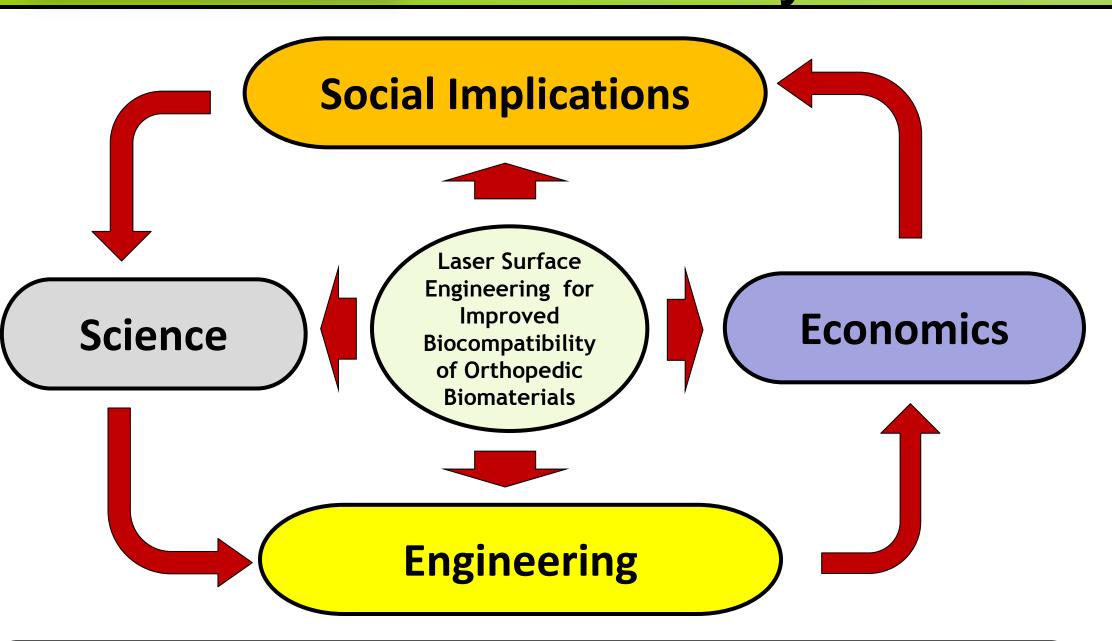


# Laser Surface Engineering for Improved **Biocompatibility of Orthopedic Biomaterials**



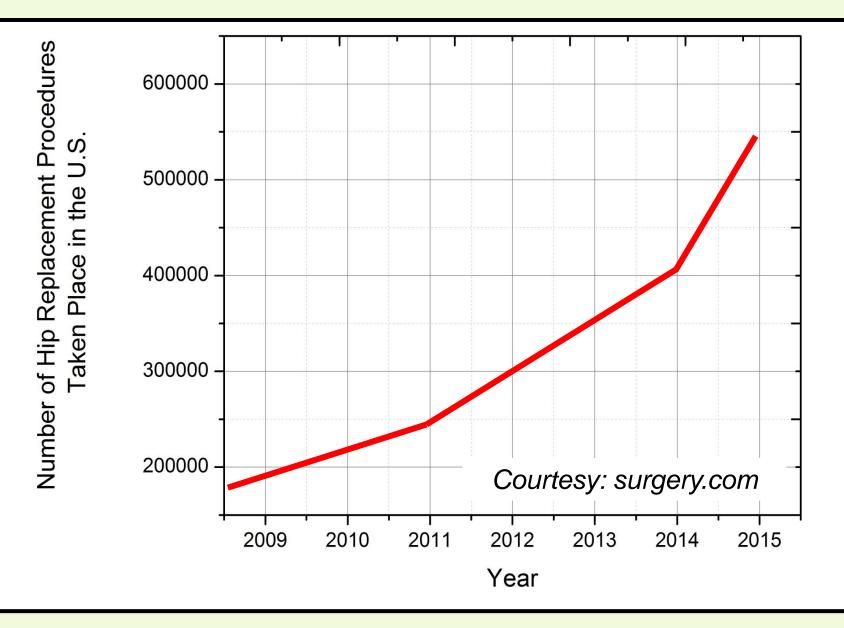


• The current research appropriately adapts an approach that integrates social implications, basic science, engineering, and economical impact for improved and increased cost effective bio-implants.

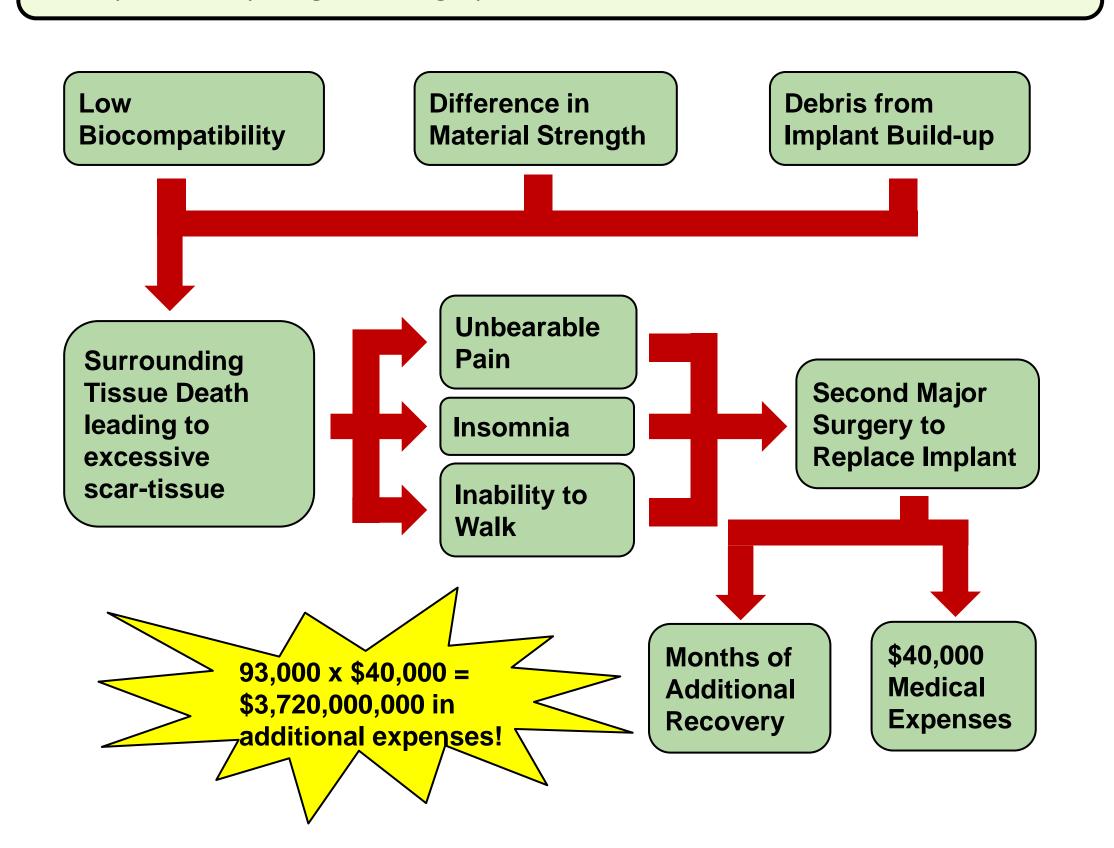
# Social Implications



- Even now, 90% of humans above the age of 40 show signs of femoral bone degeneration resulting in a drastically increased number of replacement procedures being performed.
- Patients around the world are now requiring implants that can last longer and provide less discomfort, while decreasing the cost.



• There is an increased need of a longer lasting and more cost effective bioimplants for younger demographic



### **Basic Science**

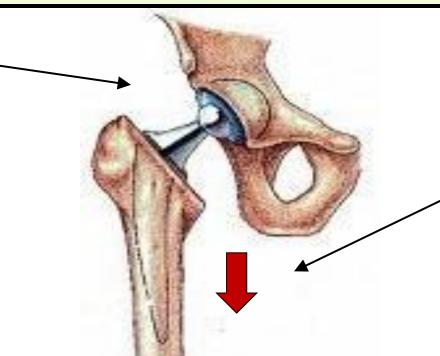
#### Titanium as a Bioimplant Material

In order to create a more efficient bio-implant, a material must be modified so that it can be as similar to body environment conditions as possible. The implant must be interpreted by the body as just another piece of bone. Titanium is already being widely studied as base bio-material. Titanium has a modulus, or strength, similar to that of human bone allowing internal body conditions to stay as constant as possible after implantation.

If the implant has a much higher modulus than the bone, as it does in present day implants...

**Scar Tissue** 

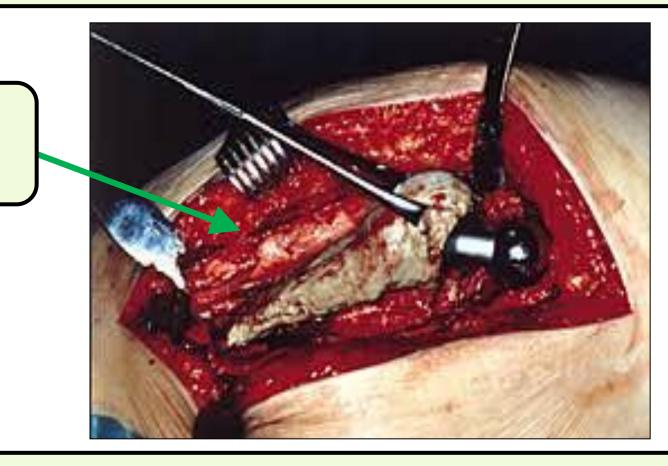
Build-up



just as muscle dies from lack of use, so will the bone, causing it to recede.

#### Lack of Chemical Compatibility

• What titanium makes up for in strength, it unfortunately lacks in biocompatibility due to a lack of suitable chemistry. In the image below, scar tissue can clearly be seen building up around the implant. This leads to a second surgery to replace the implant.

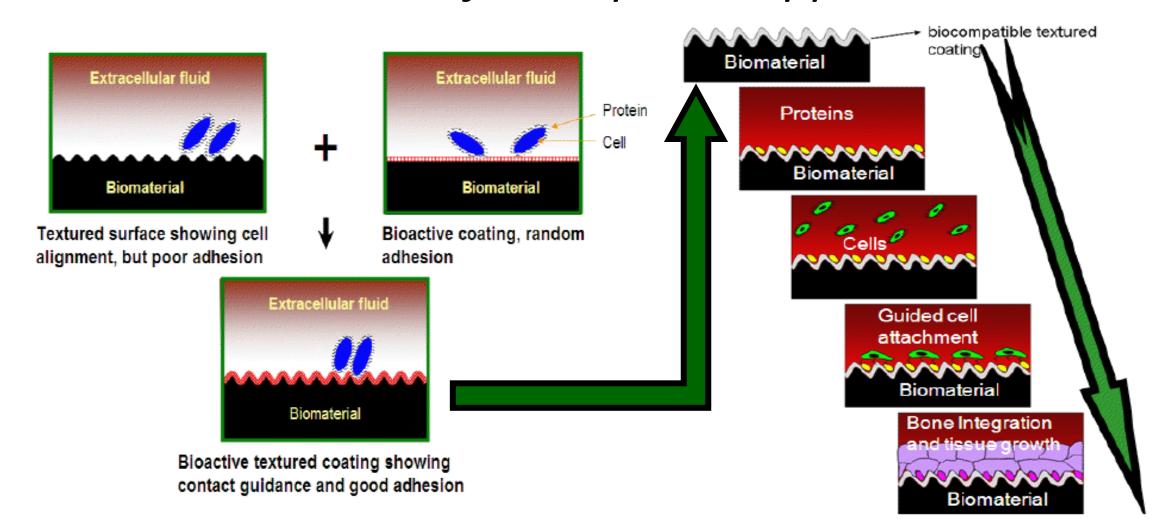


• The goal of this project was to find a way to increase the biocompatibility of titanium implants so as to increase the success of future implants.

#### **Need for Chemistry & Texture for Biocompatibility**

- Due to lack of chemistry, cells that should surround the implant are unable to attach to the metallic surface, preventing bone growth. This is due to two factors: cells not recognizing the foreign metal implant and a surface that cells are not capable of adhering to the implant surface due to a lack of texture.
- In order to address this, we are proposing synthesis of a textured calcium phosphate (major constituent of human bone) based coating on the implant surface, which is likely address both issues.

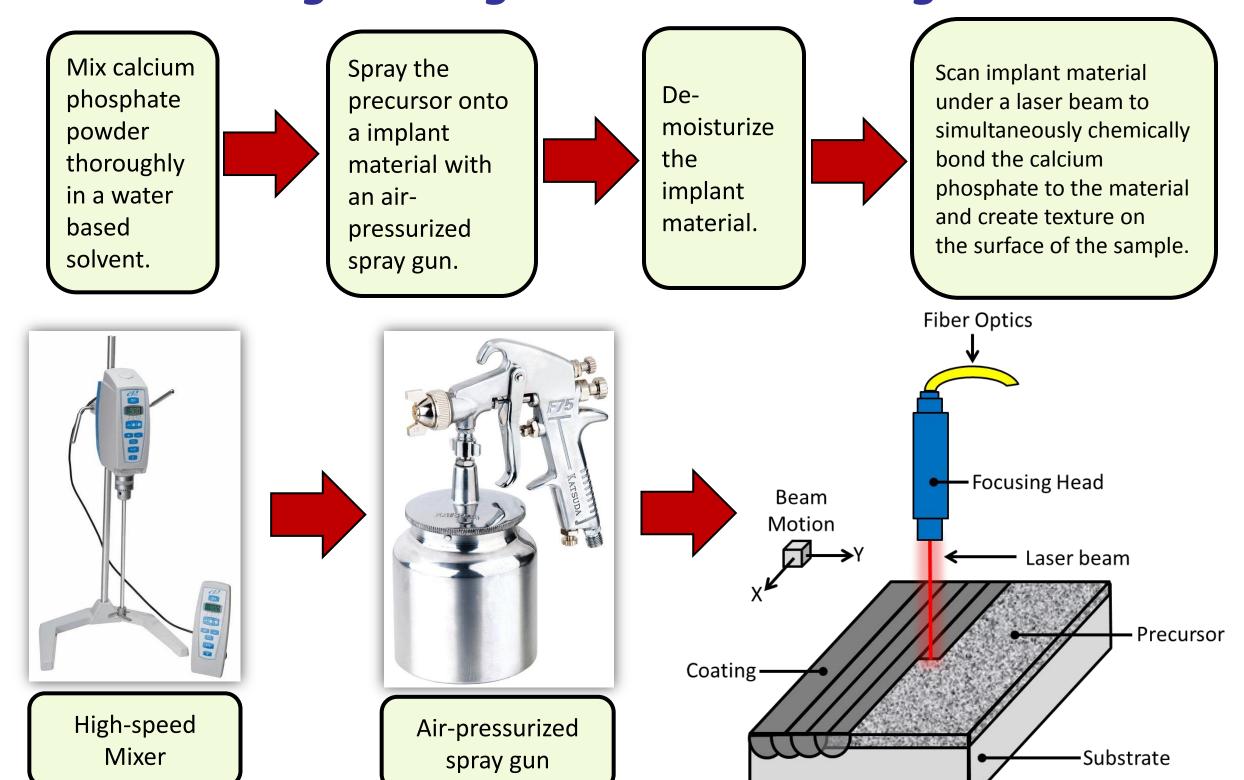
#### Rationale for Proposed Approach



A calcium phosphate coating was chosen because of its similarity to bone. Cells that surround the implant will recognize the implant as a piece of bone and attempt to adhere. But its not that simple. Just as we cannot attach ourselves to a smooth wall, cells cannot attach to the smooth surface of an implant. They require a microscale level of texture to which they can adhere onto.

## Engineering

#### Engineering a Textured Coating





In order to create texture

while scanning, the high

power laser beam passes

through splitter, dividing the

beam into two or more sub-

beams. The beams are then

beams to interfere with each

other on the sample surface.

determine the spacing along

guided along an optical

system that causes the

The angle between the

beams determines the

spacing in the intensity

distribution. A simple

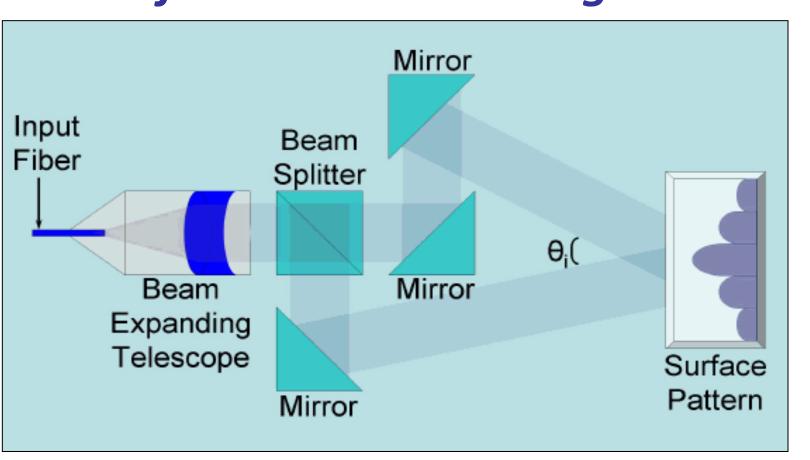
formula was used to

 $d = \lambda / 2 \sin\theta$ 

the sample:

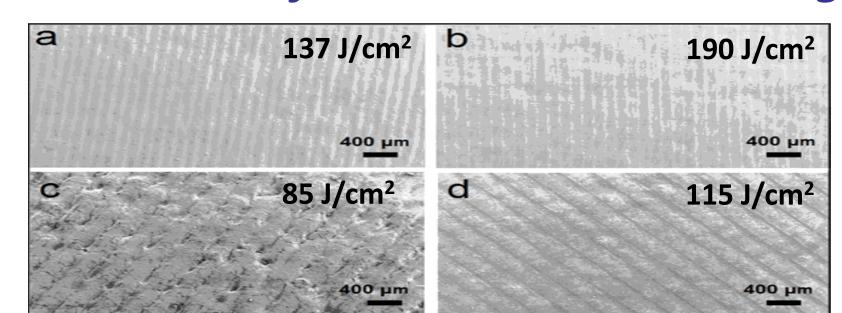
- Nd-YAG laser beam (1.6 micron wavelength)
- Dual Laser Beam Interference Configuration
- Processing energies: 137 J/cm<sup>2</sup>, 190 J/cm<sup>2</sup>, 85 J/cm<sup>2</sup>, 115 J/cm<sup>2</sup>
- Coating Precursor: Calcium Phosphate Tribasic Powder
- Substrate: Titanium (Ti/6wt%Al/4wt%V)

### Laser Interference Configuration for Textured Coating



Interference patterning to create periodic surface textures at length scales ranging from the micro to nano in a single step process.

#### Laser Interference Textured Coating



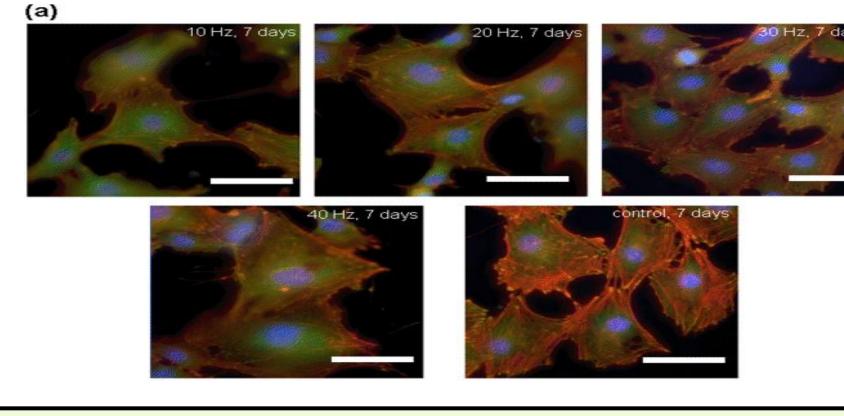
Multilevel surface texture provides enhanced cell adhesion & proliferation

Laser textured Ca-P coating at various laser input powers

#### Biocompatibility of Textured Coatings

Effect of laser surface modification on biocompatibility of bio-implant materials

Lifect of laser surface infouncation on biocompatibility of bio-implant materia							
	Laser Input Energy (J/cm <sup>2</sup> )	Surface Roughnes s, R (microns)	$x10^{4}$	Cell Shape Index (4 x pi x area /perimeter <sup>2</sup> ) (Biocompatibility)	Absorbance	Absorbance 3 Days (Biocompatibility)	Absorbance 5 Days (Biocompatibility
	Untreated	10	0.45	0.63	0.039	0.045	0.059
	85	29	0.32	0.59	0.040	0.051	0.077
	115	35	0.21	0.57	0.035	0.043	0.049
	137	71	0.39	0.62	0.037	0.049	0.067
	190	74	0.58	0.69	0.035	0.037	0.040



- After applying modifications to the surface of the implant material sample, levels of cell growth on the implant were compared to an untreated sample employing in-vitro culture of mouse MC3T3-E1 osteoblast cells.
- The sample's cell coverage was much more complete than the untreated sample. Also, modifications improved cell adhesion of the laser textured coatings via anchoring of the lamellipodia to the textured grooves and developed network of focal adhesion contacts.

# **Economic Impact**

Present implant manufacturing approaches can be prohibitively laborious and expensive, calling for novel approaches for future implant manufacturing.

#### Existing Approach

- Environmentally non-benign treatments involved
- Prohibitively time consuming
- Labor oriented steps for quality and accuracy
- Not amenable for automation
- Prohibitively

#### **Proposed Approach**

- Non-equilibrium synthesis process leading to formation of novel phases
- Processing can be done without a controlled
- environment (in air) Laser beam can be transported to remote locations via fiber optics
- Environmentally benign • Fiber optic delivery of the laser beam allows
- processing of complex shapes and sizes of the
- Due to the high laser flux densities, process can be conducted at extremely rapid speed
- Laser machine integrated with a computer for precision and automation, thereby leading to high rate of output and easy commercialization
- Highly economical

By reducing the price and increasing the availability of femoral implants, the hope is to be able to make the surgery accessible to a larger prospective patient base around the globe. In all third-world countries, orthopedic implantation surgery is prohibitively expensive to the masses, and even the surgeries that are carried out, are carried out with reused scraps from previous implant patient whom have passed away. This research could offer a unique solution by providing implants less expensive and last much longer.

### Acknowledgement

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- Dr. Wei He of the University of Tennessee.