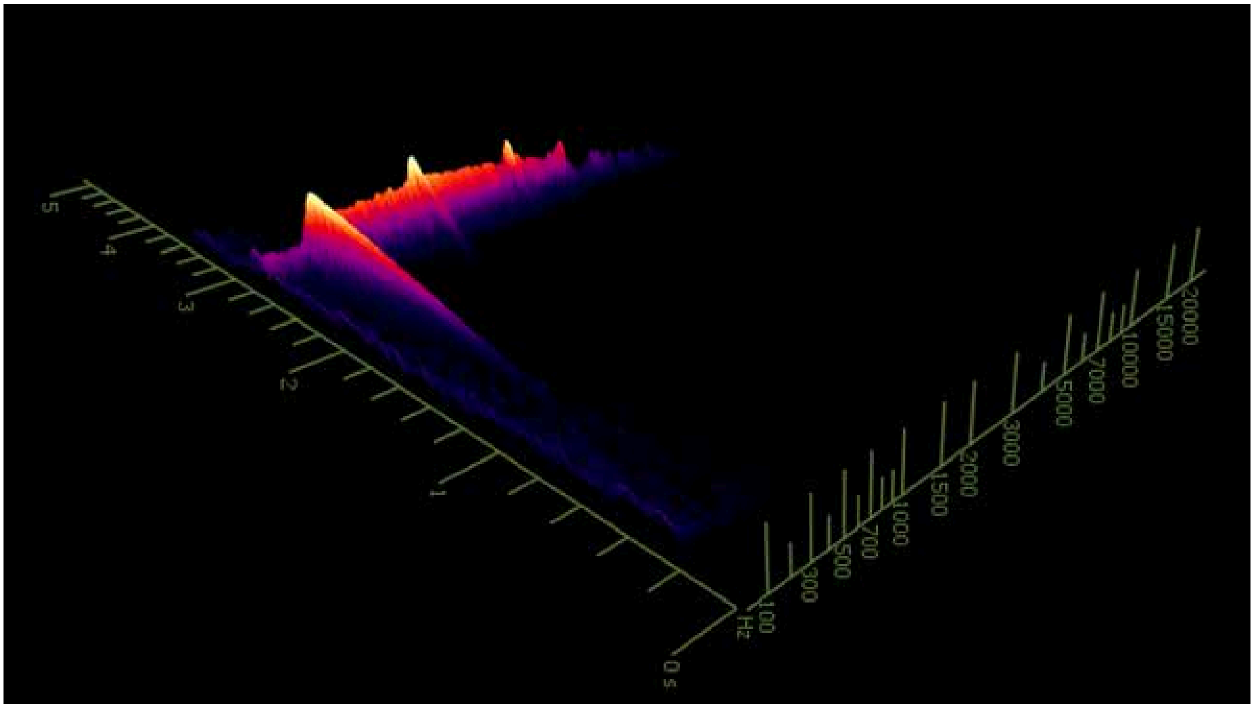
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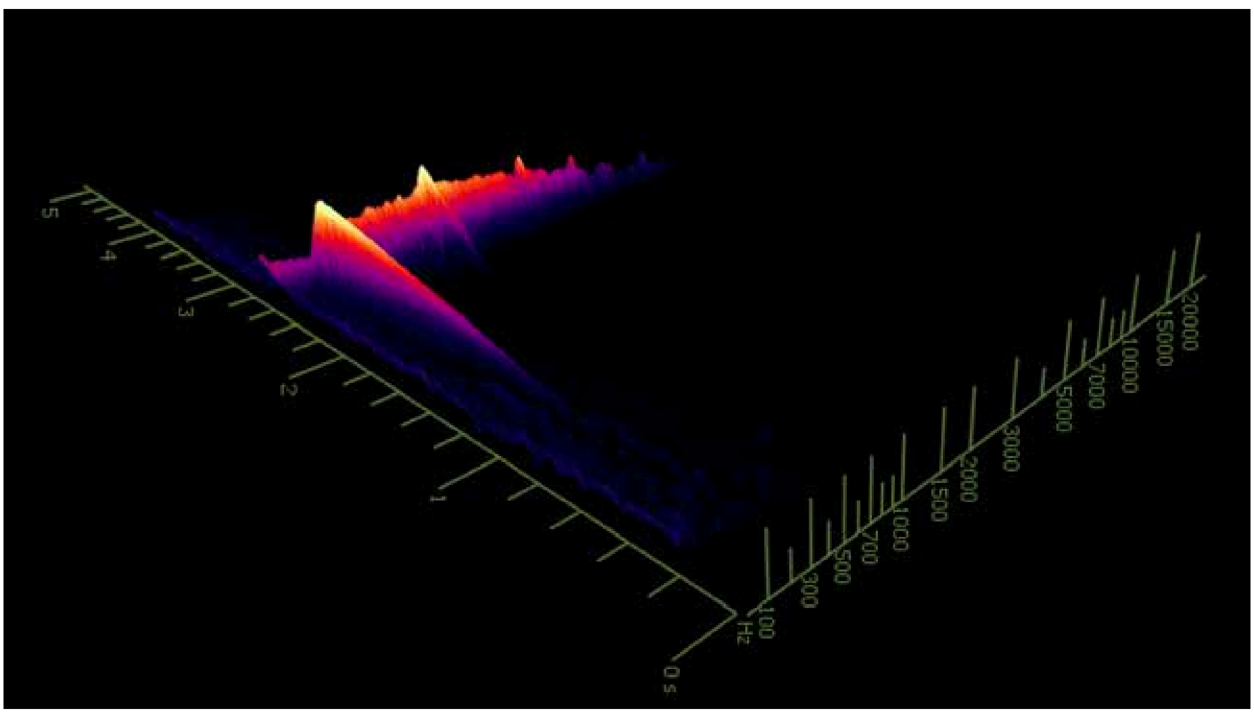
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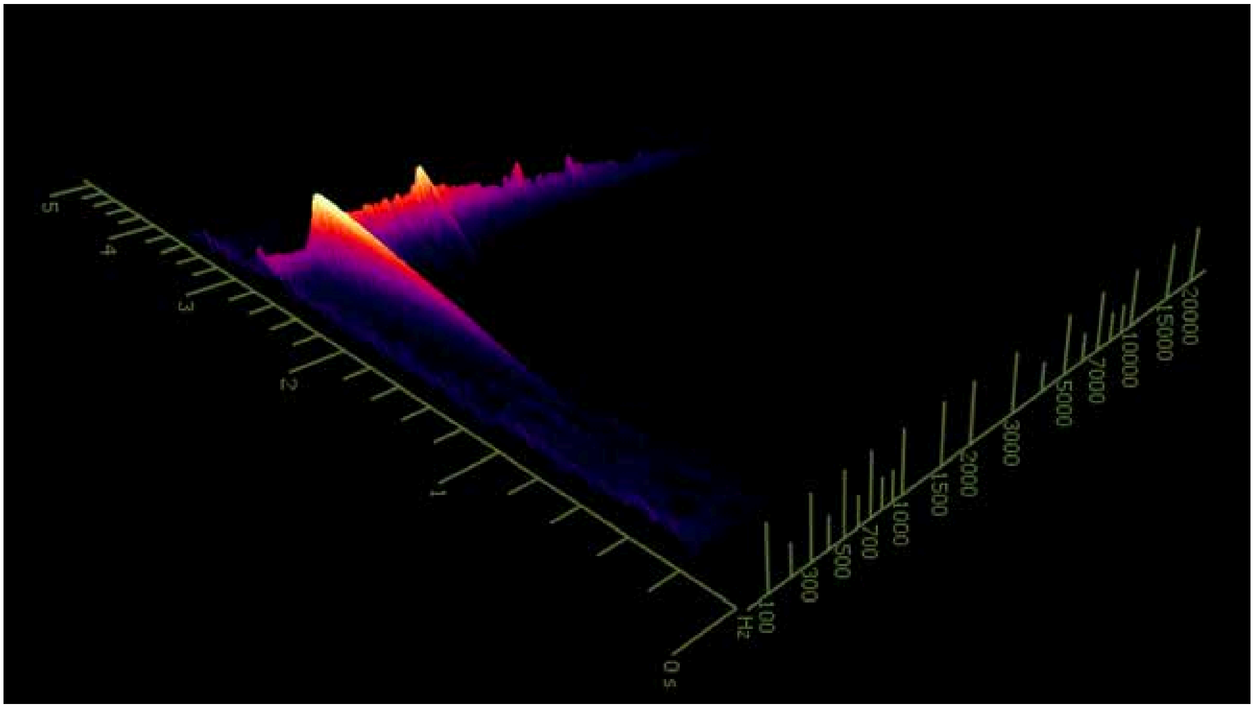
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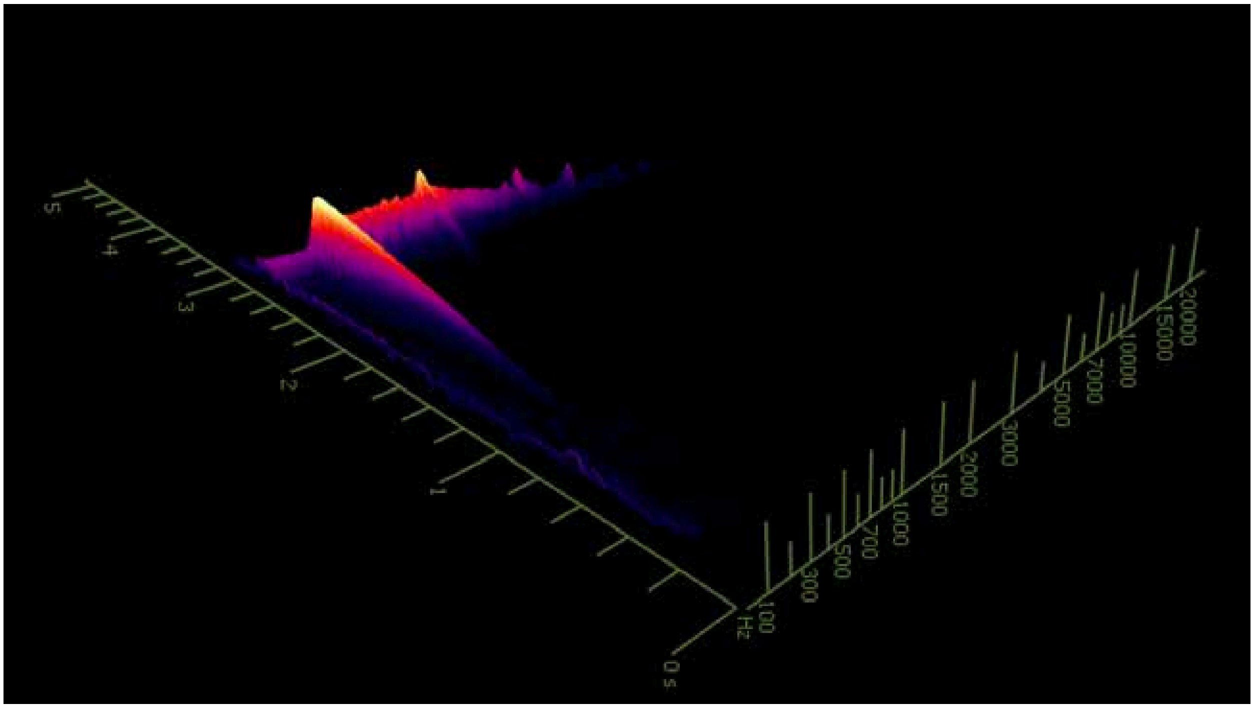
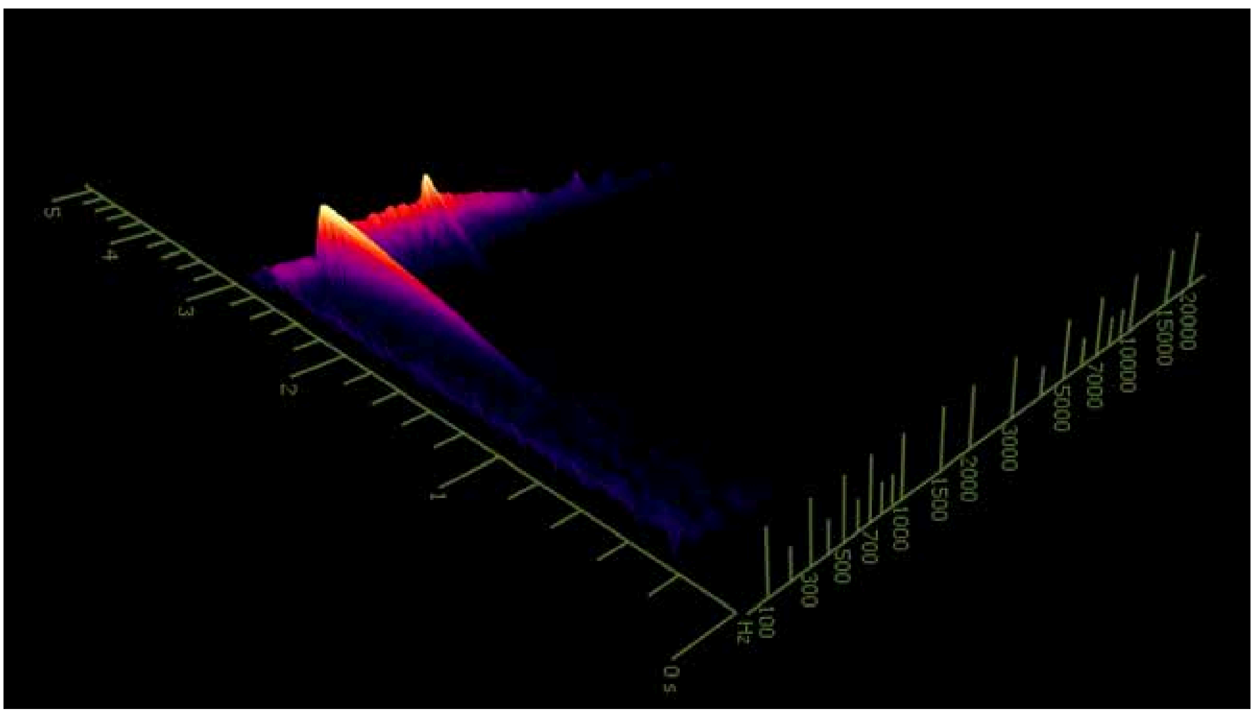
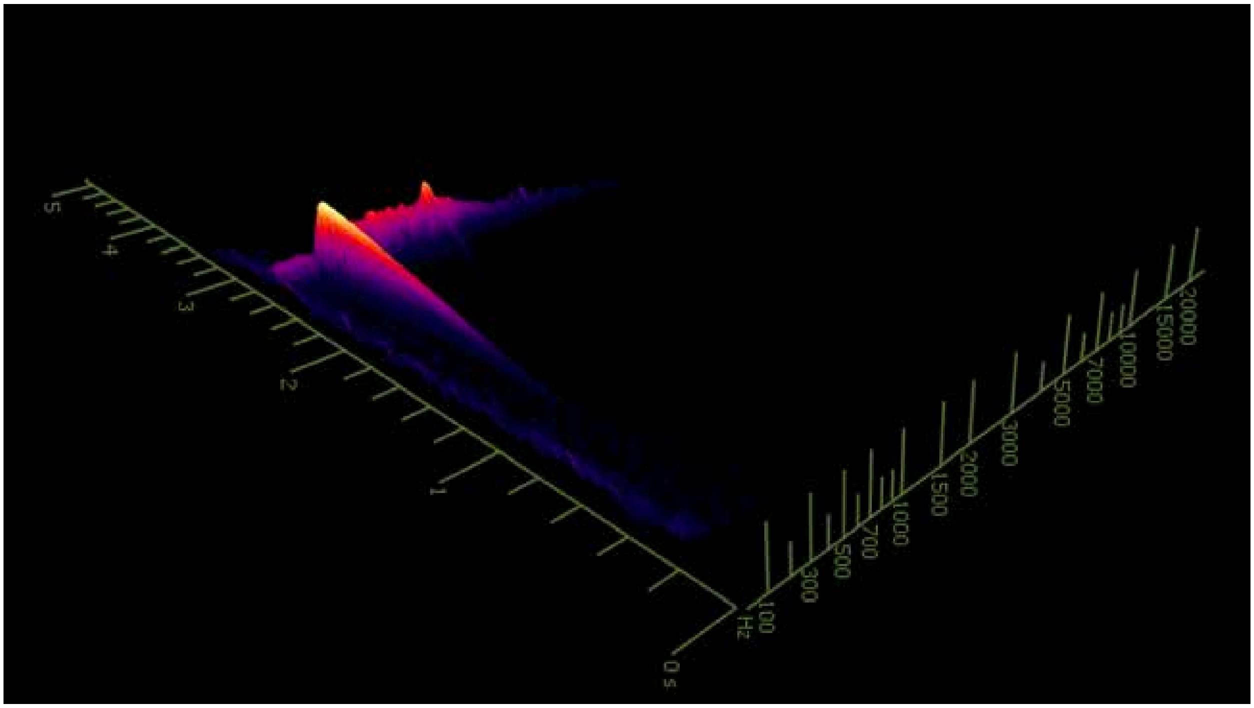
Slow Stroke, Just Off-Center



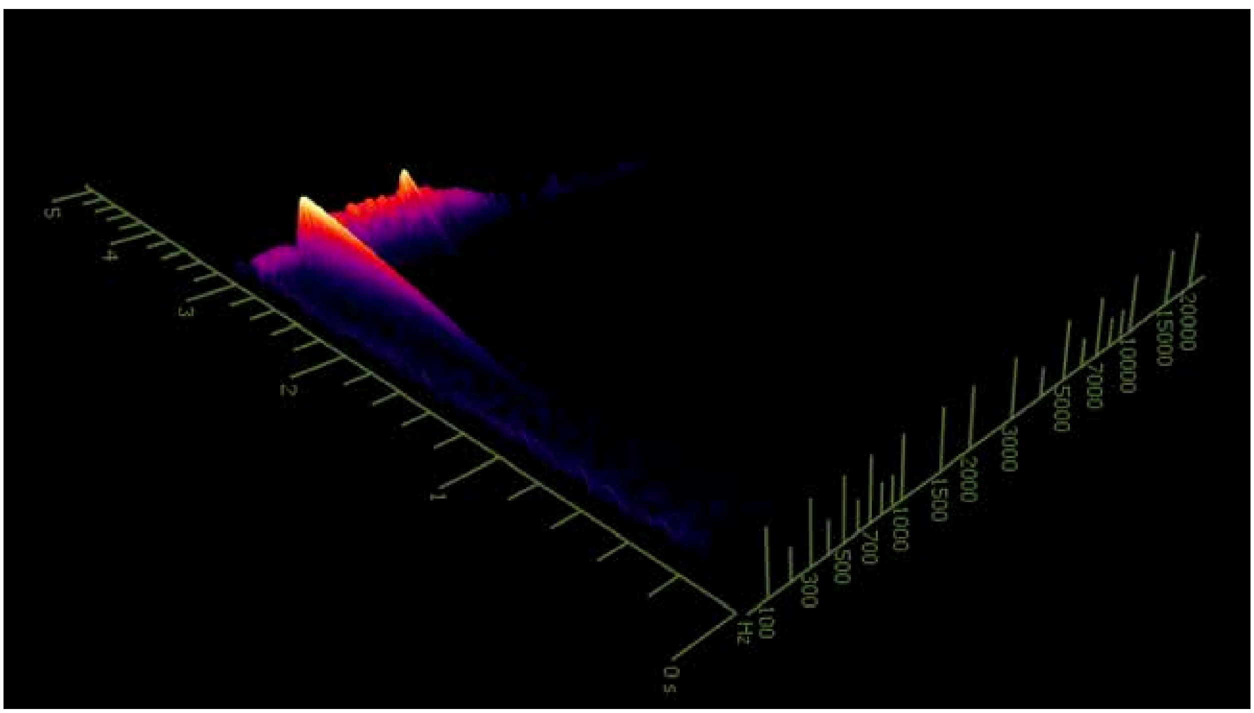
IP 3016B



IP 3106



Weighted IP 3106 B



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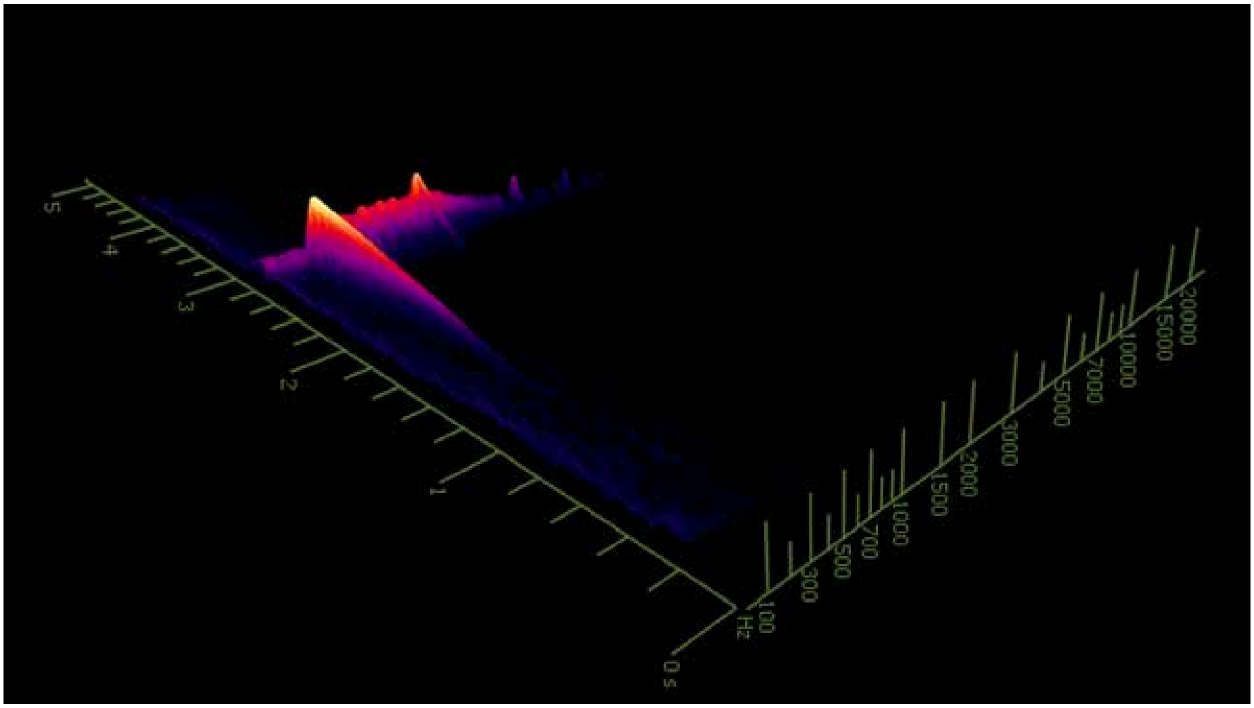
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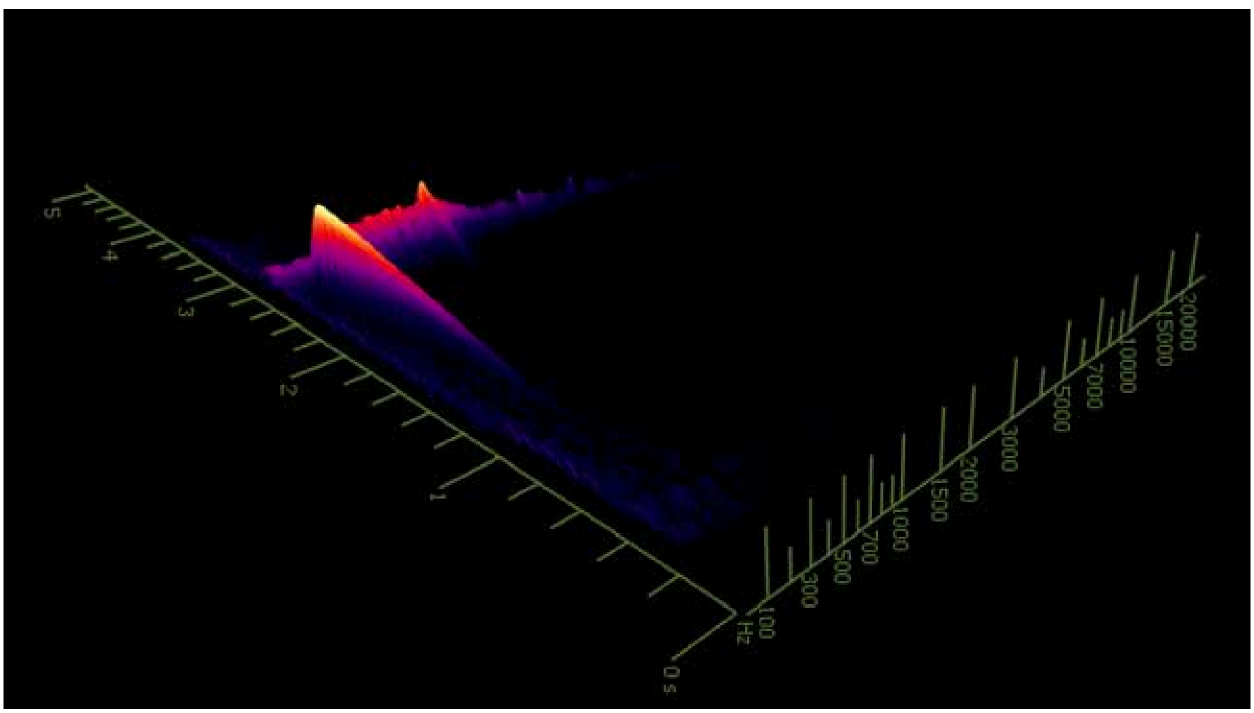
IP 813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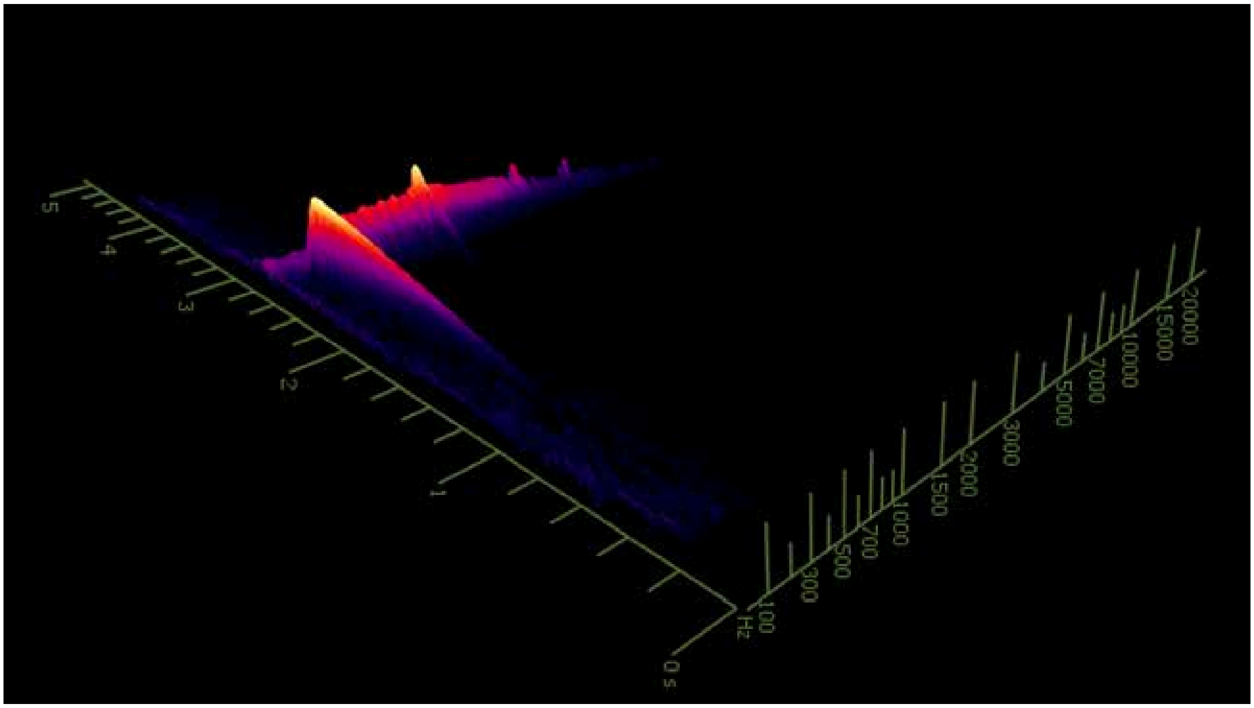
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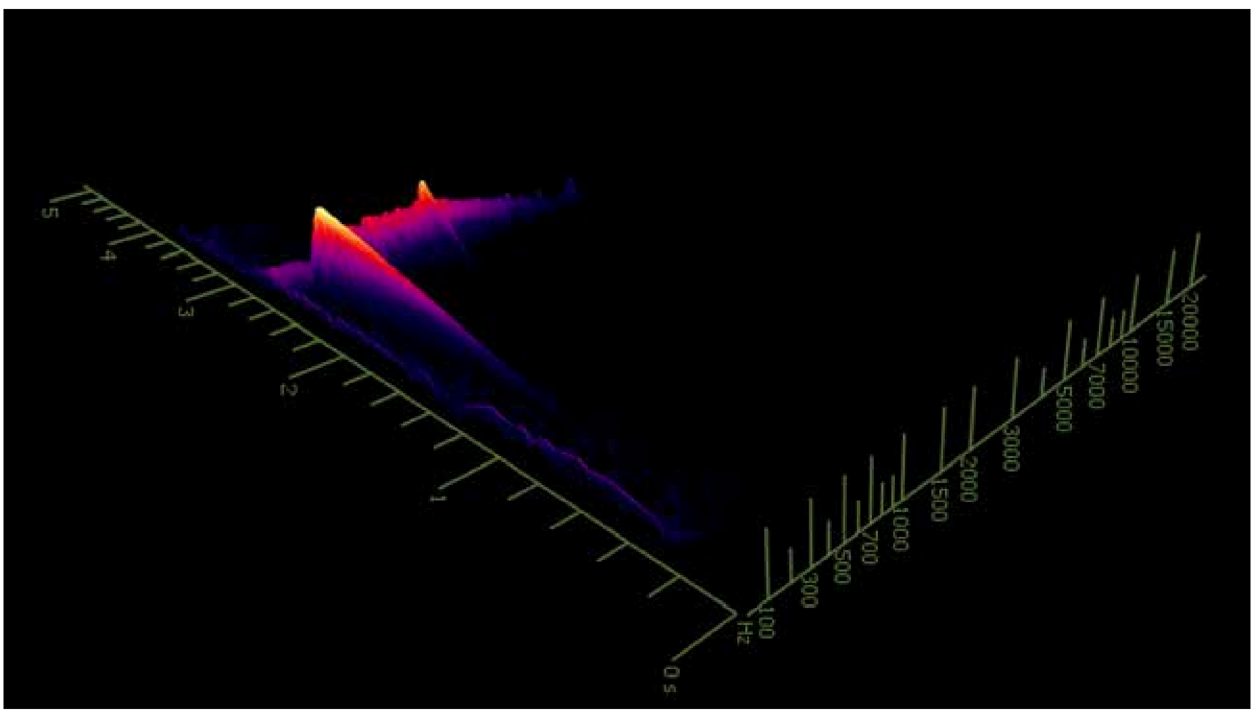
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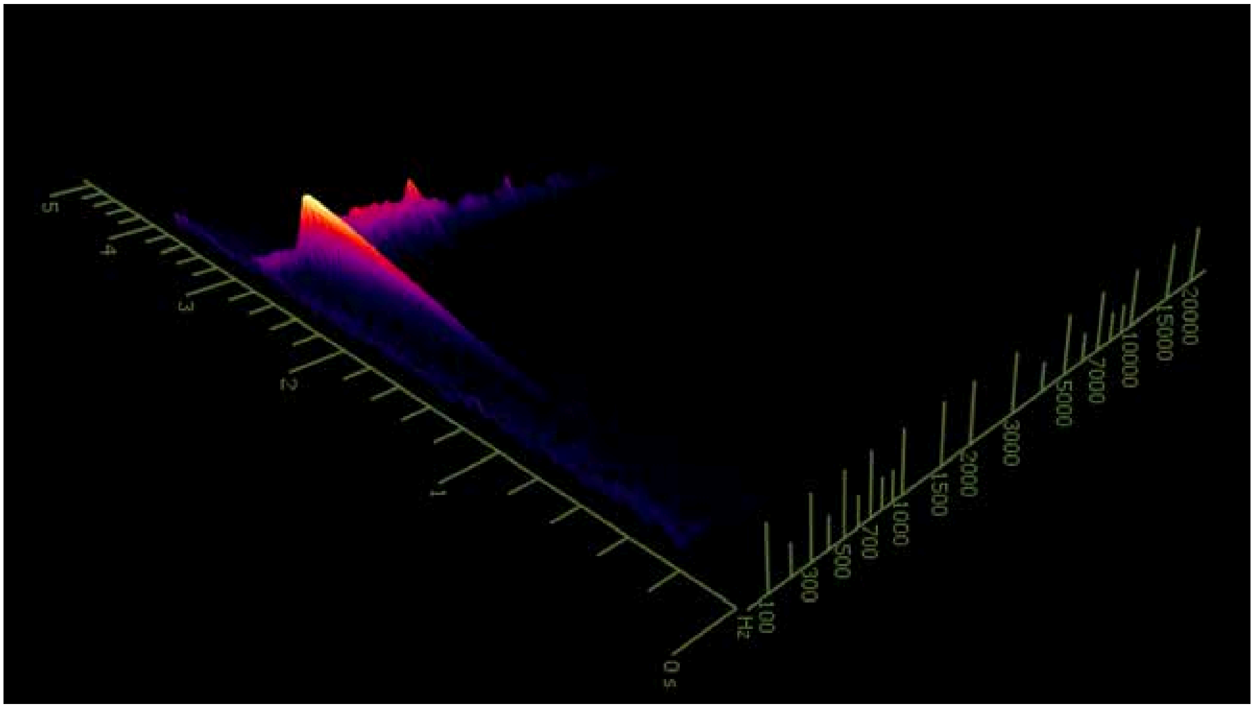
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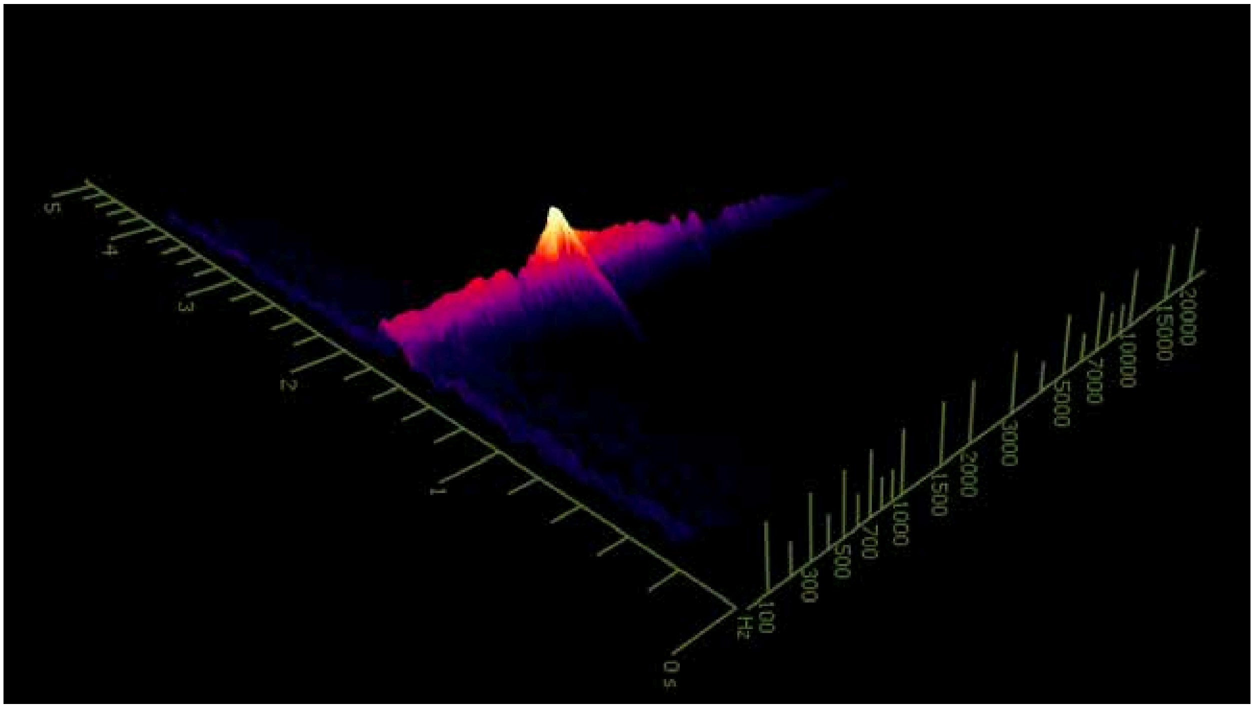
APPENDIX C

3D SPECTROGRAM IMAGES, BAR E_6

Fast Stroke, Center of the Bar



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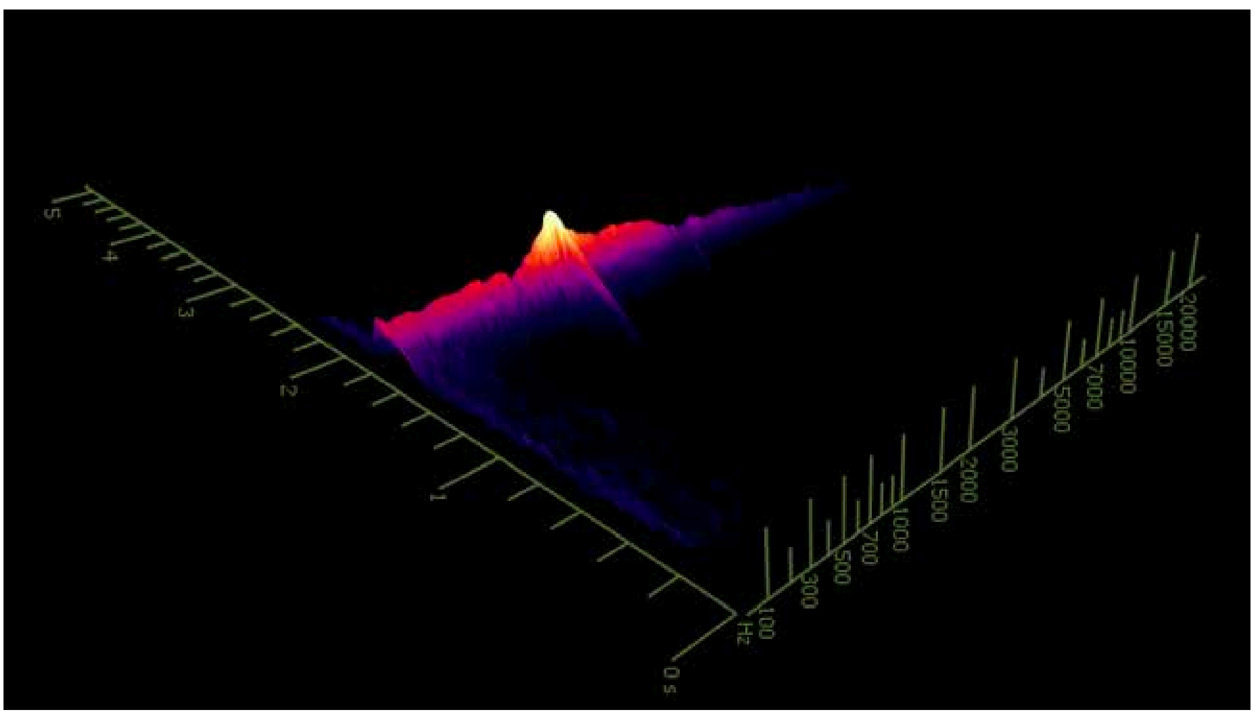

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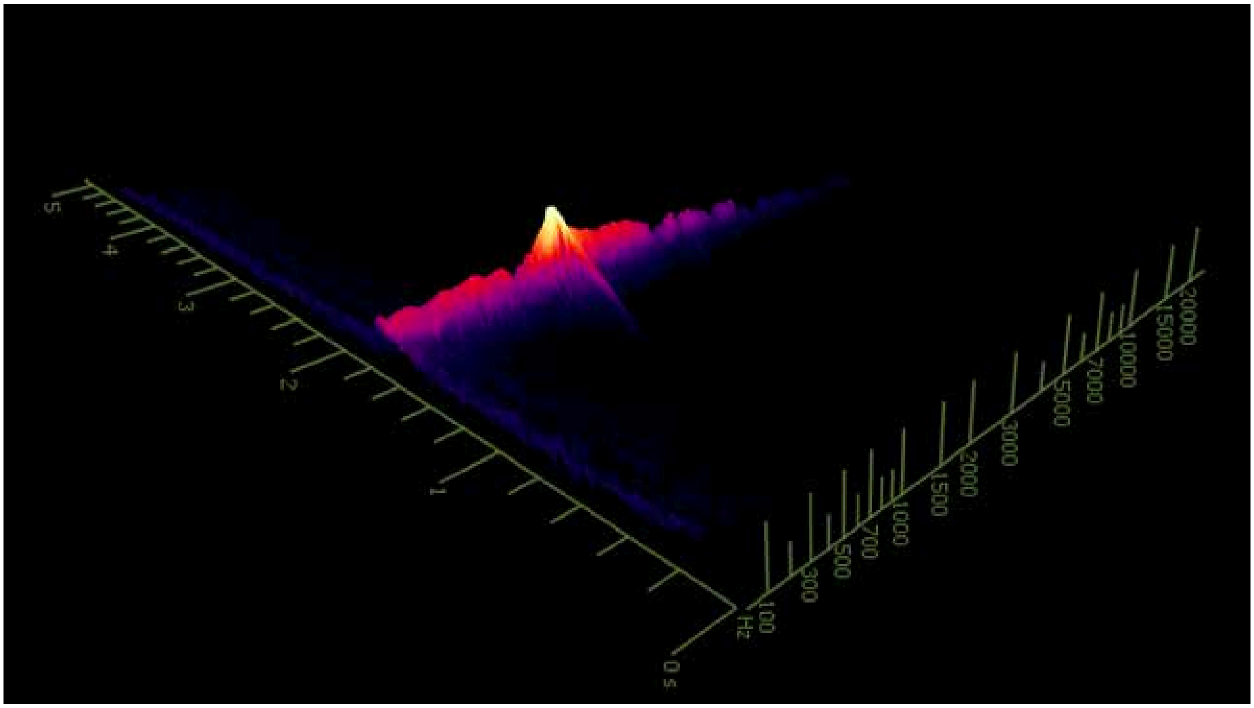

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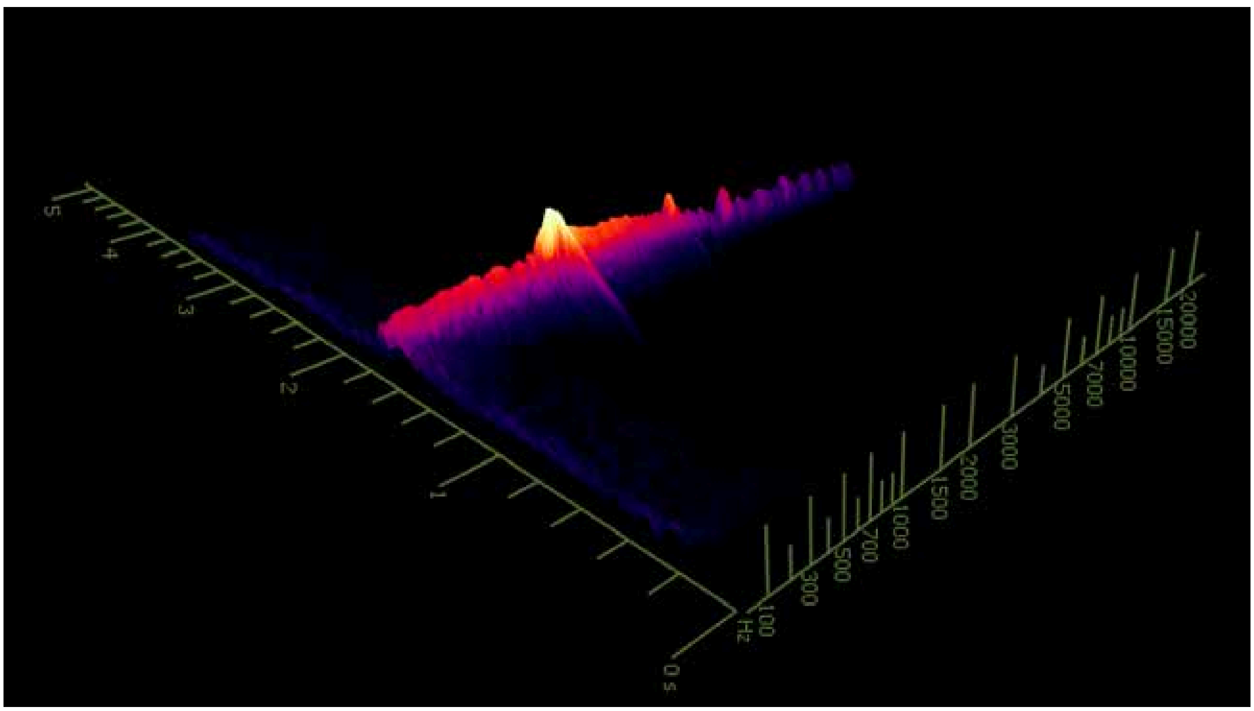

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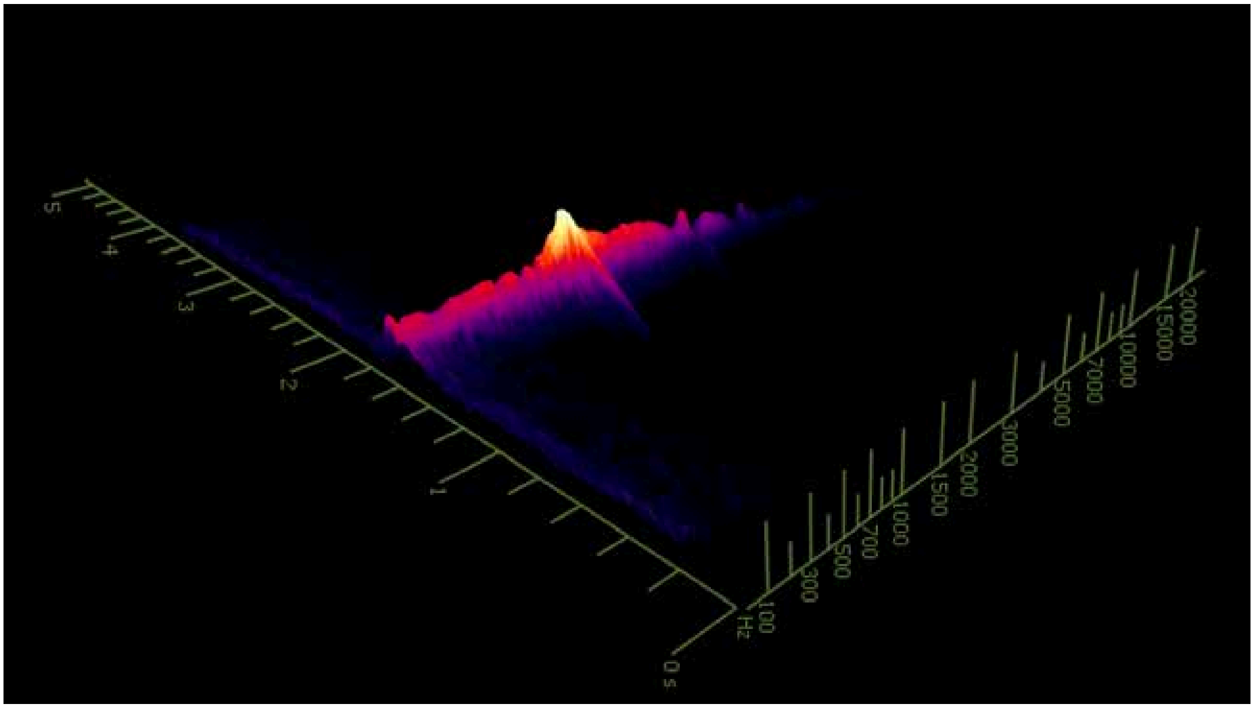
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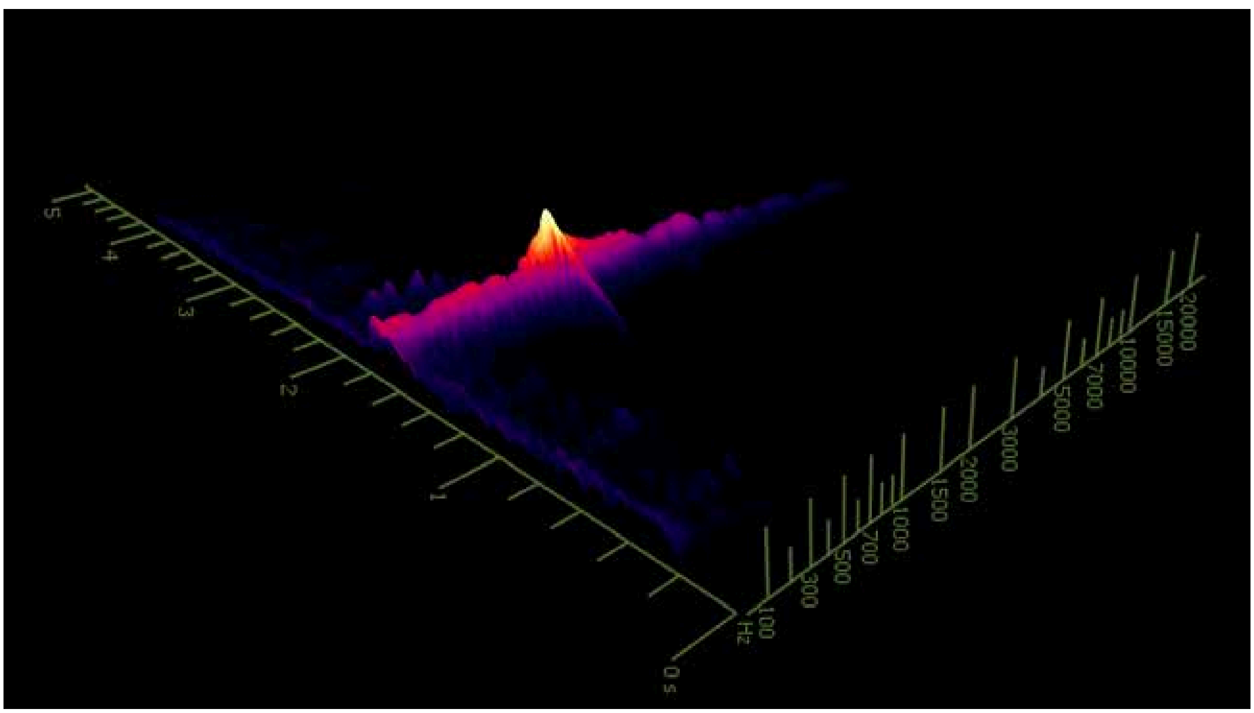
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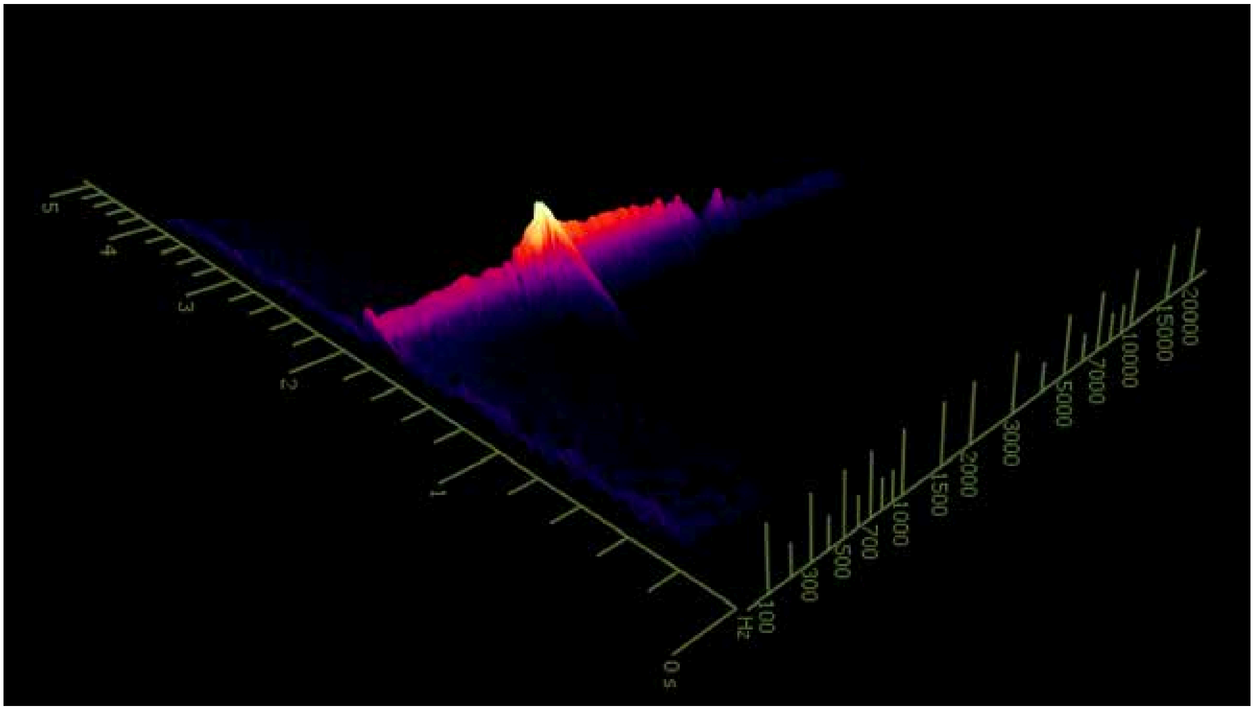
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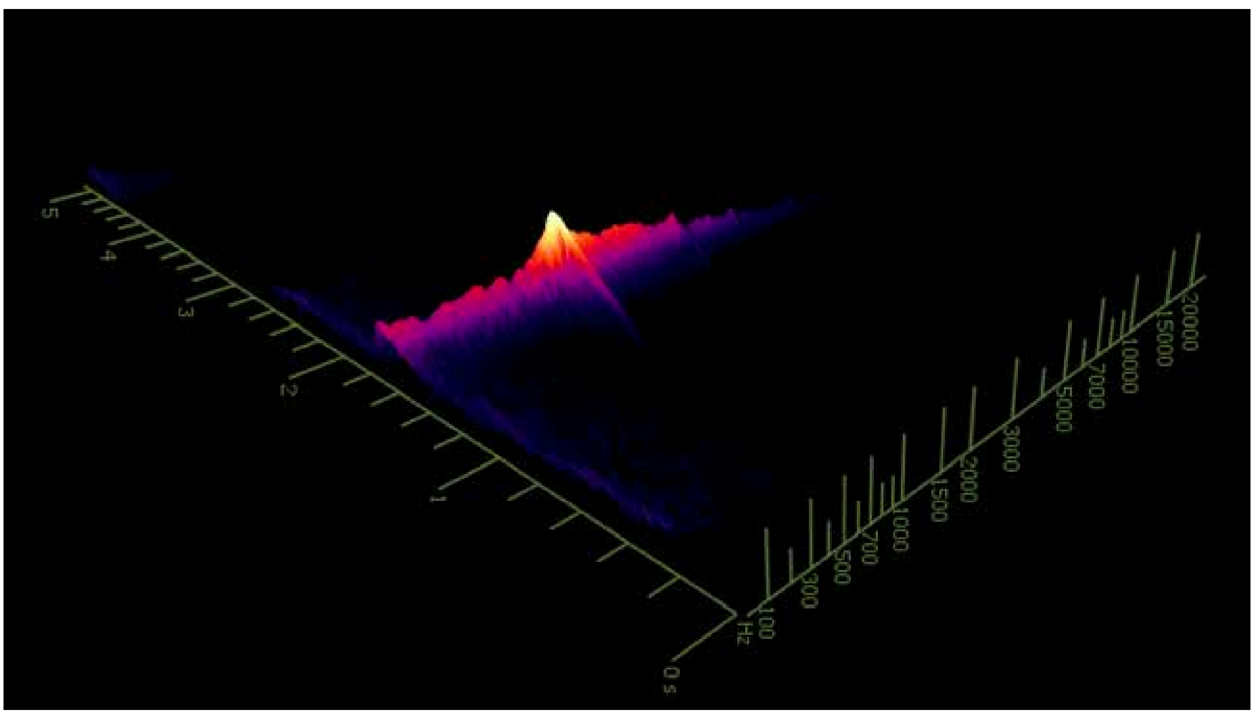
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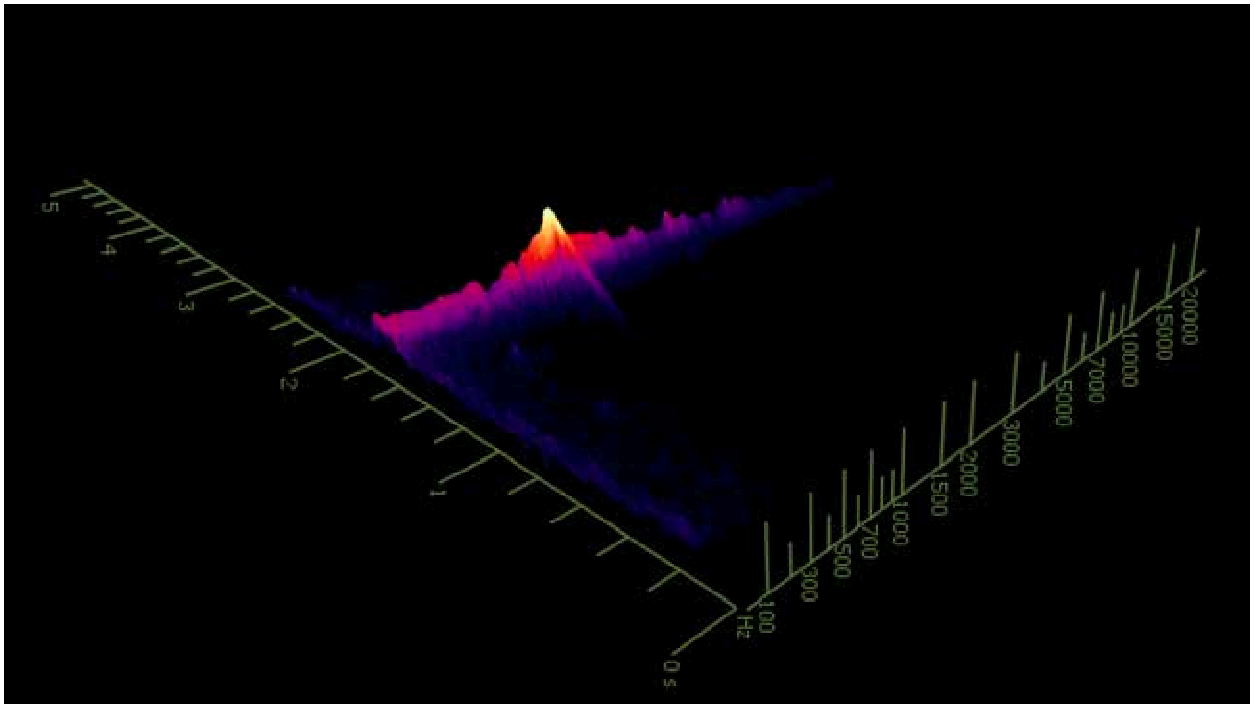

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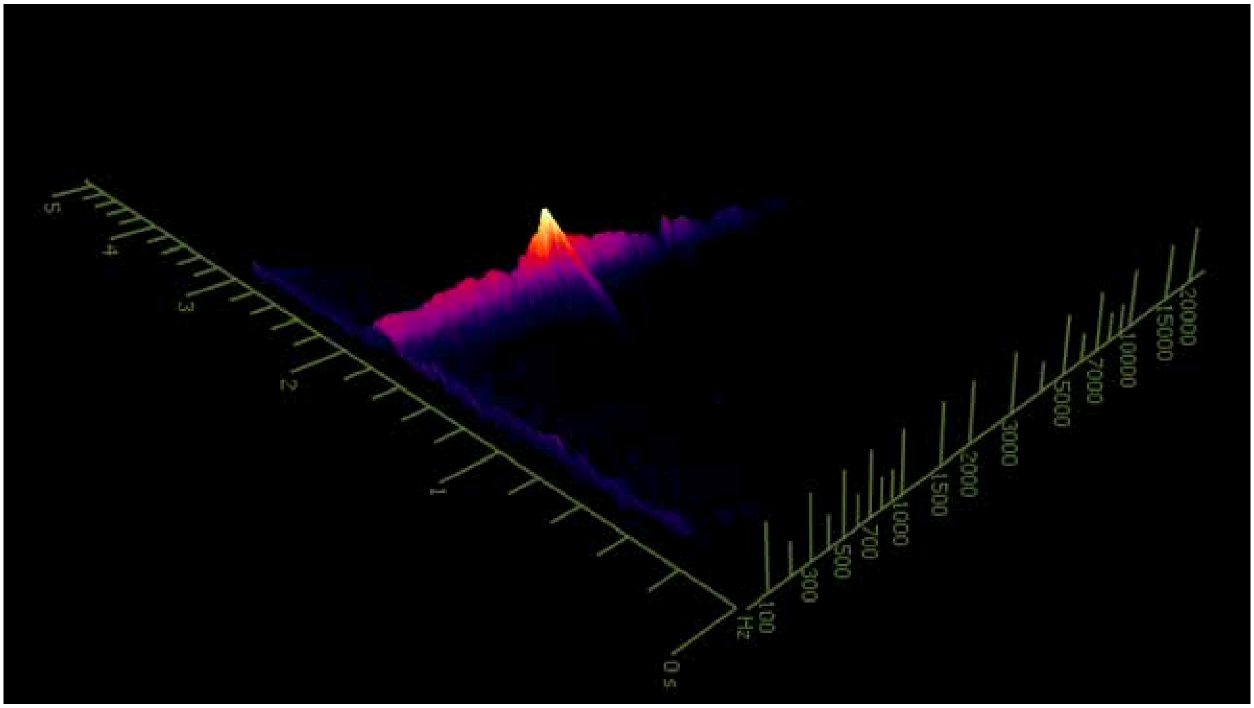
Slow Stroke, Center of the Bar



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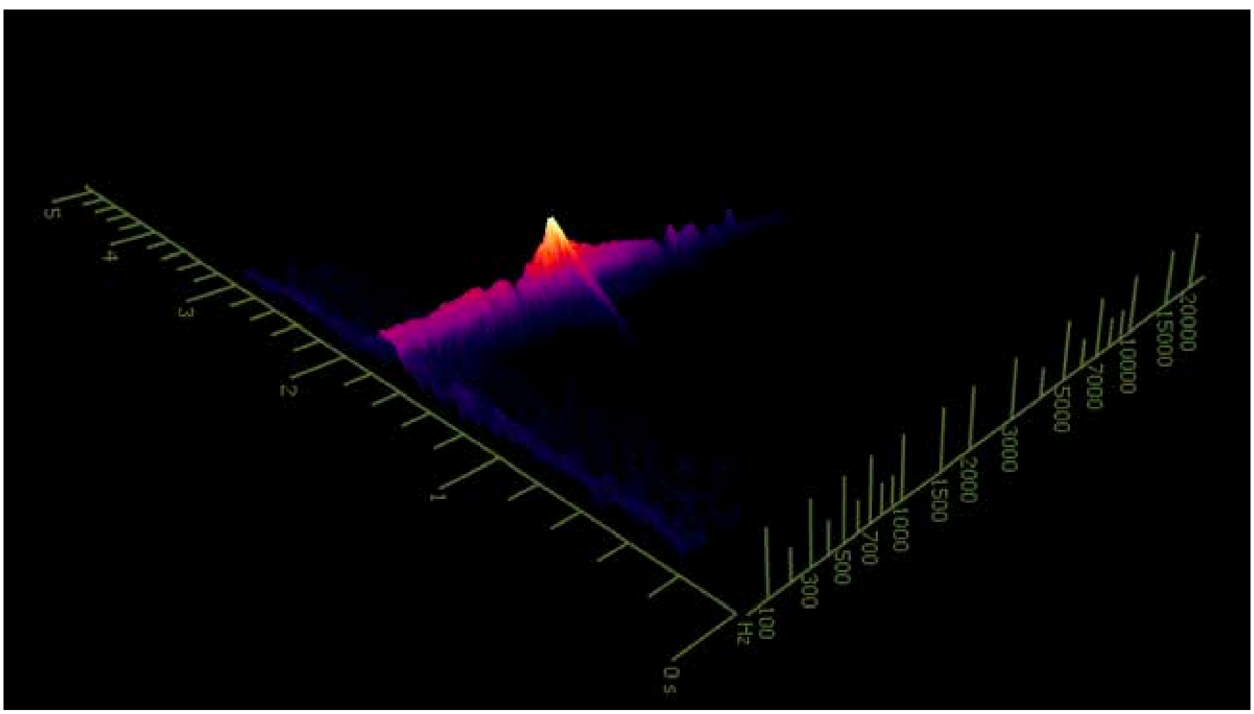

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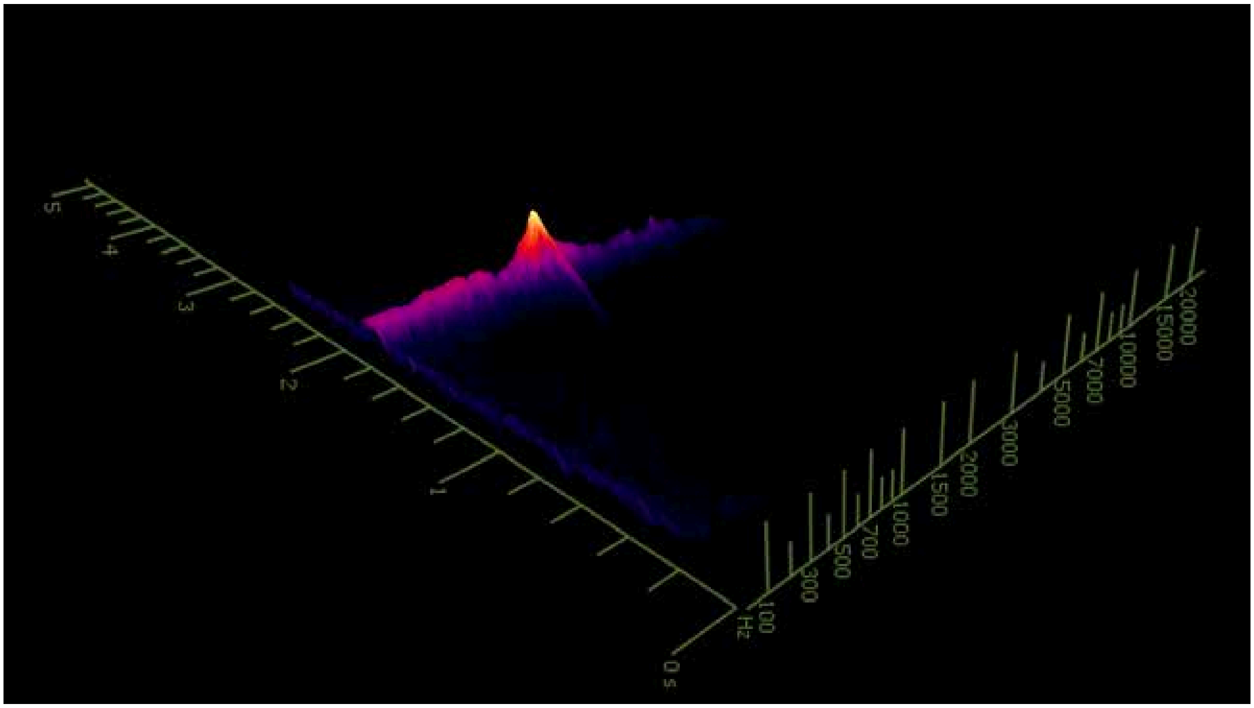

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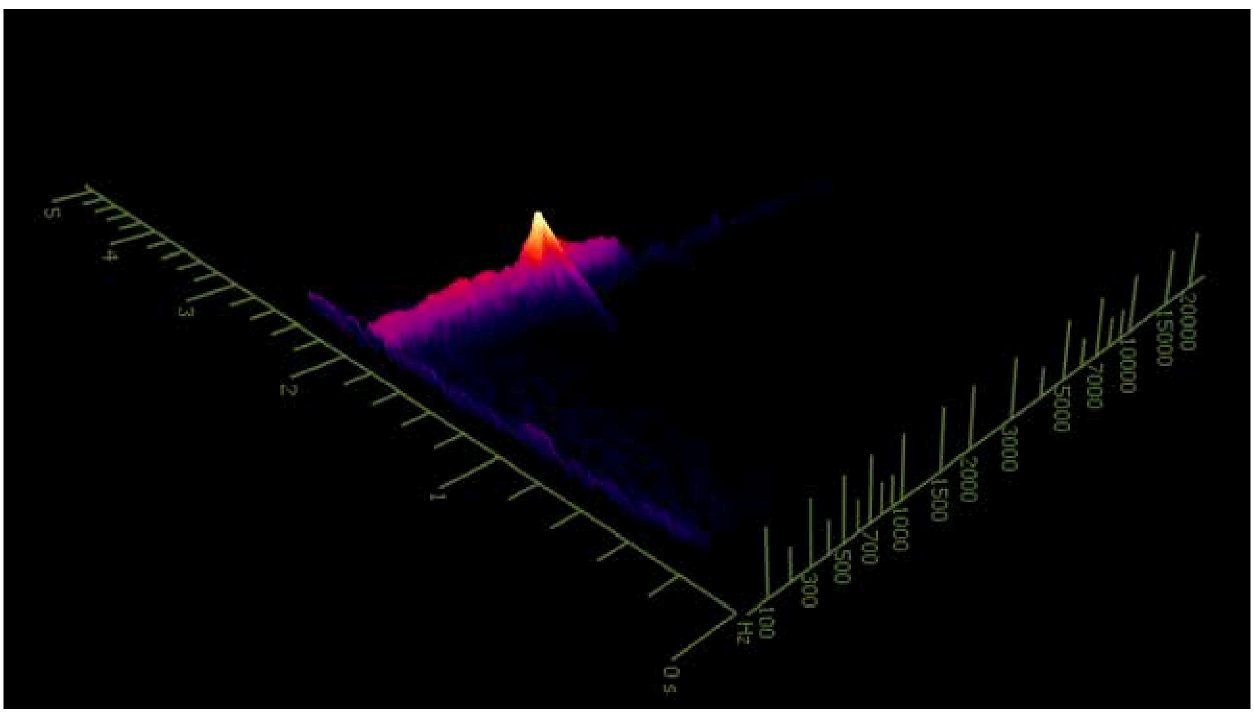

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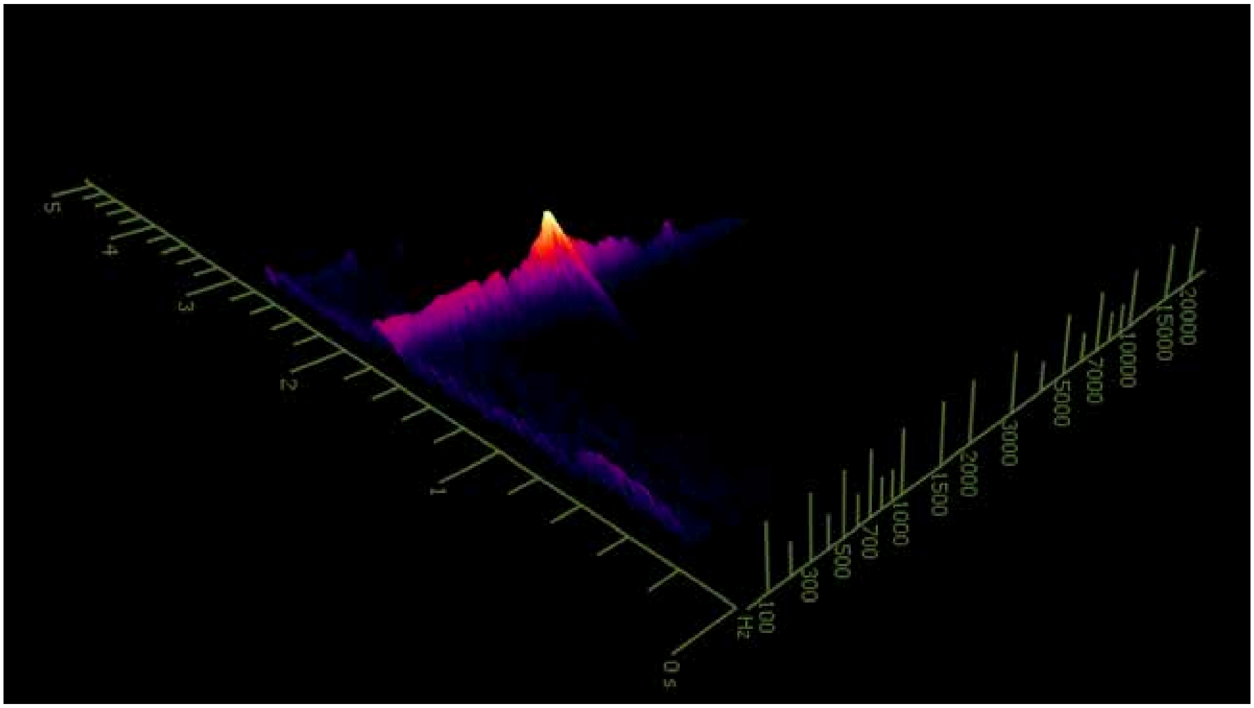

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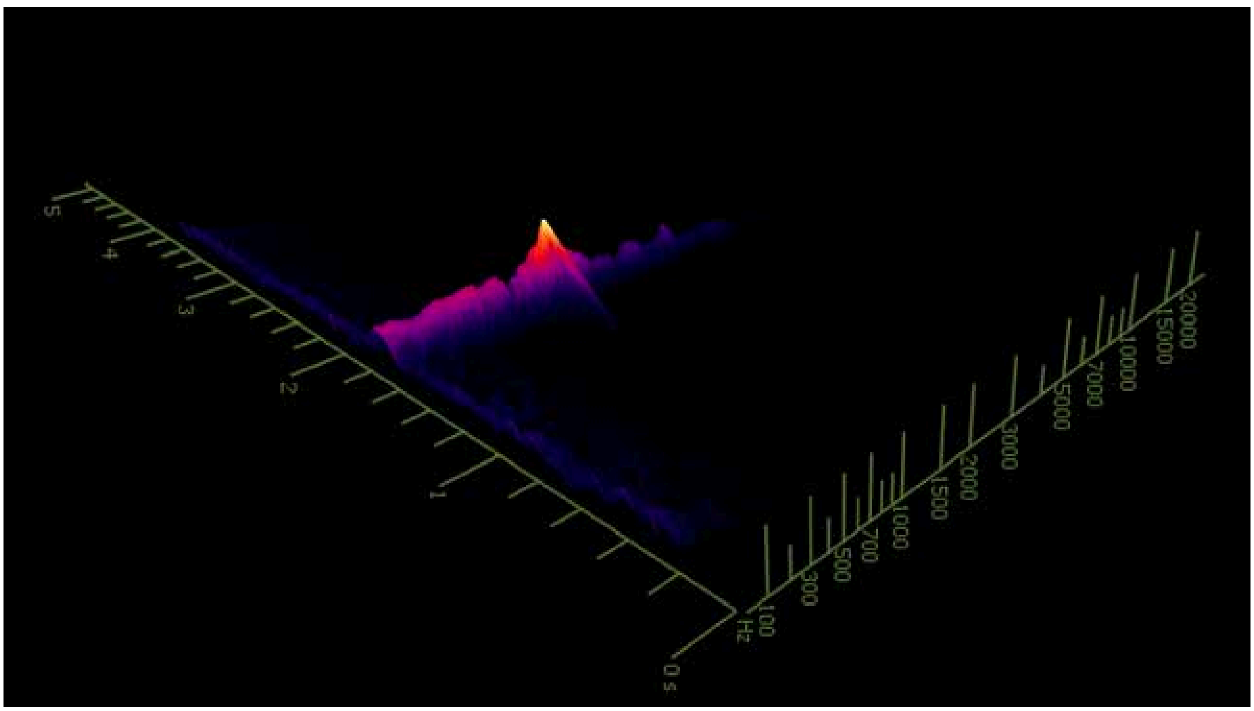

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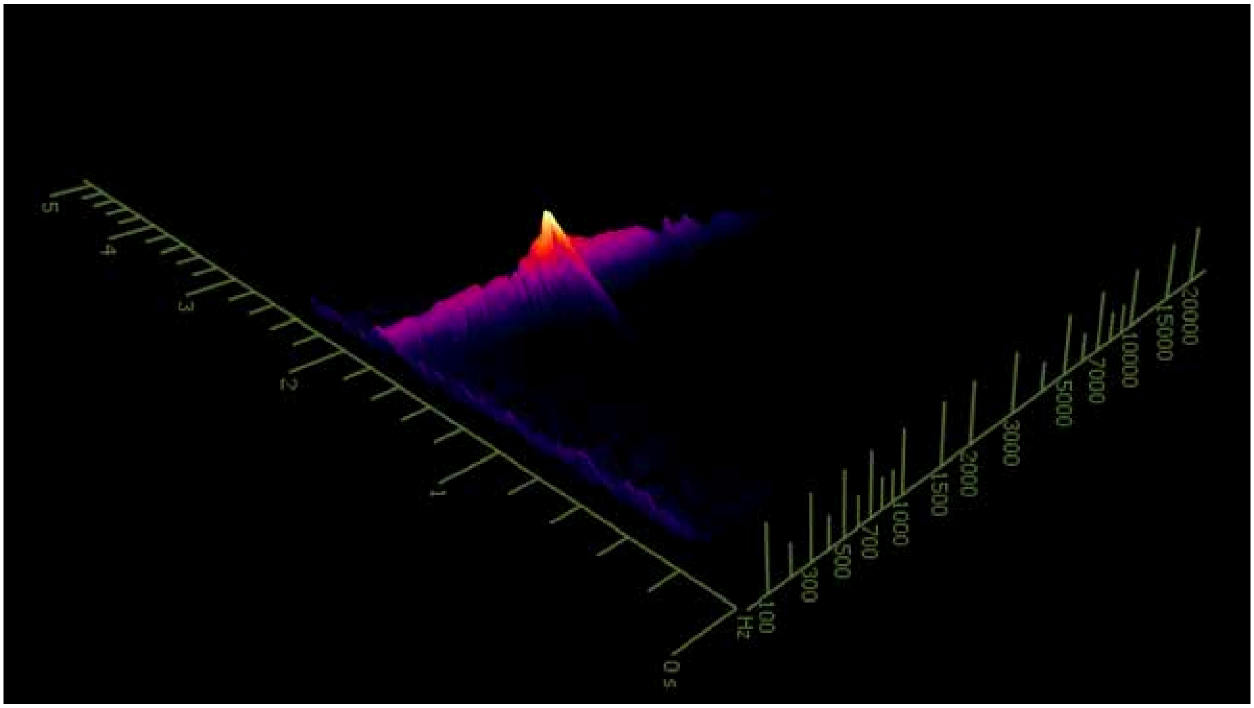
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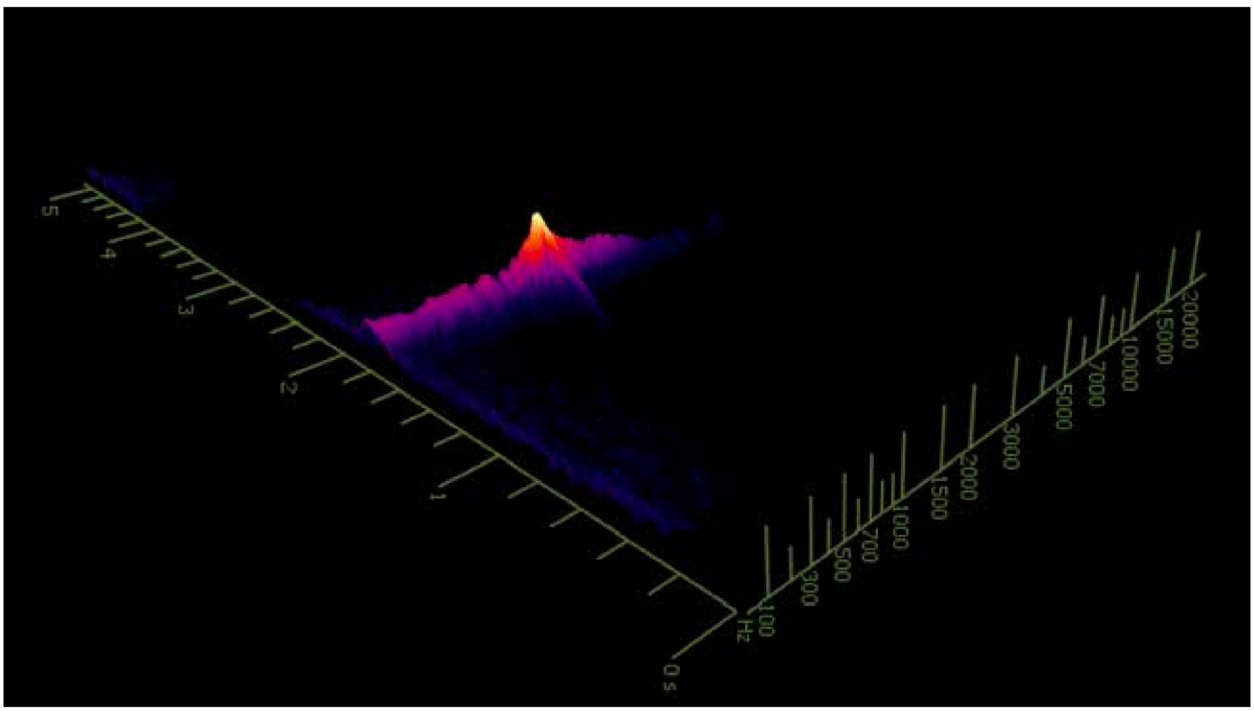
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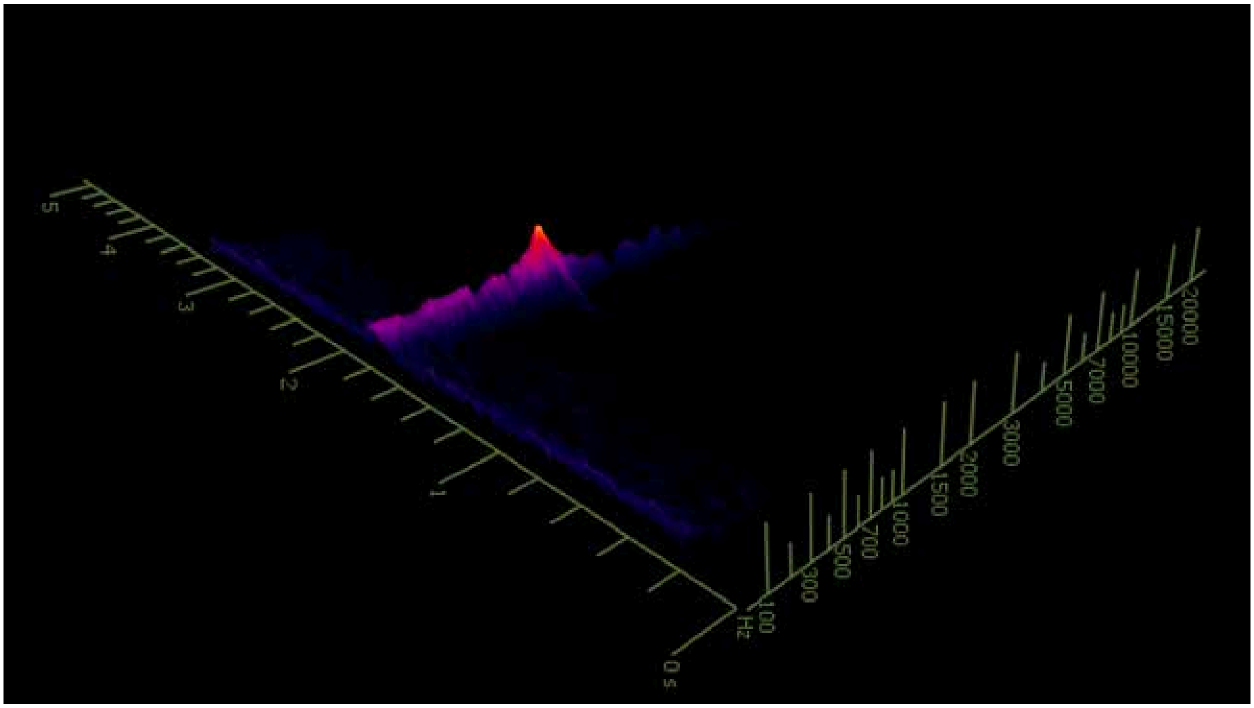
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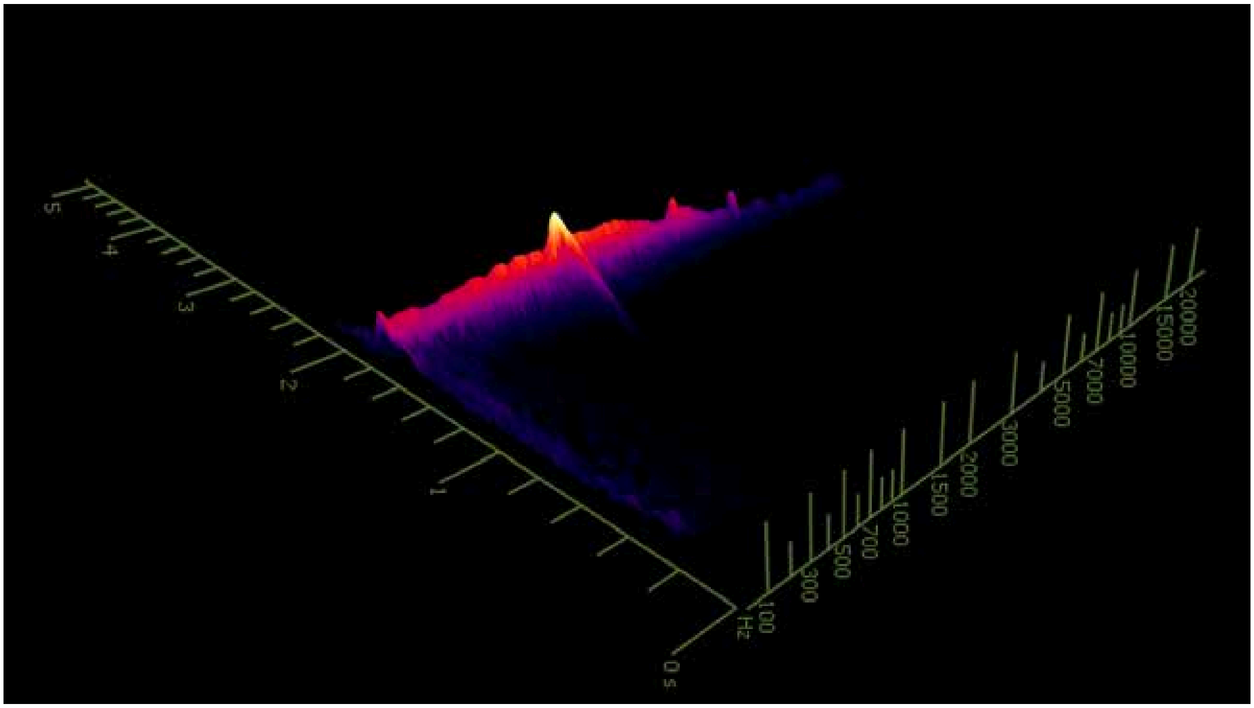
Fast Stroke, Node



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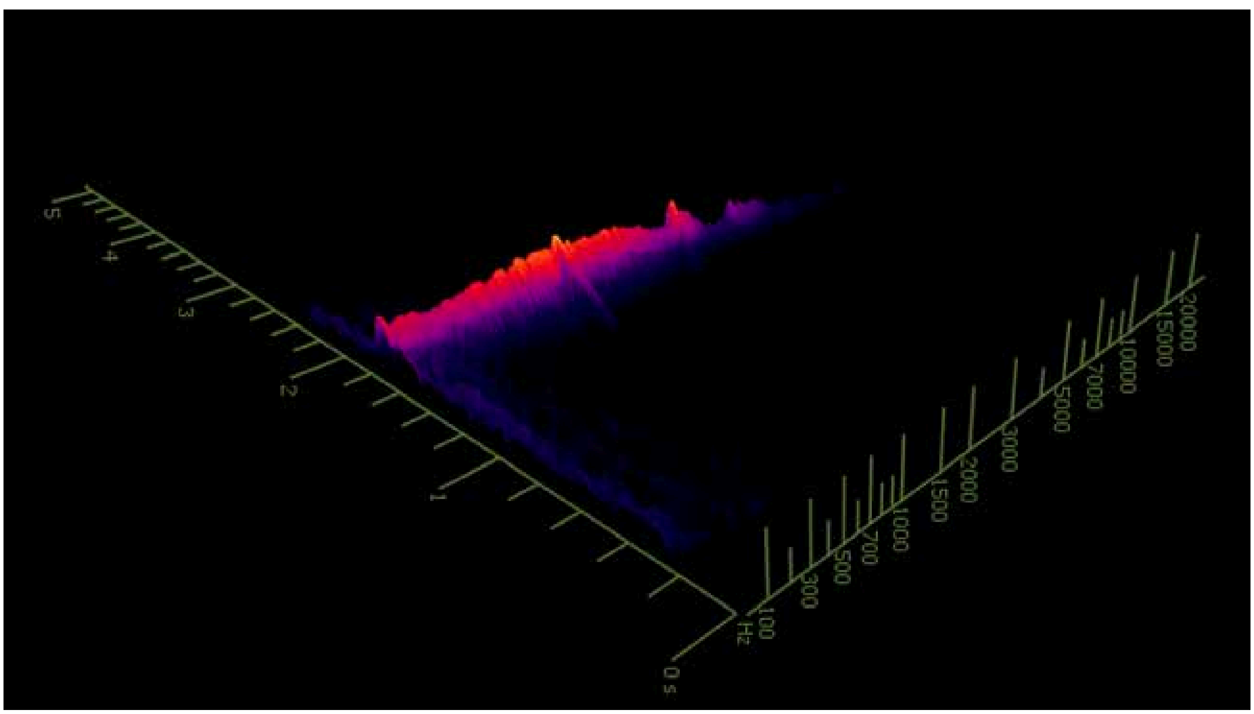

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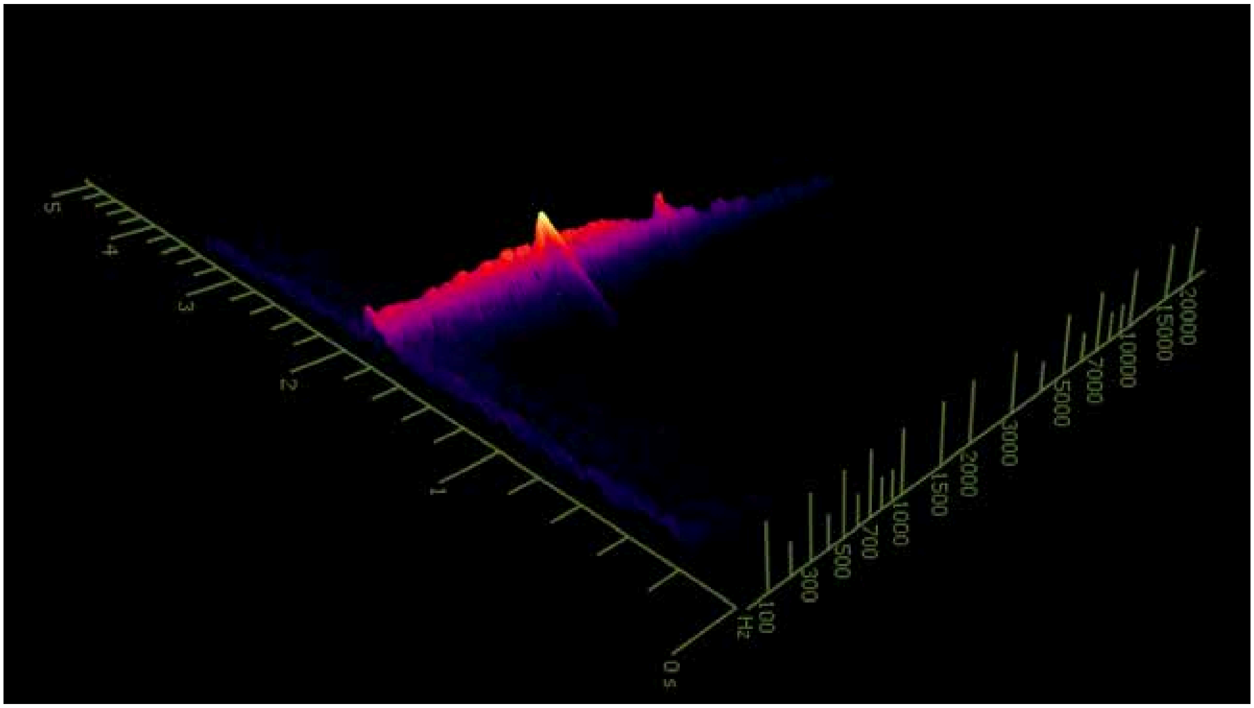

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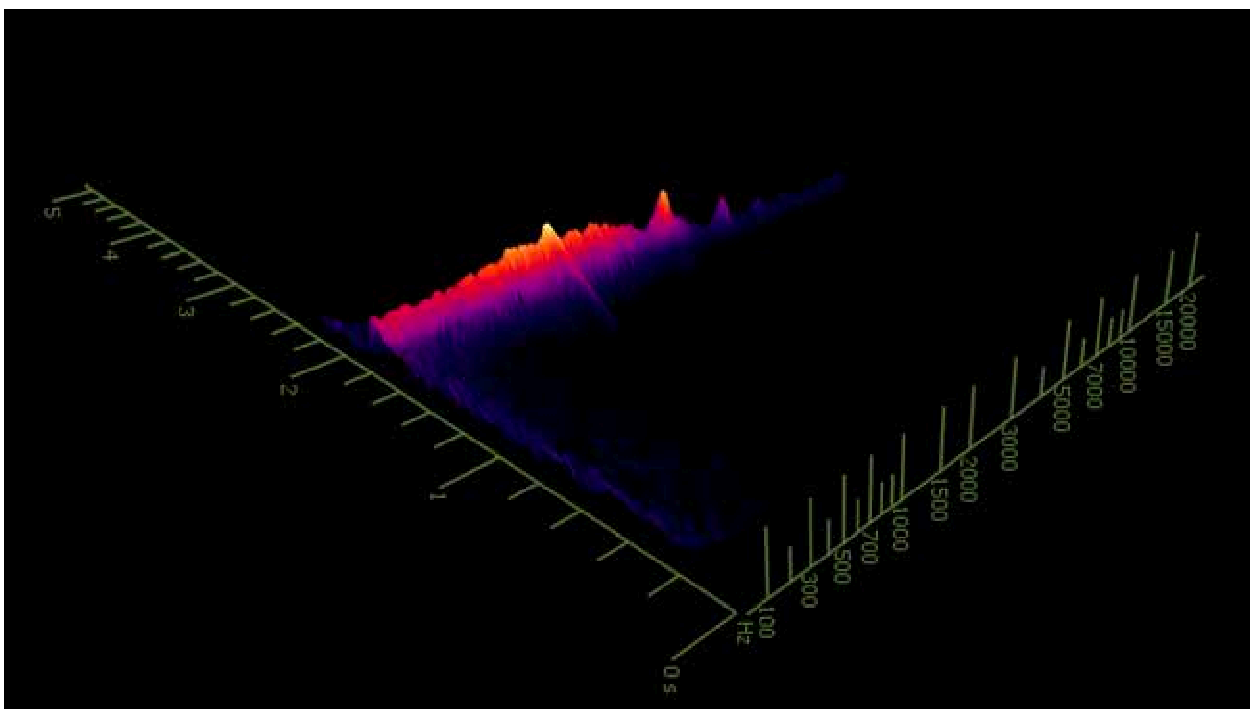

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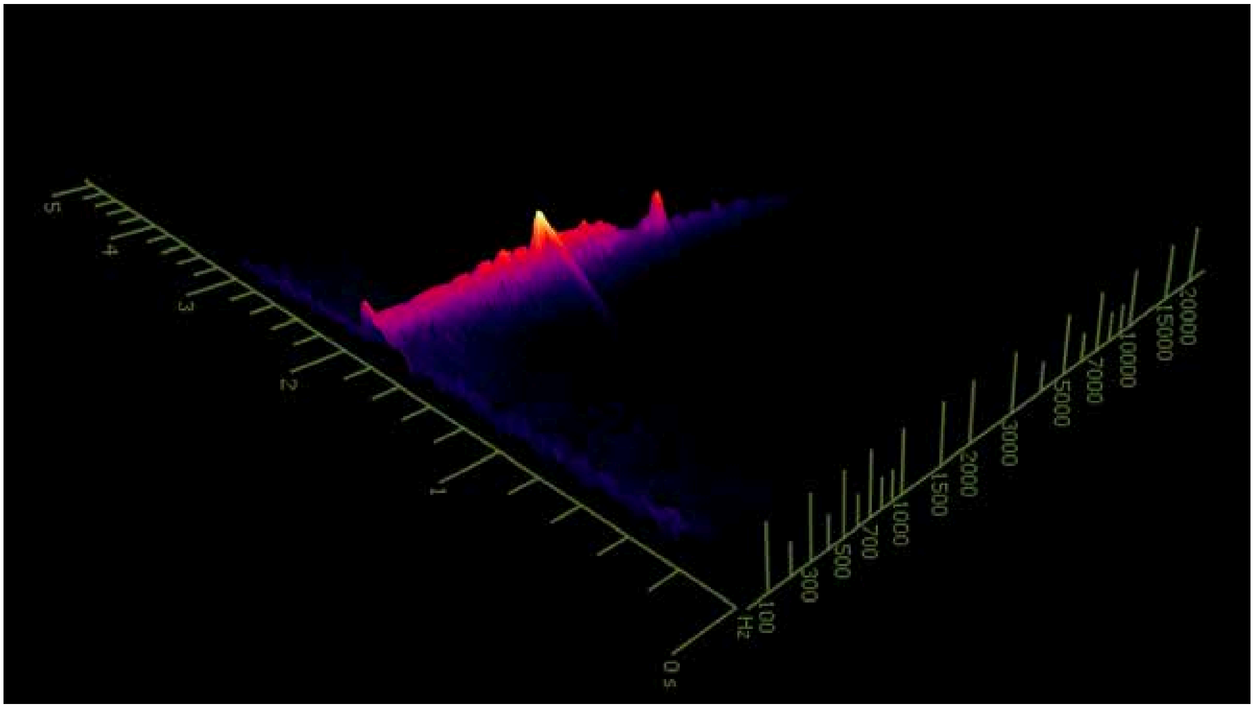

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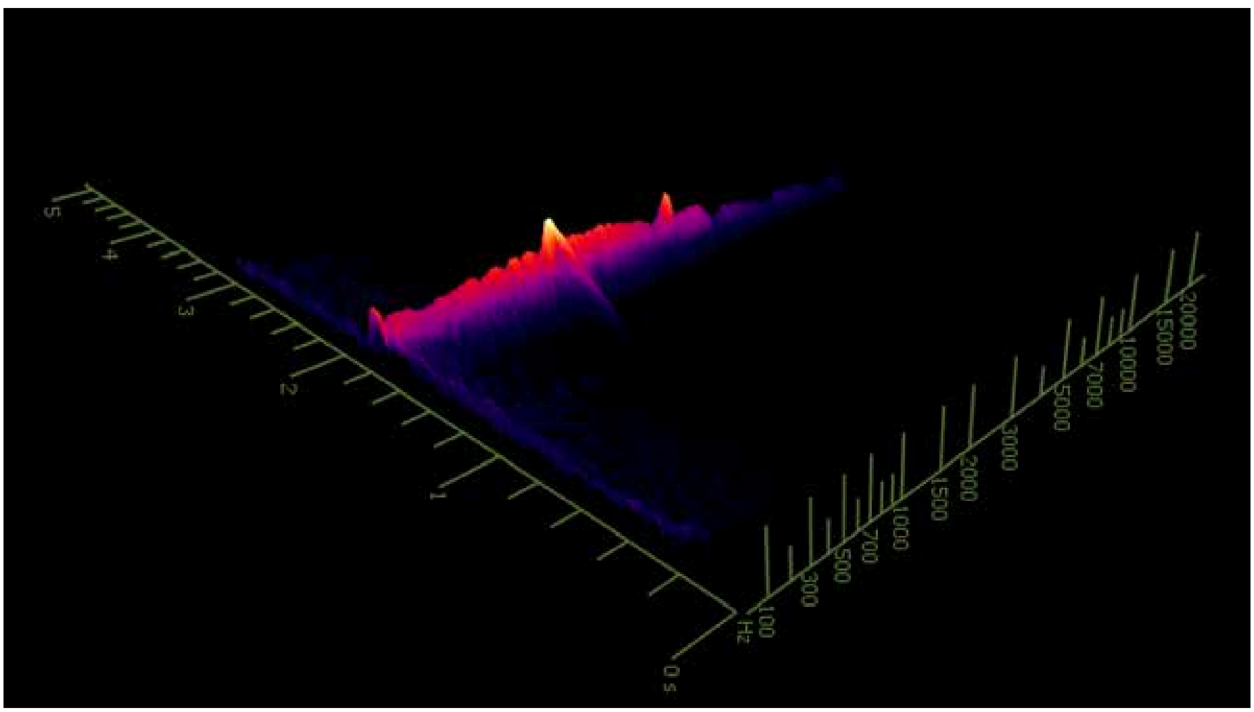

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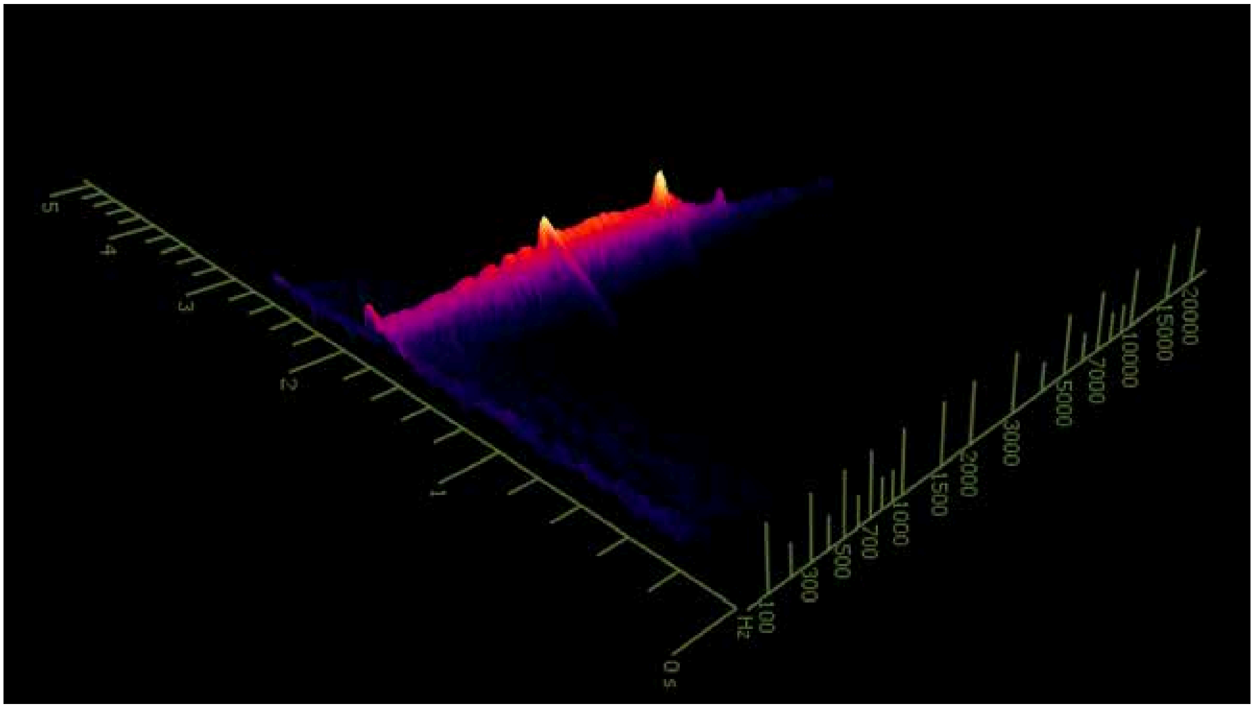
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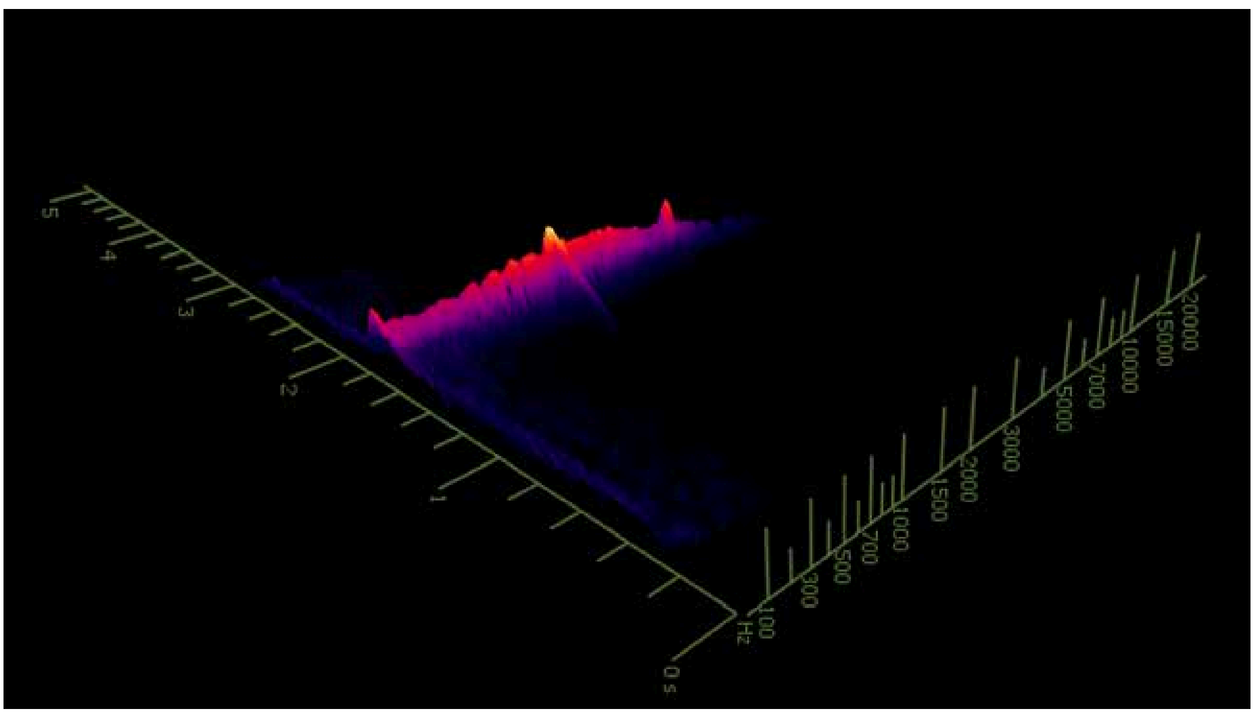
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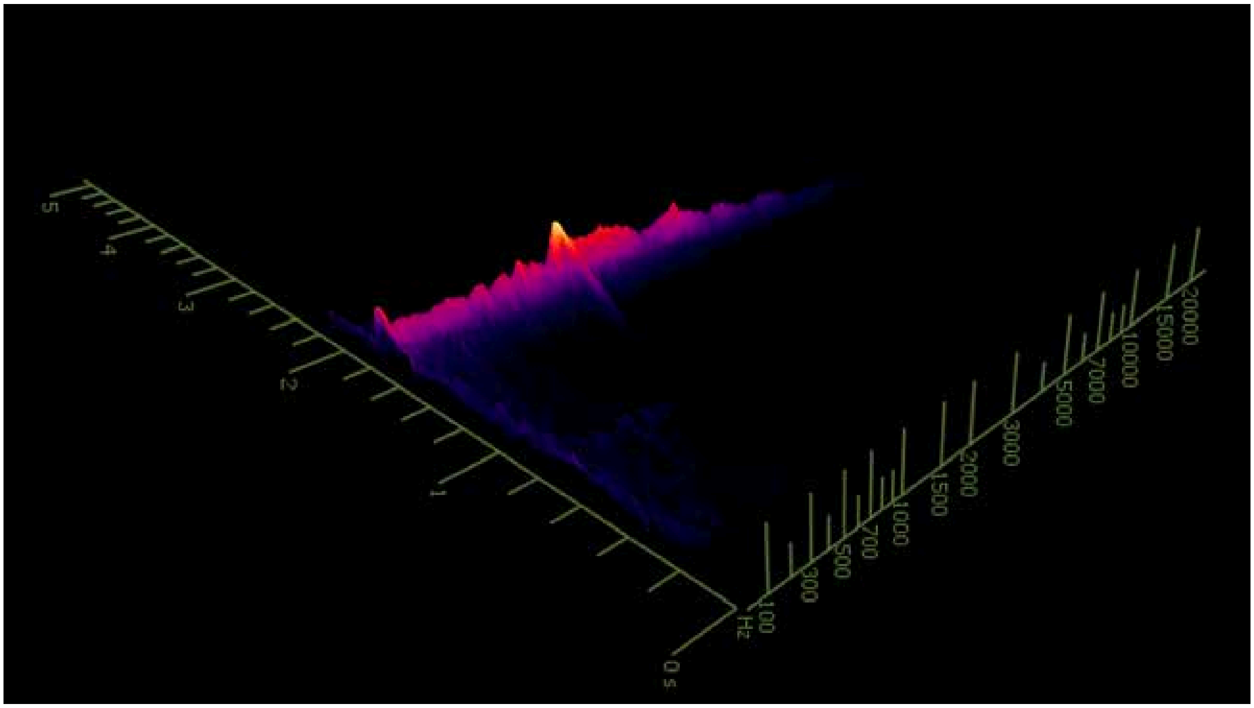
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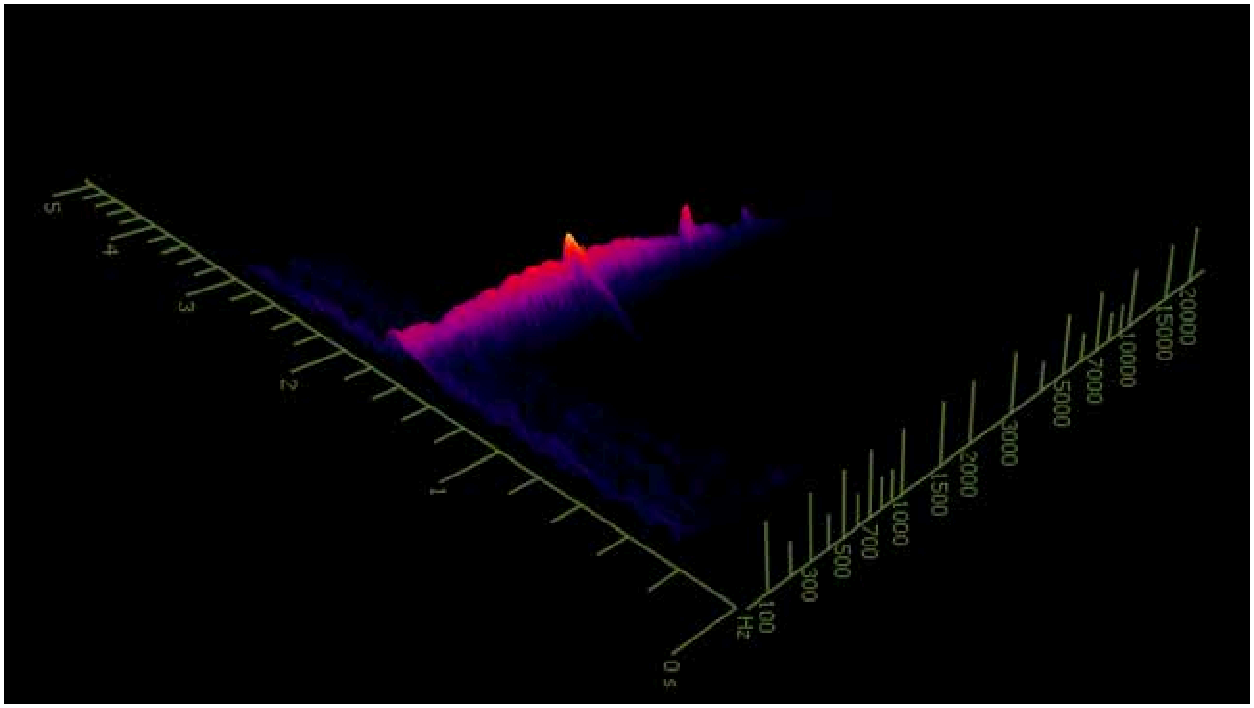
Slow Stroke, Node



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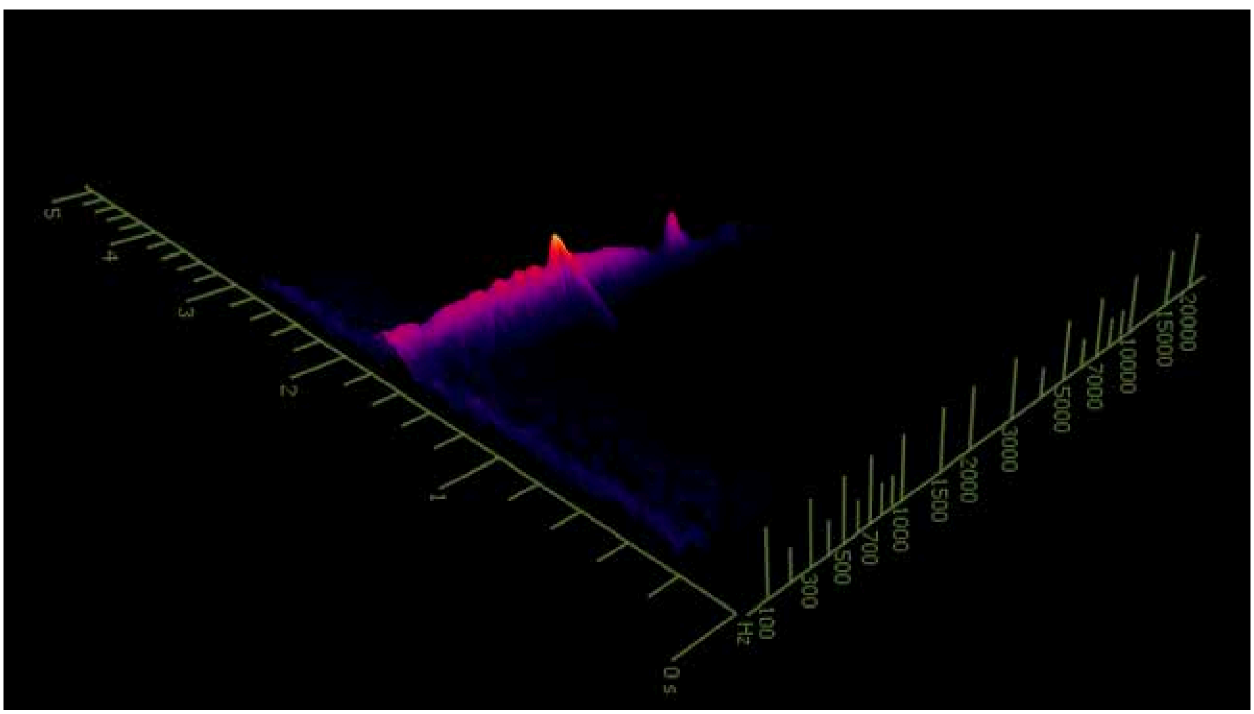

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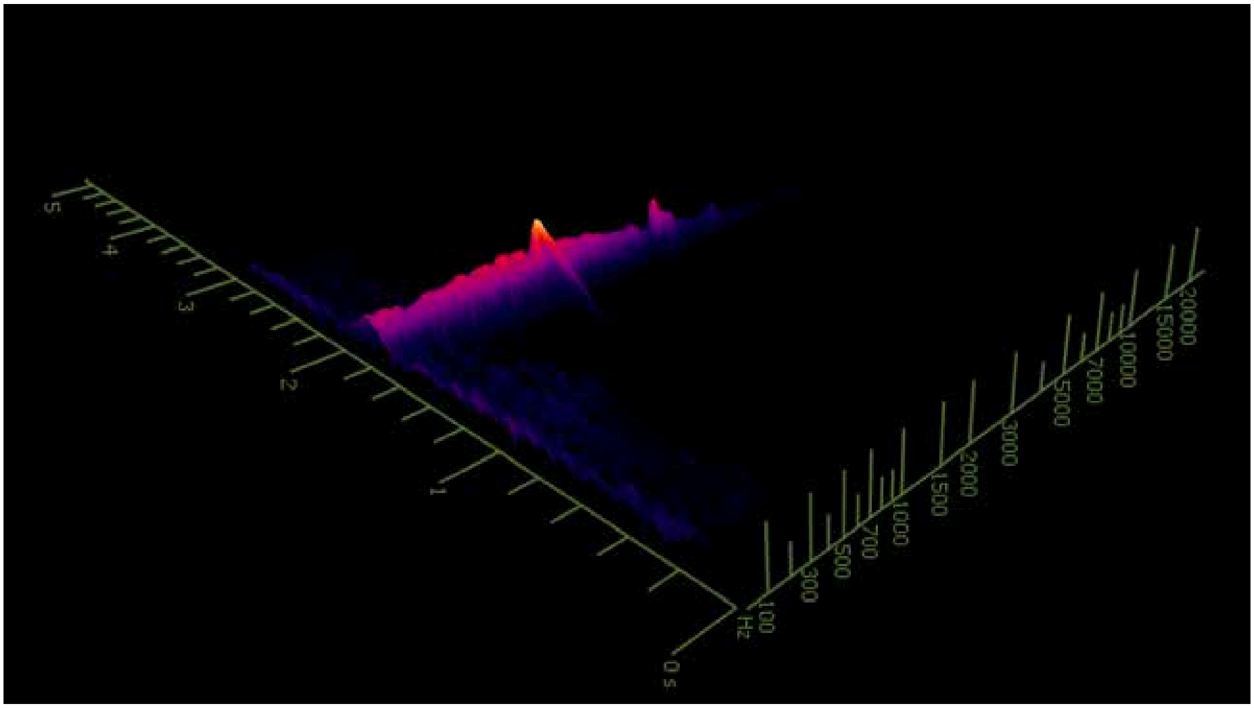

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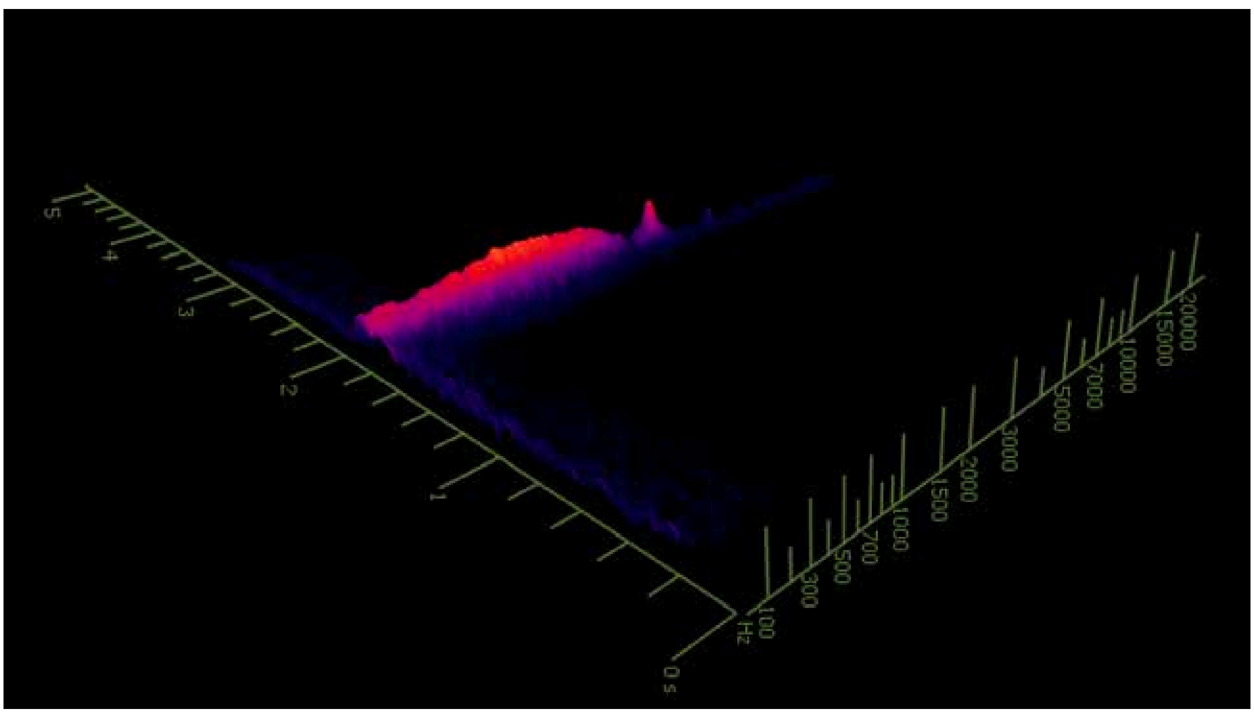

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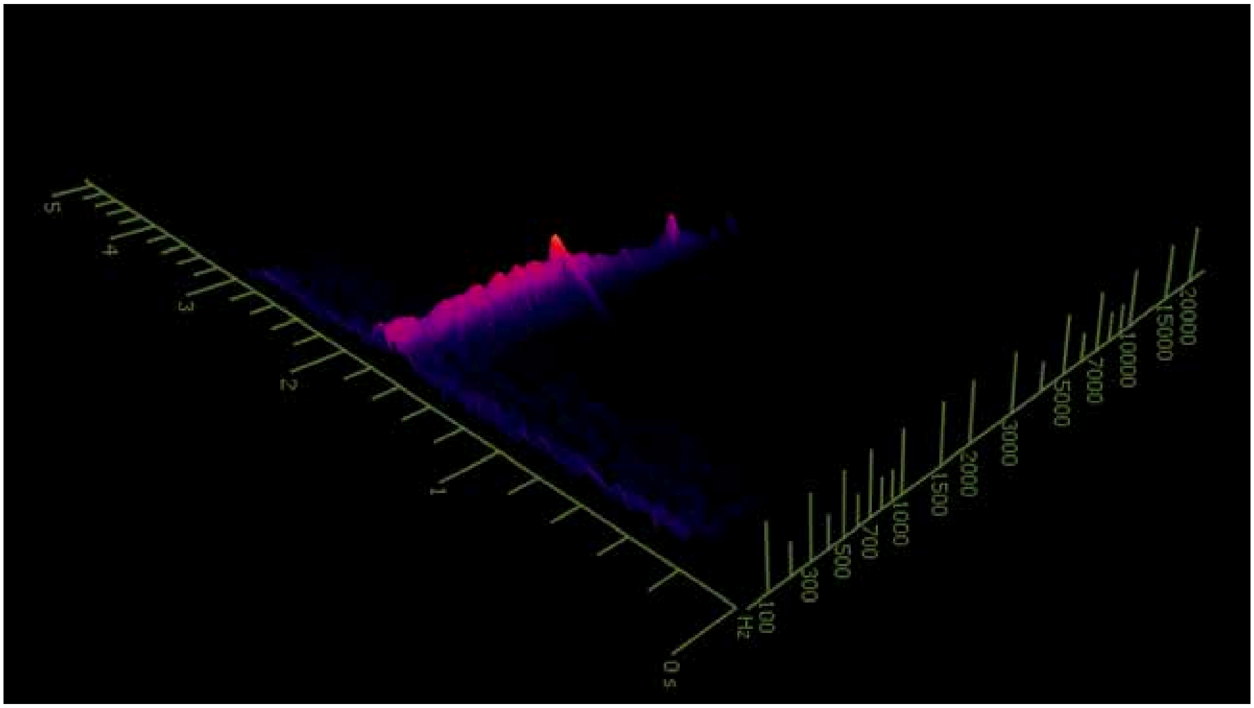
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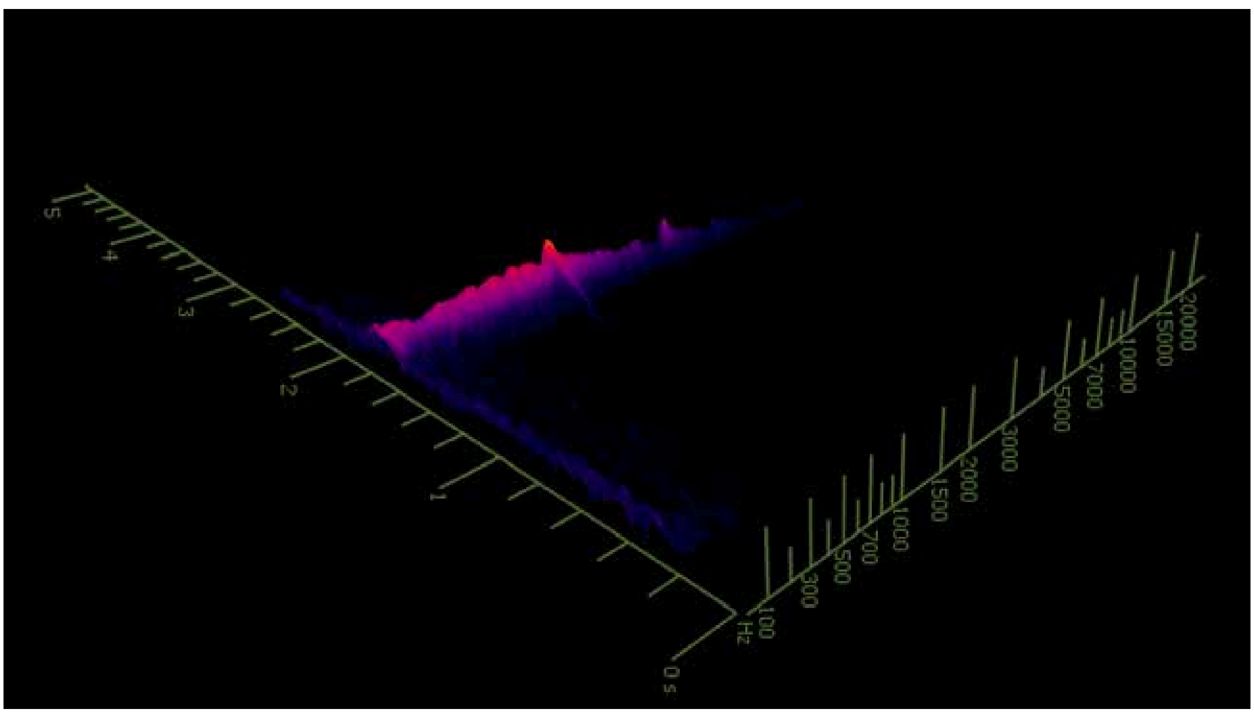
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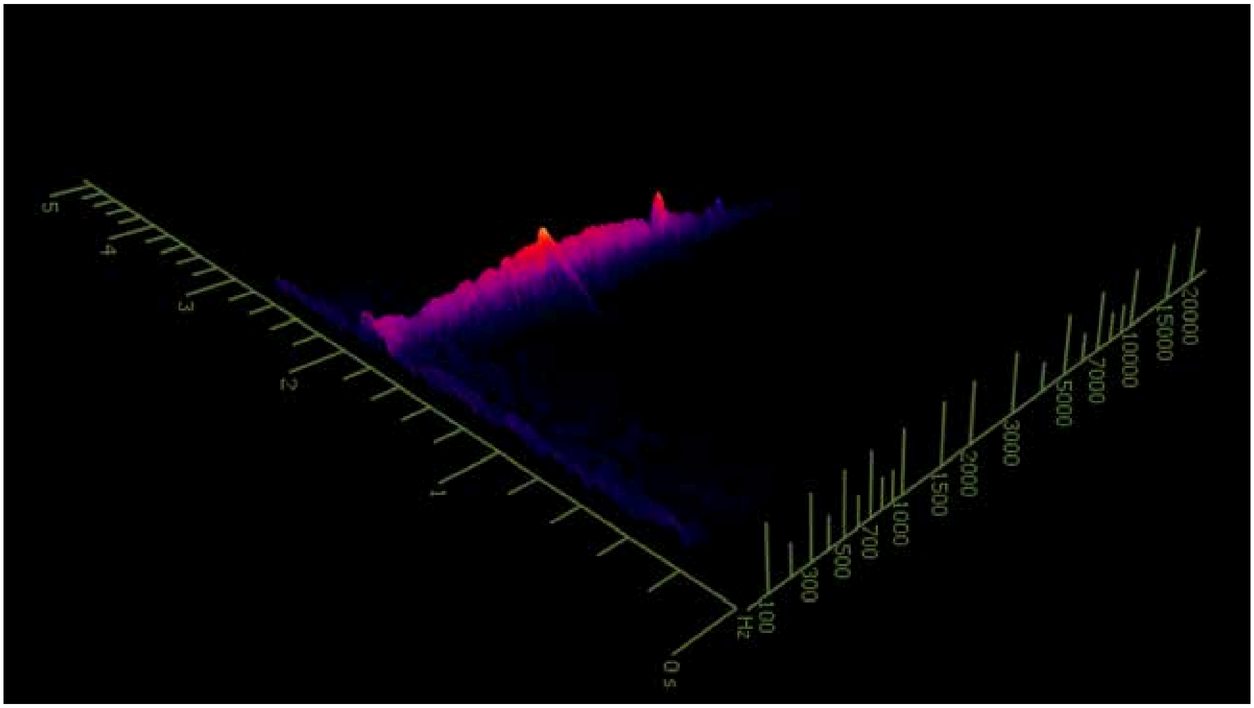

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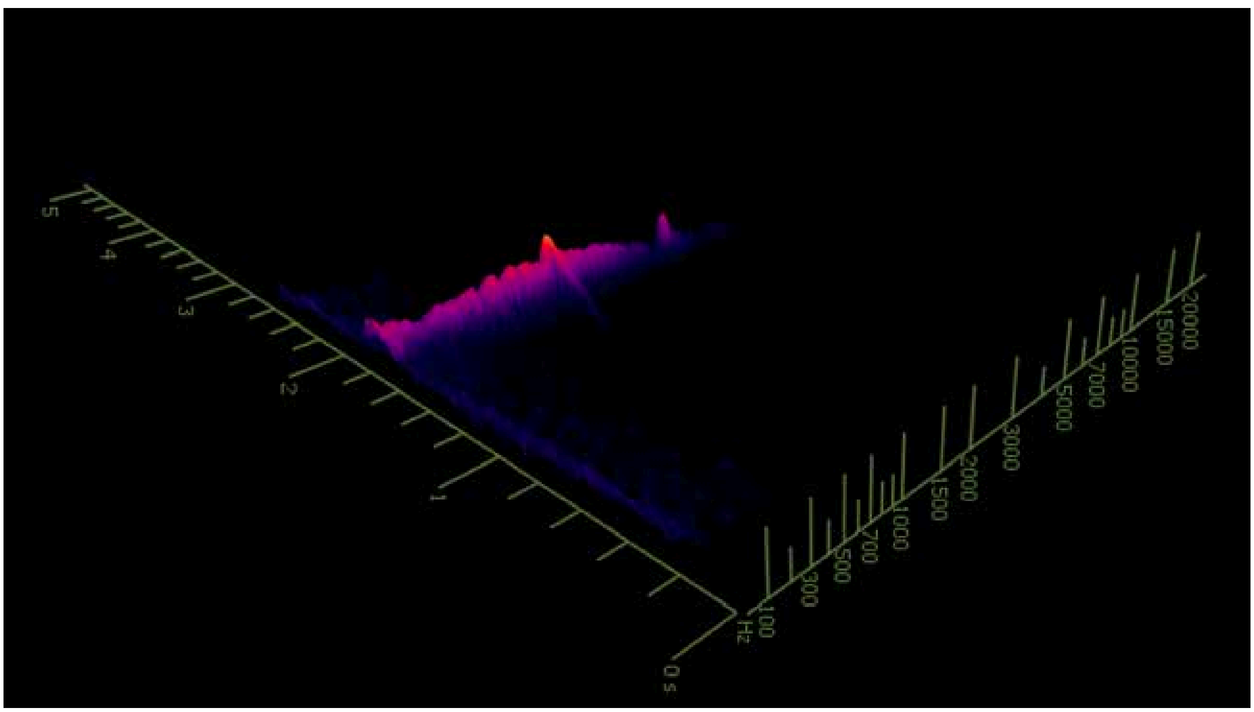

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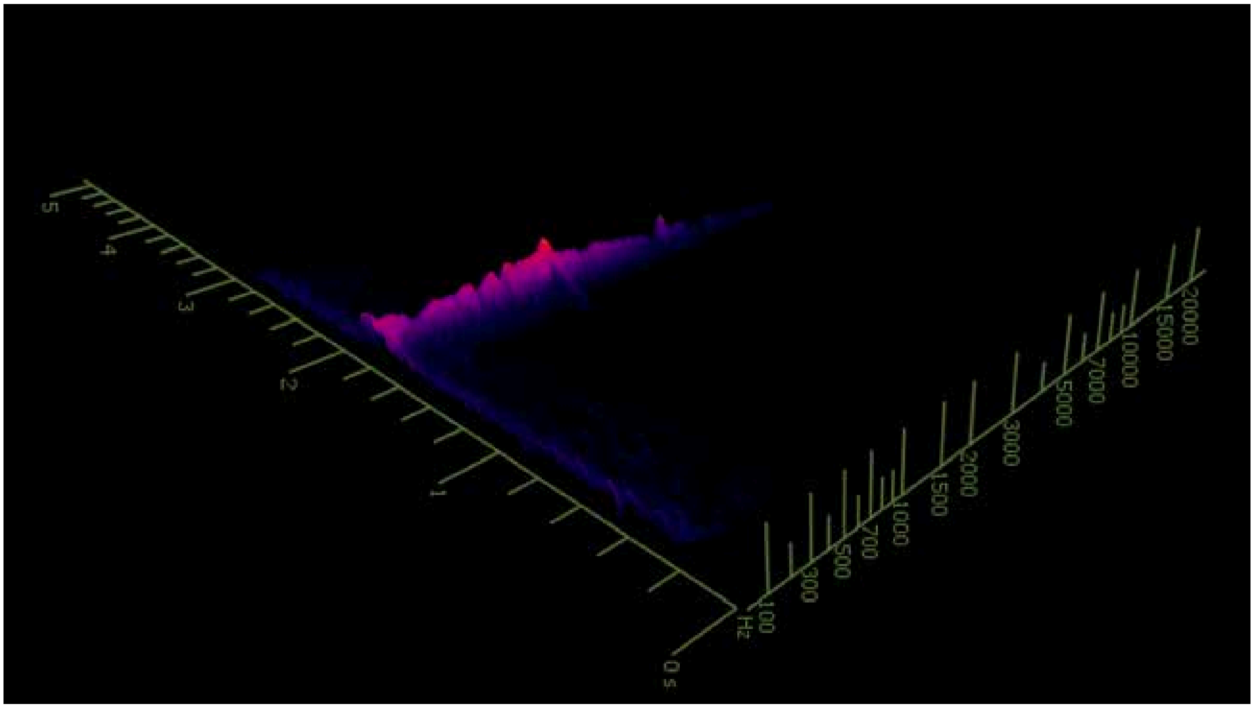
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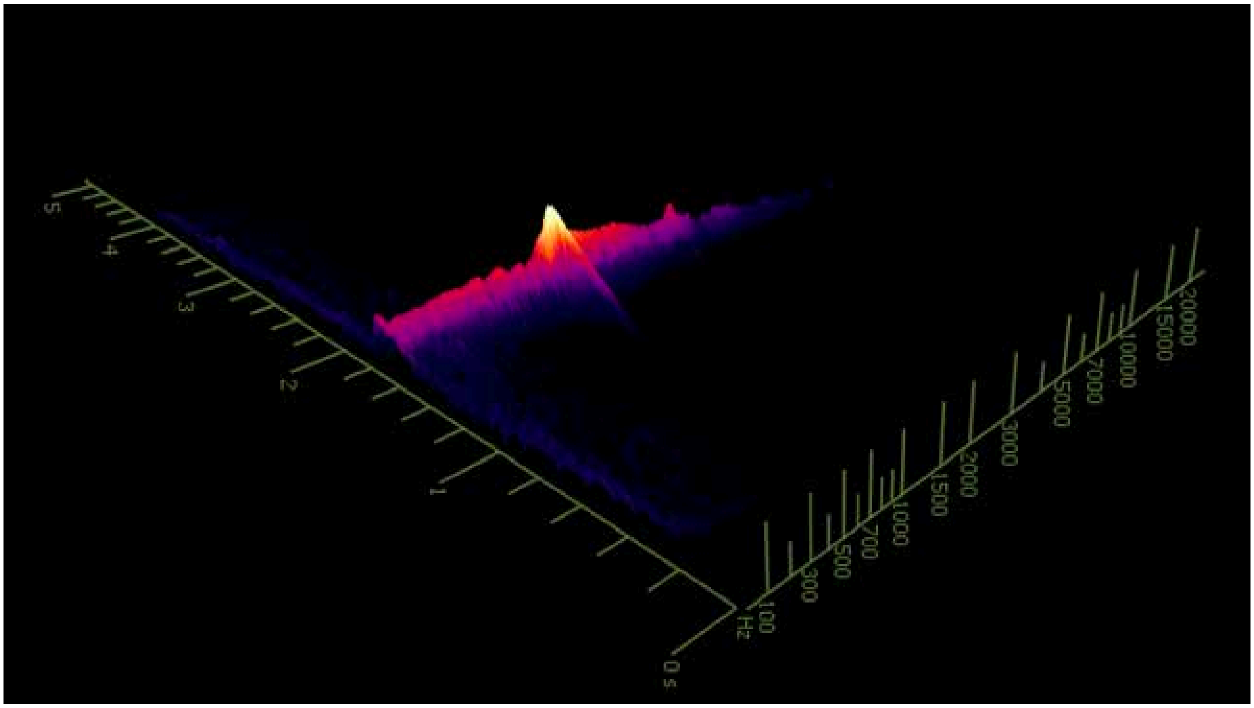
Fast Stroke, Just Off-Center



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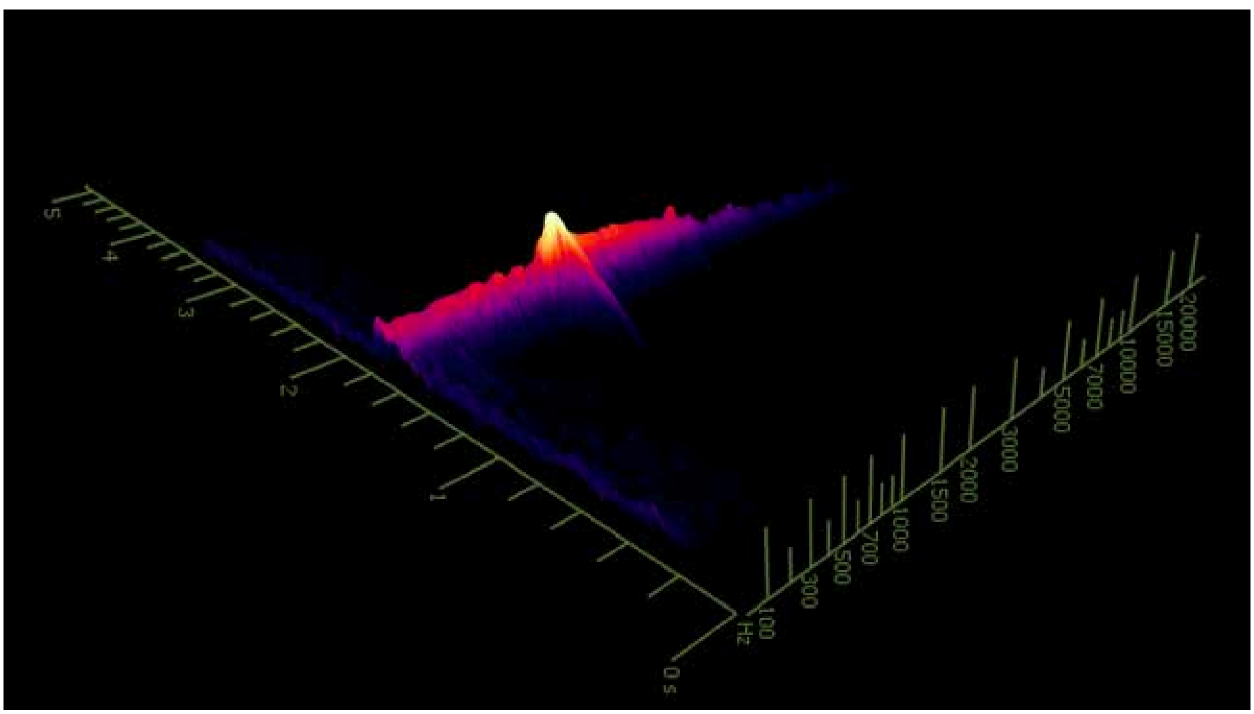

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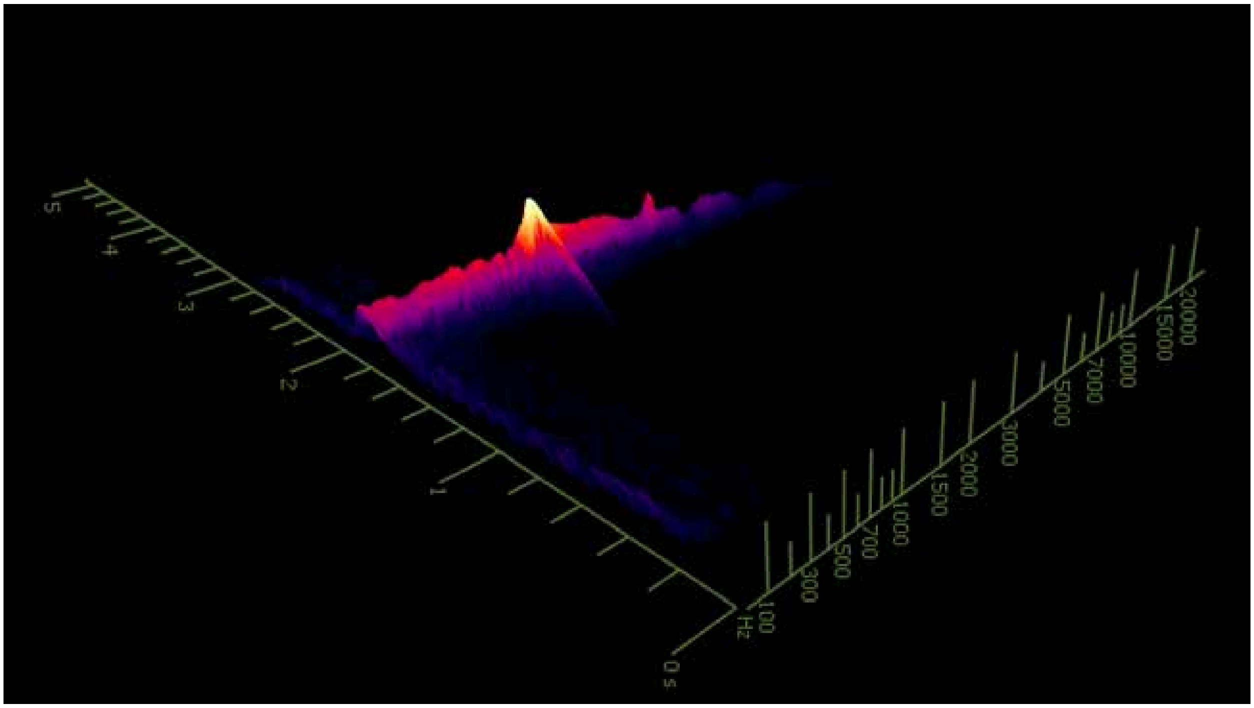

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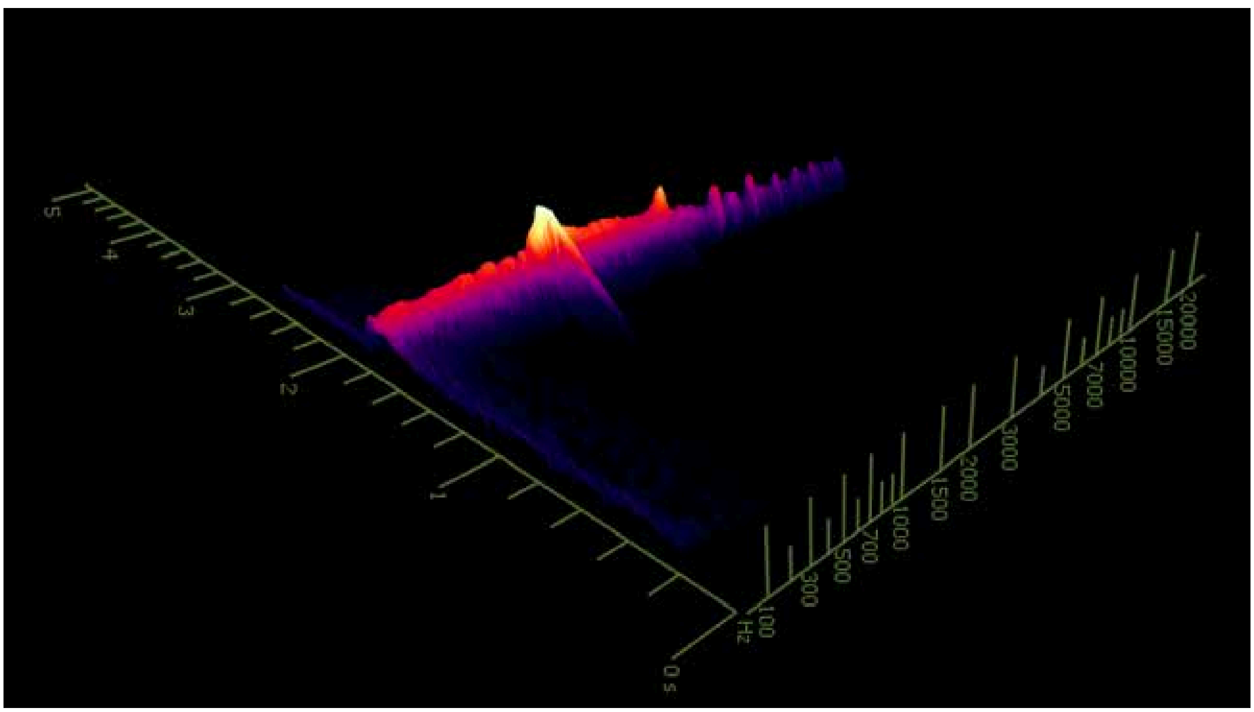

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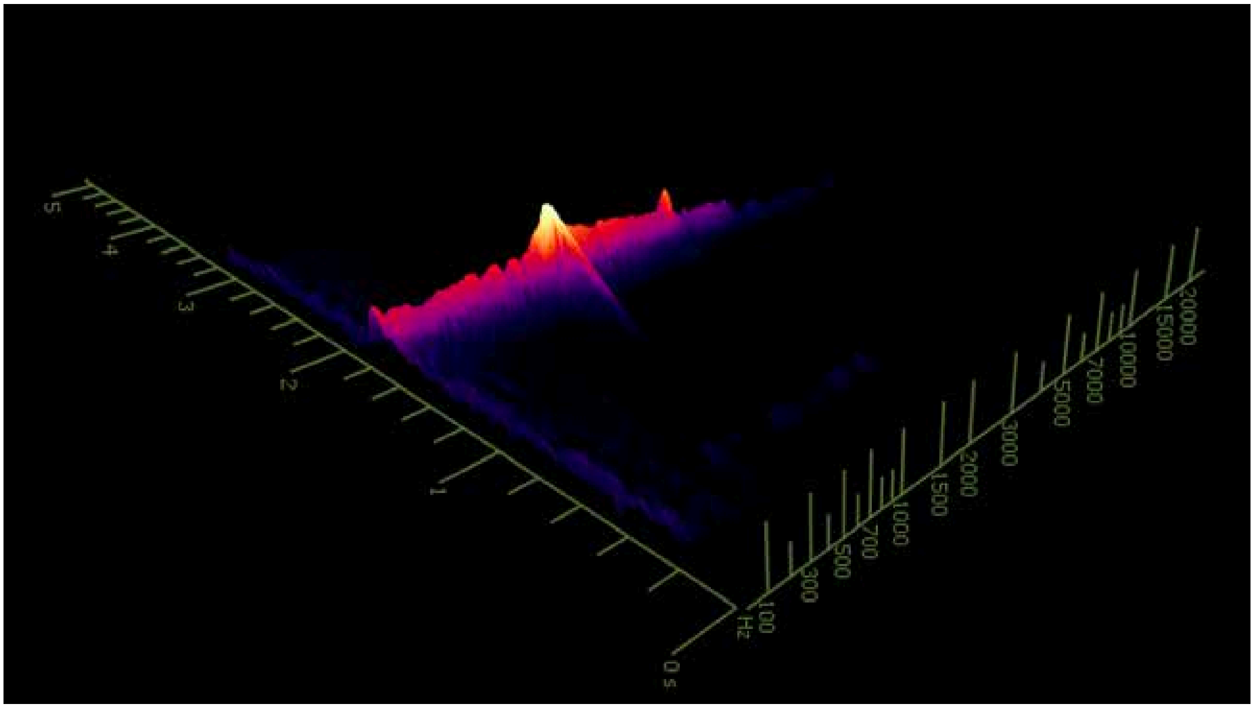
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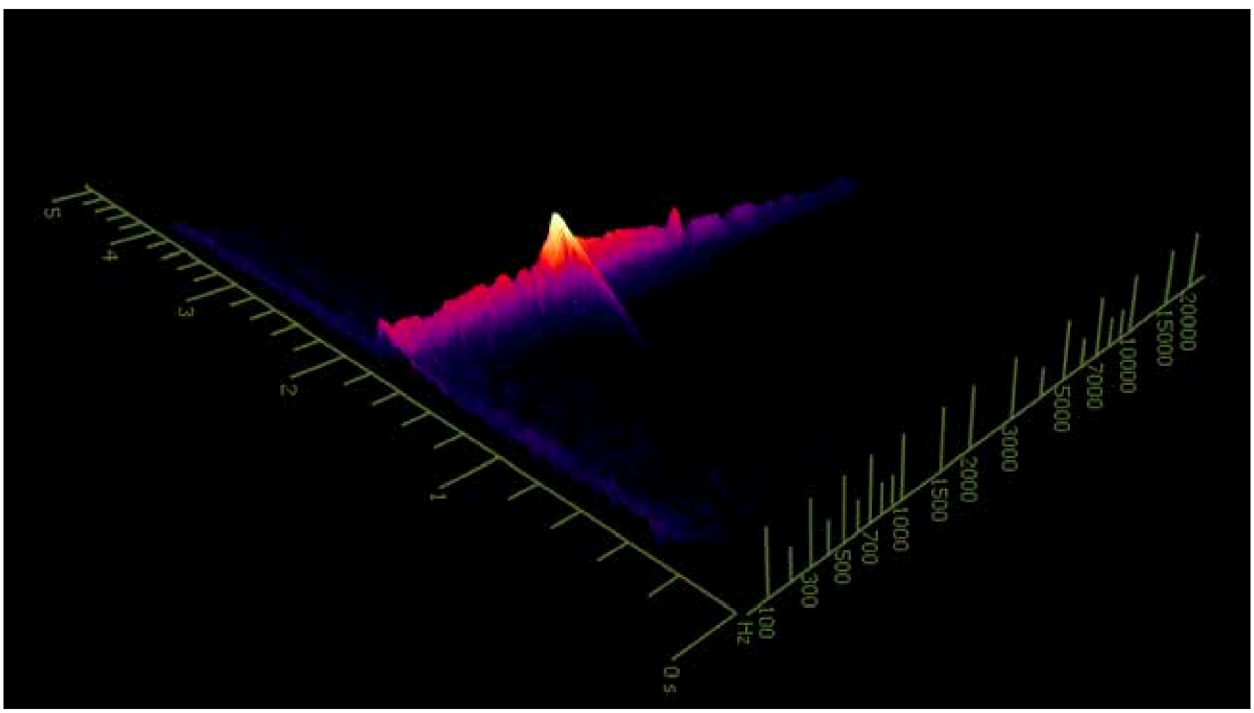
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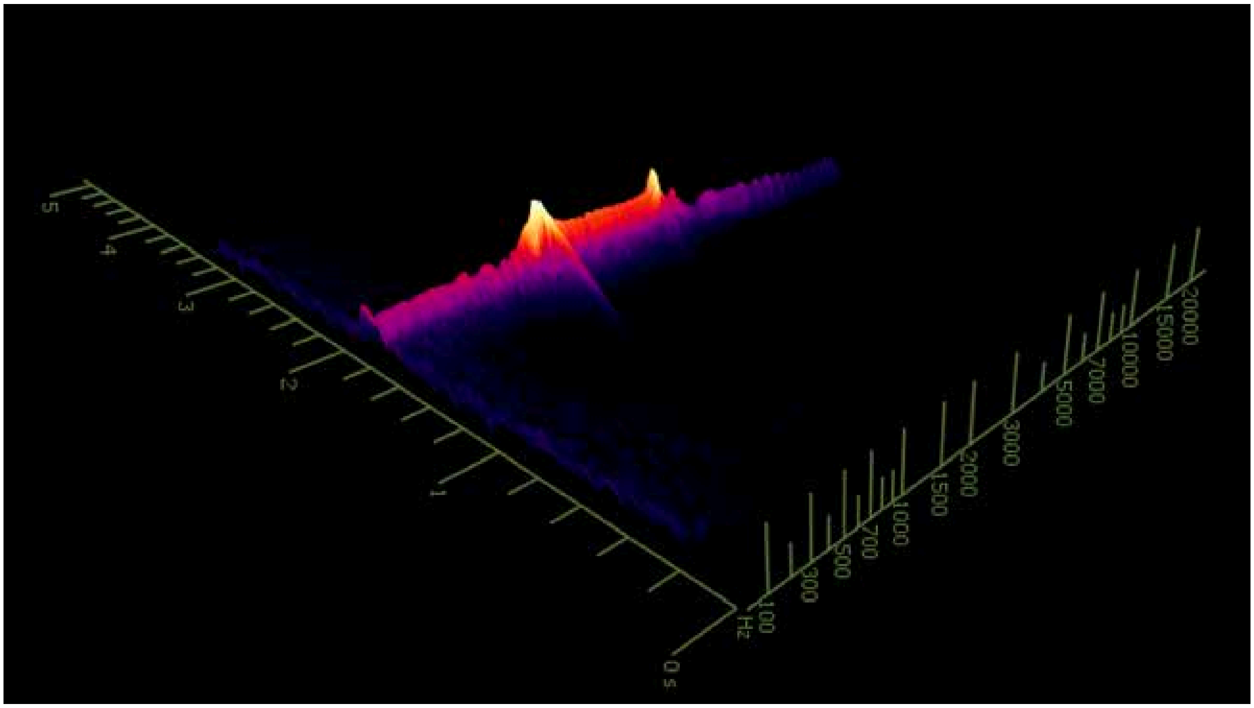

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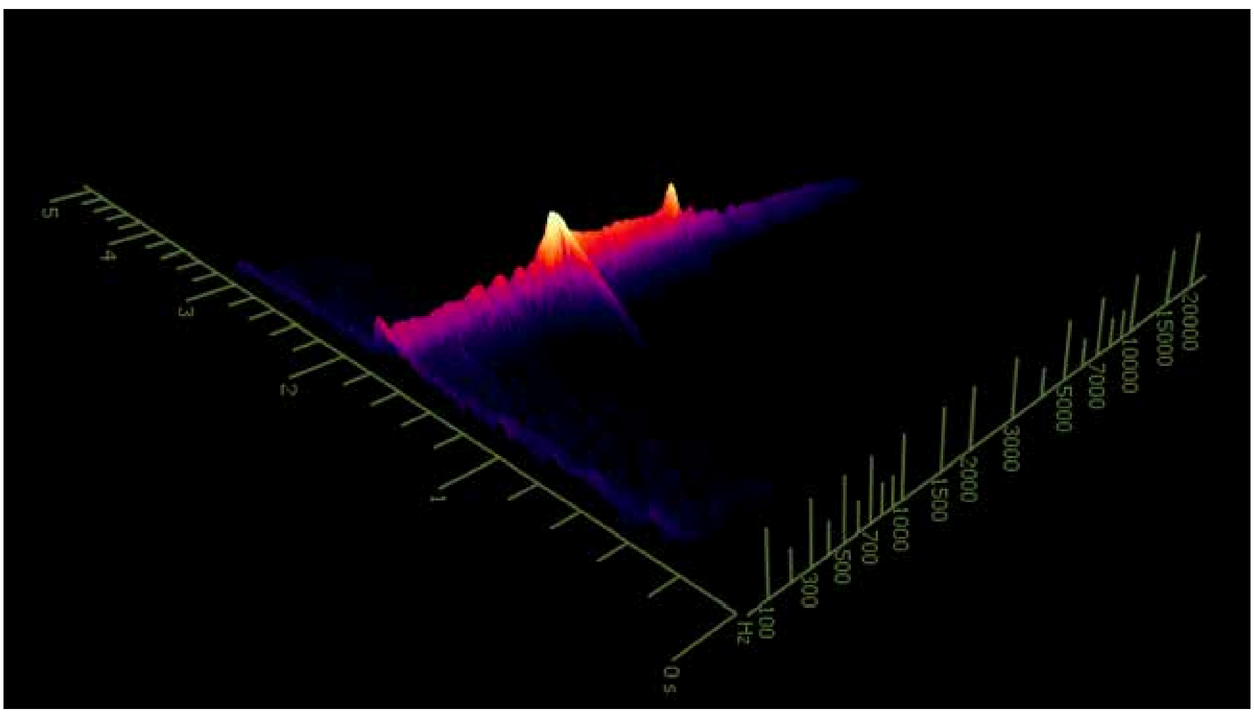

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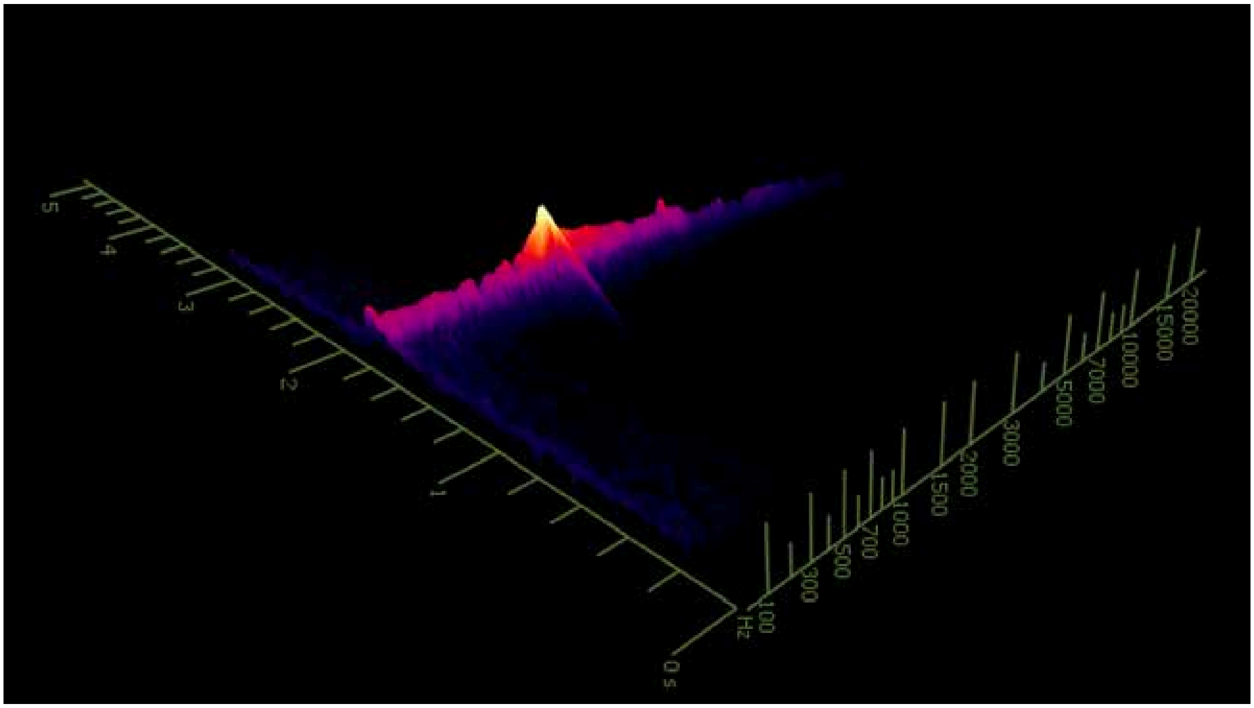

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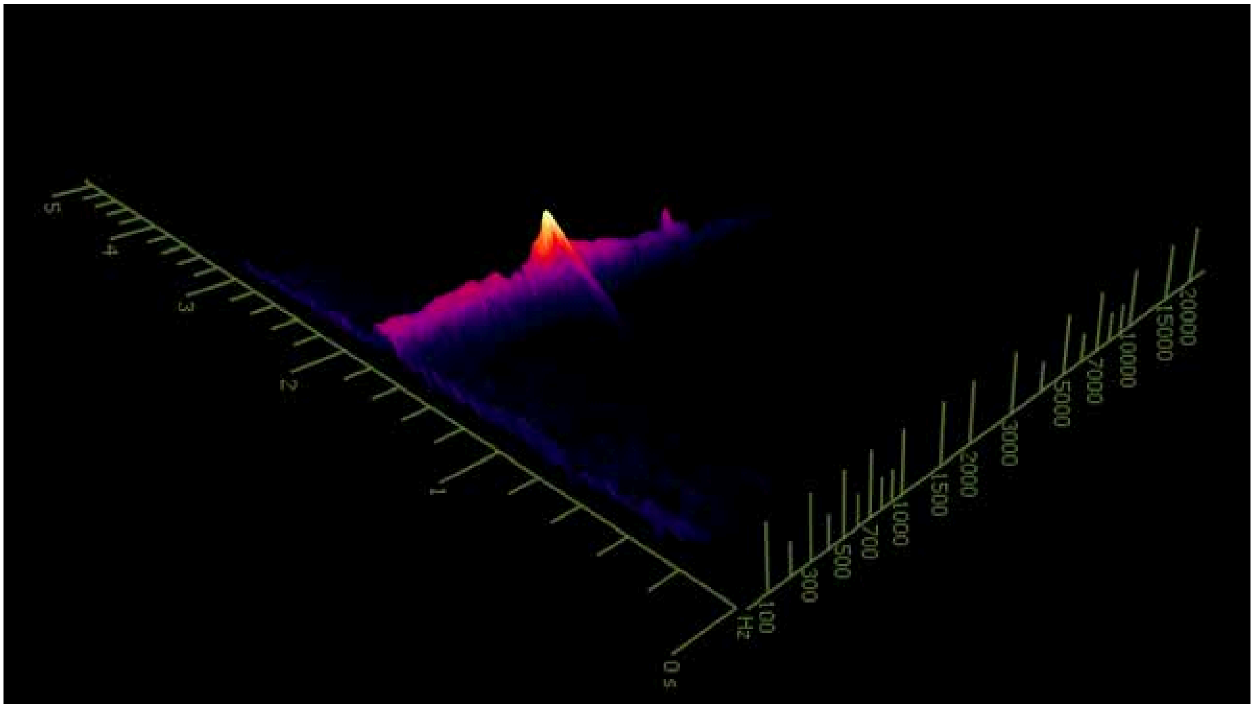
Slow Stroke, Just Off-Center



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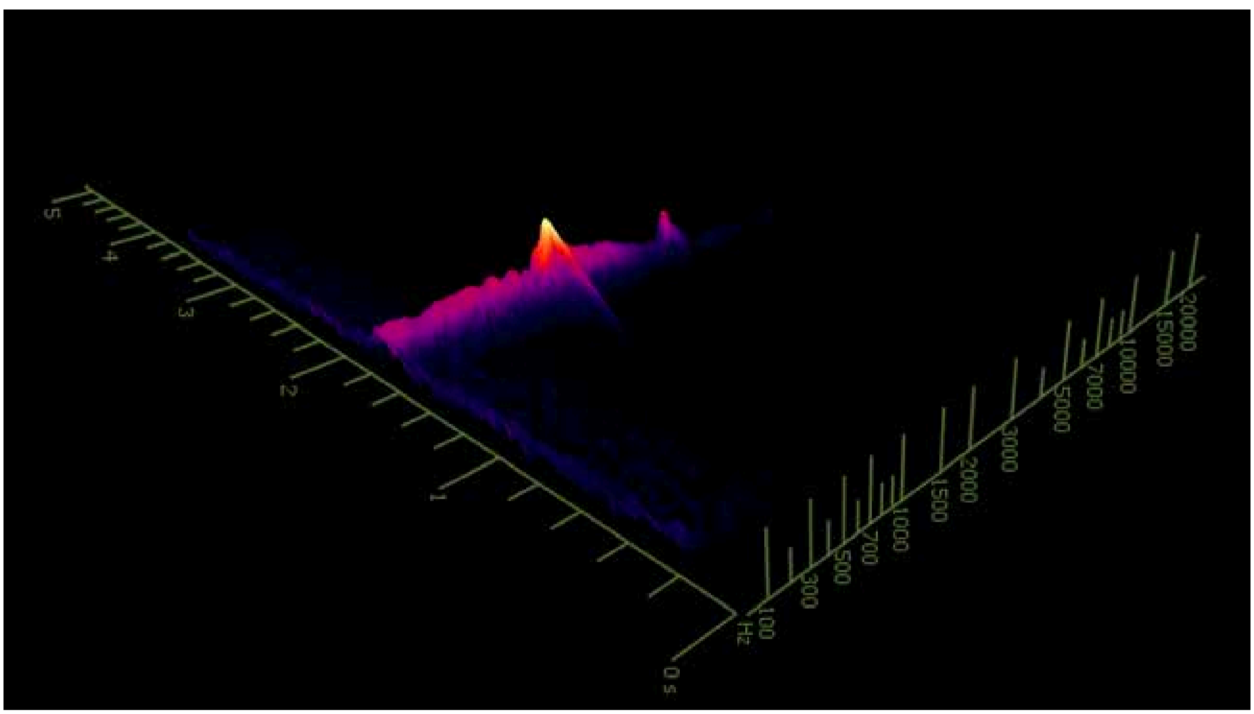

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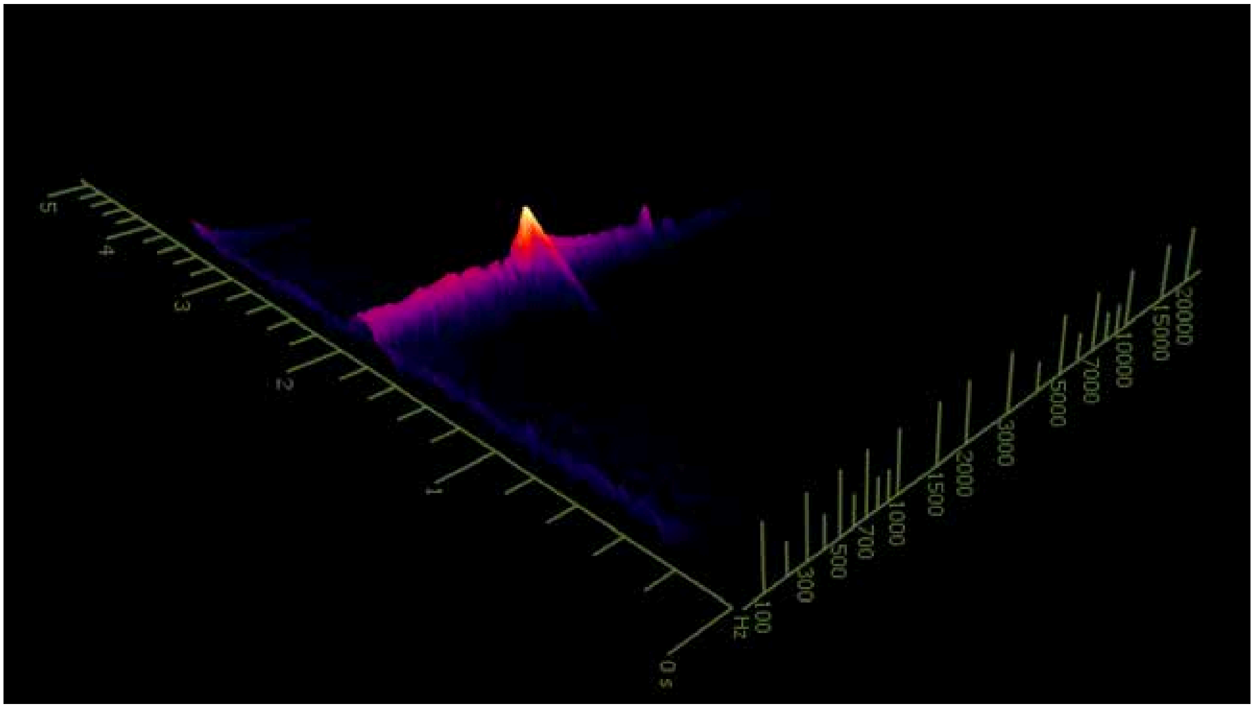

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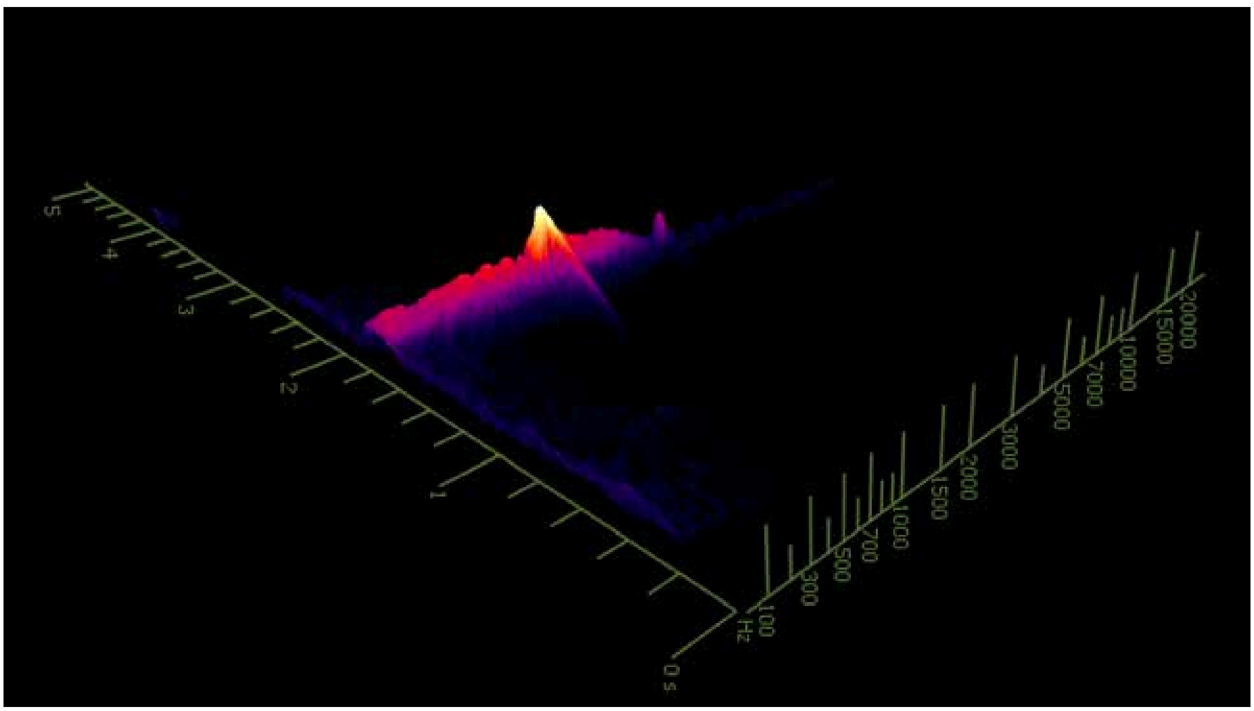

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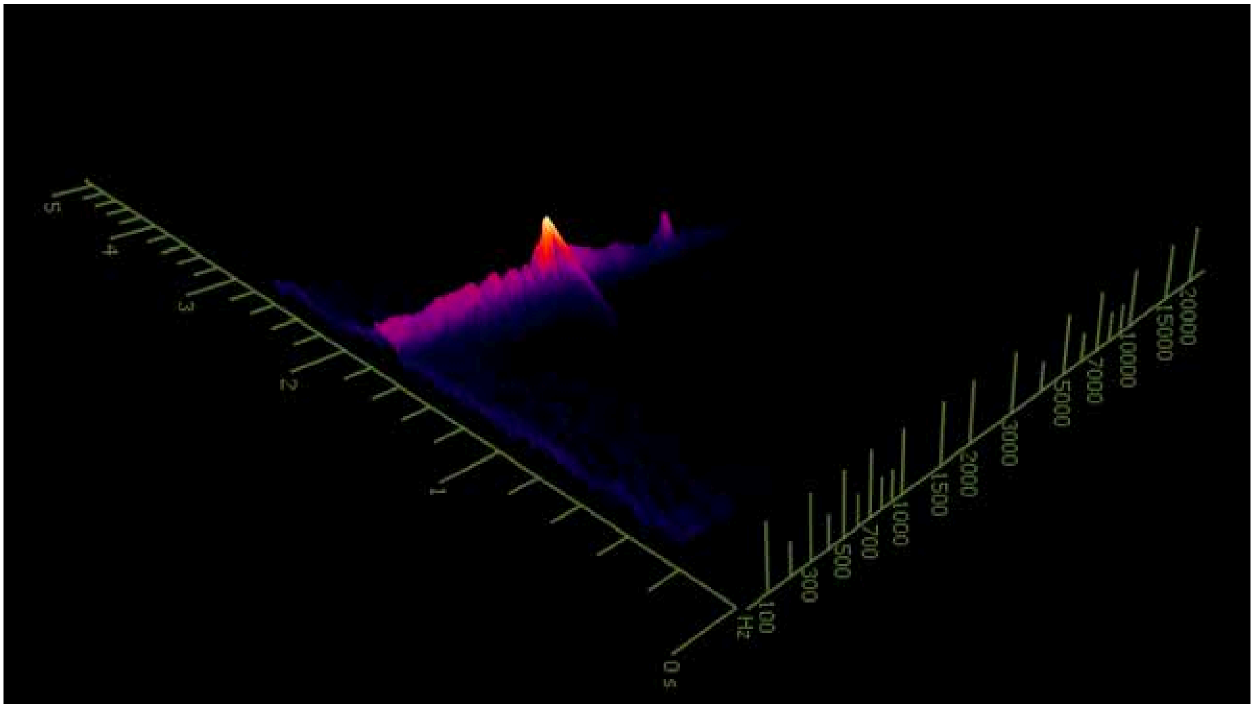
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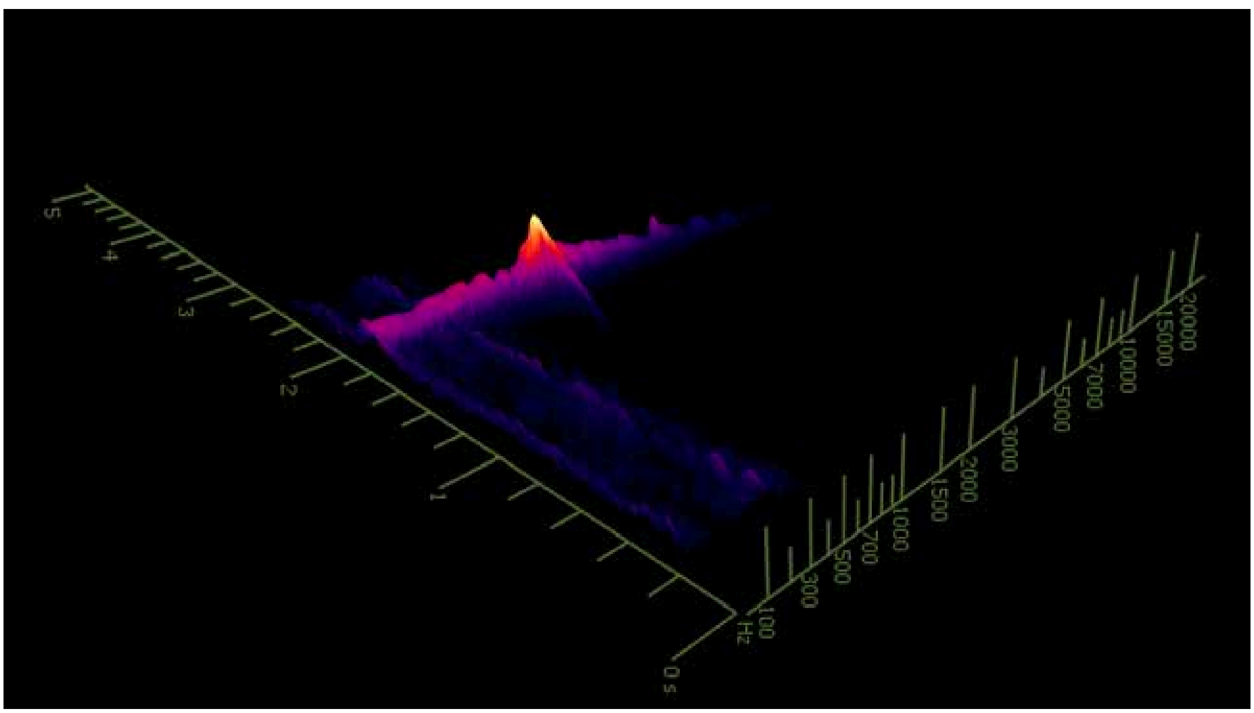
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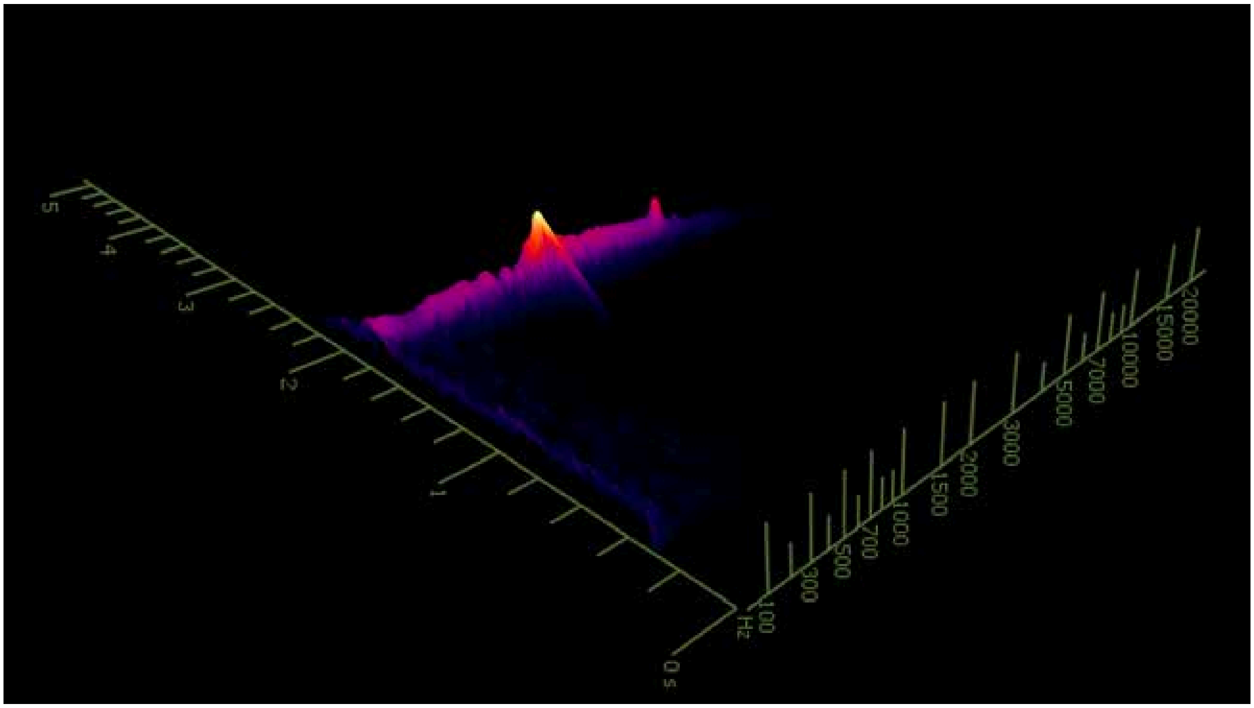
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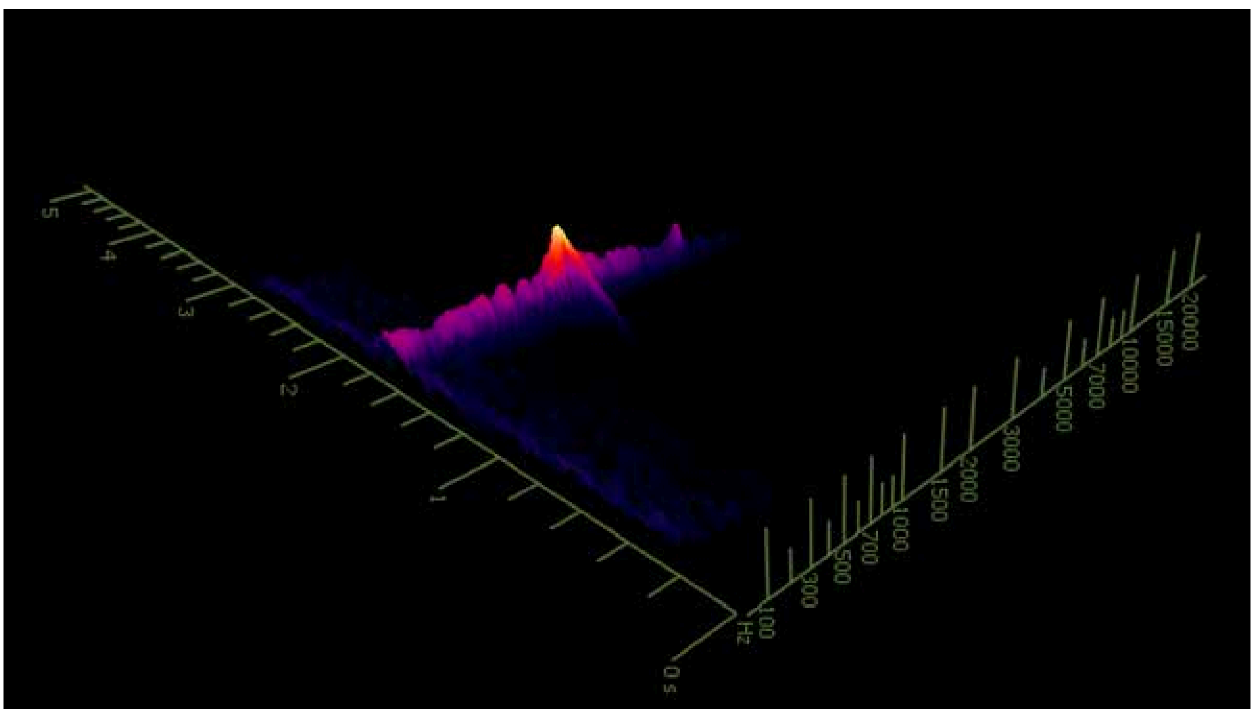
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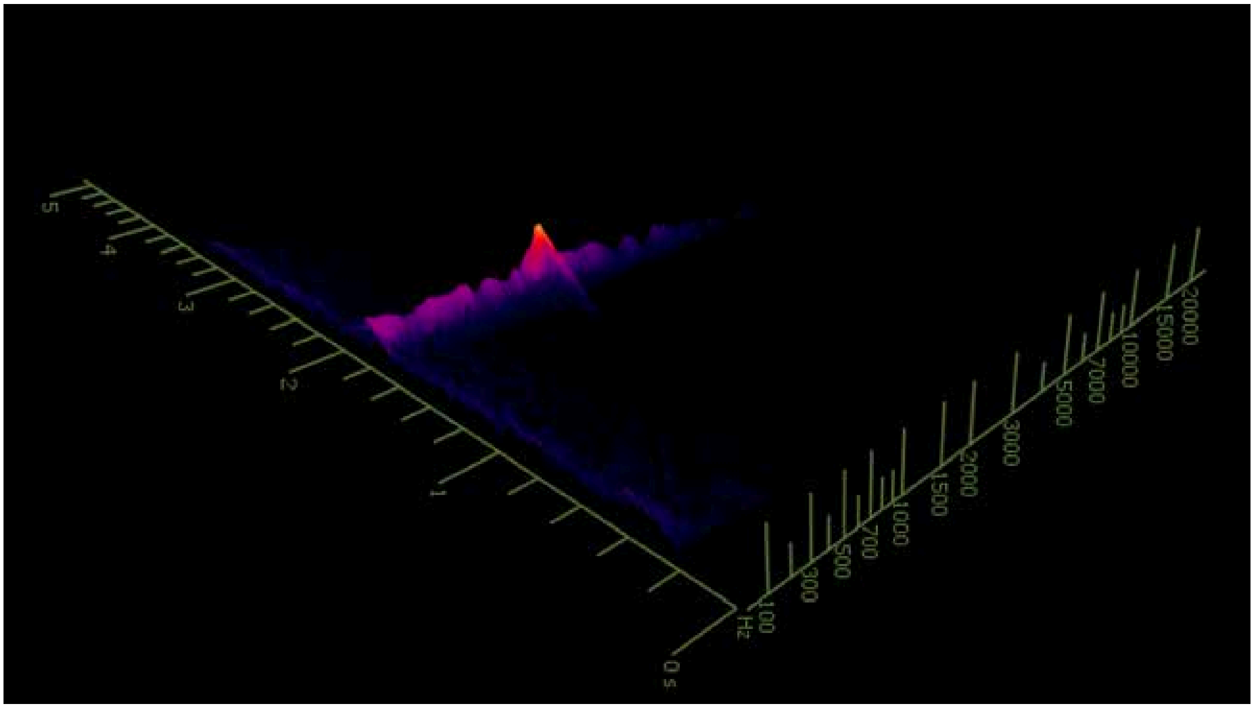
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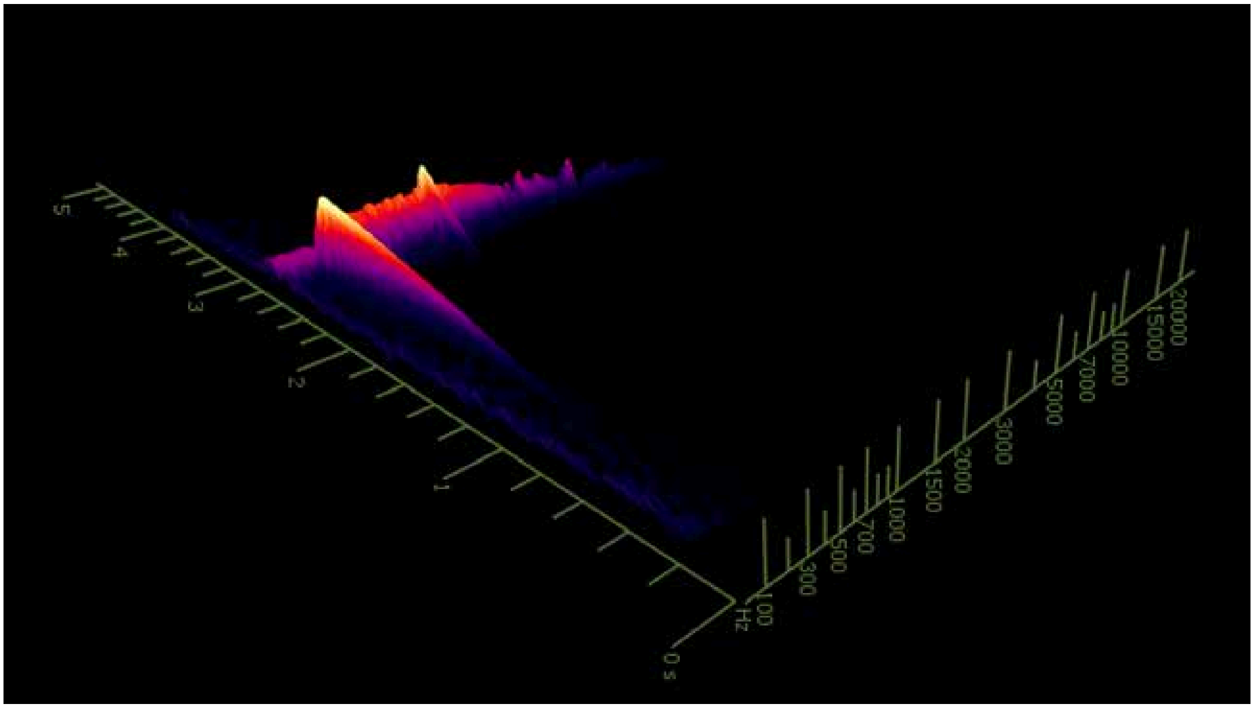
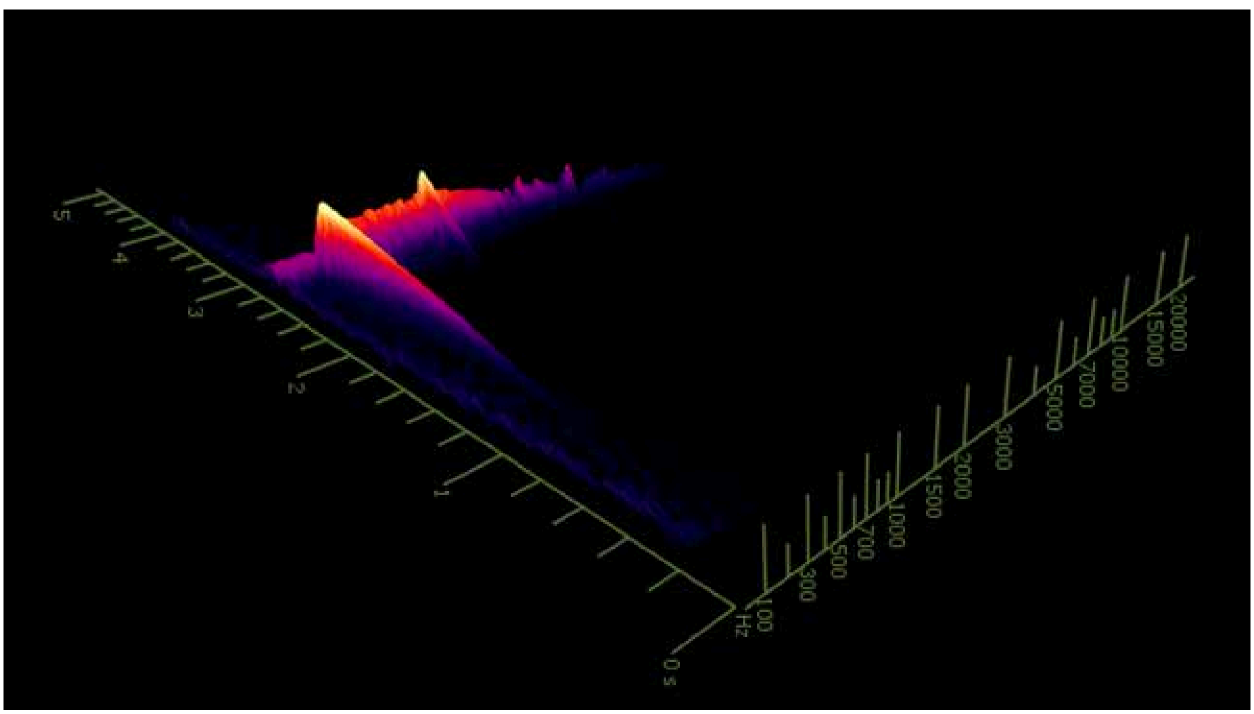
APPENDIX D

3D SPECTROGRAM IMAGES, STROKE DIRECTION

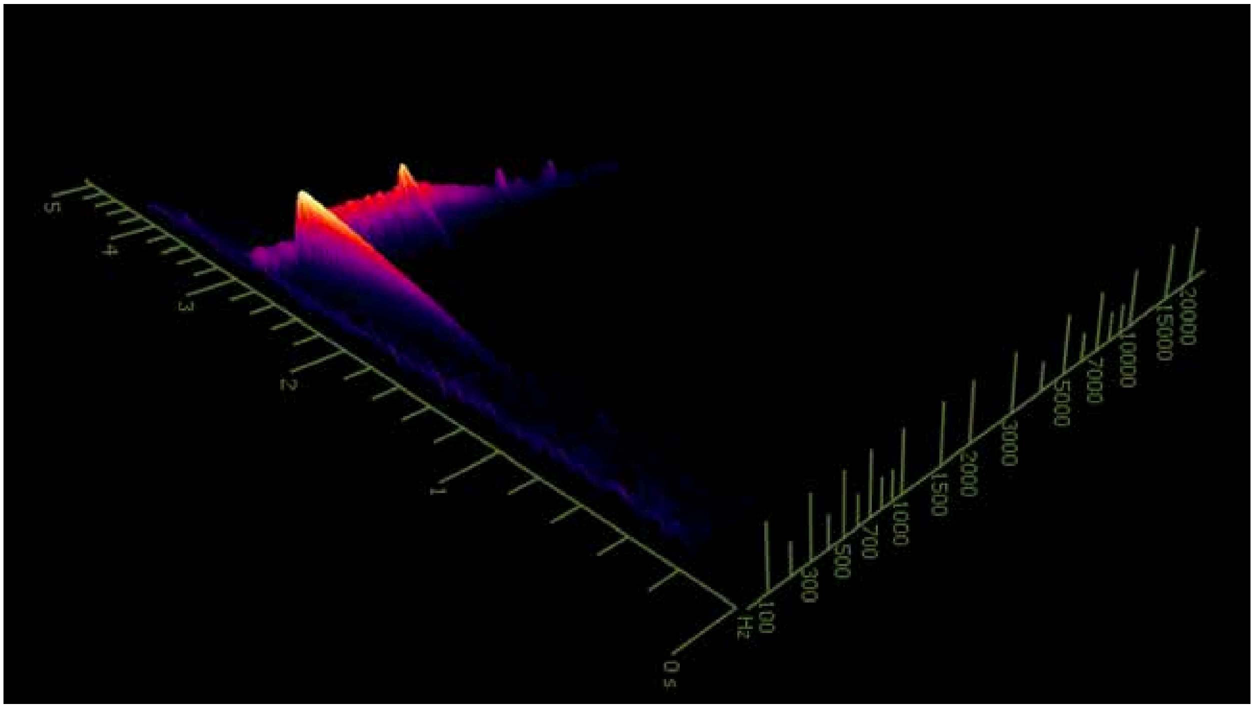
Stroke Direction, Just Off Center



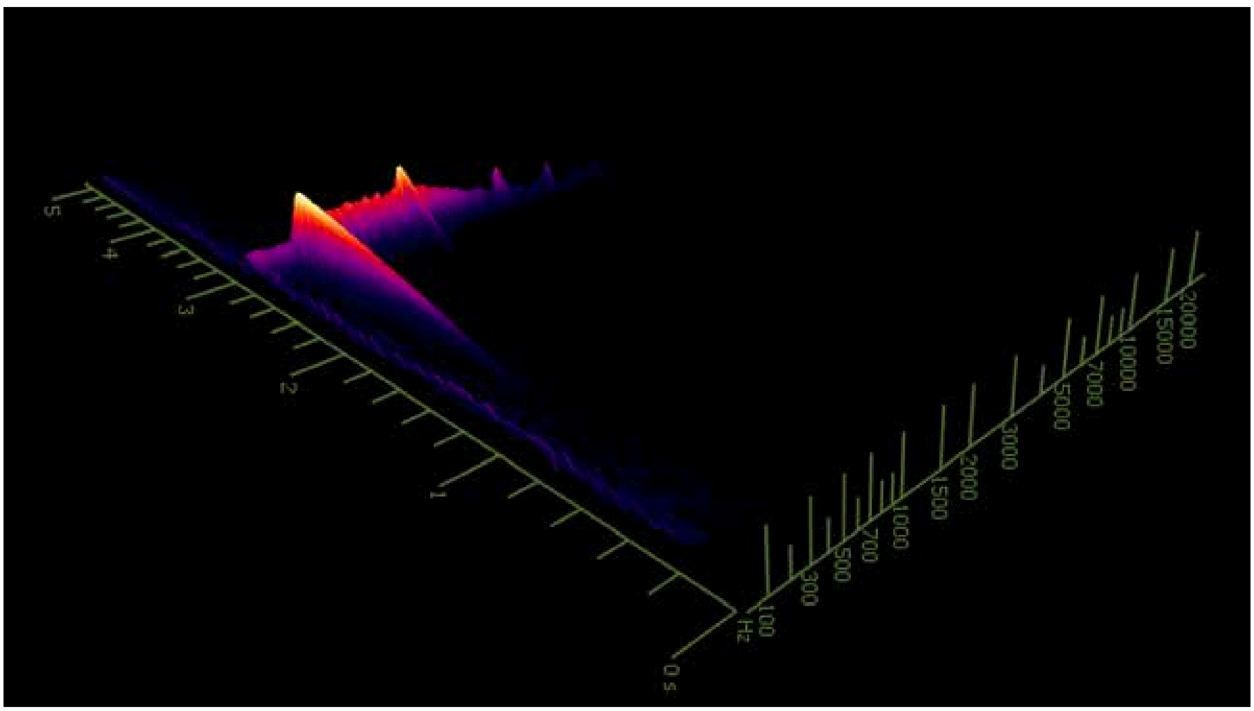
Fast Down Stroke



Fast Up Stroke



Slow Down Stroke



Slow Up Stroke

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