Conical Emission Properties associated with Atmospheric Self-focussing Femtosecond Pulse Propagation

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Abstract: Divergence angles and spectral distribution of conical emissions produced by self-focussing filaments using an 800nm 50fs laser are measured. The spectral distribution of the conical emissions showed qualitative agreement with the pulse self-steepening model.

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1. Introduction

Numerous groups have demonstrated that tabletop high peak power femtosecond lasers are capable of inducing nonlinear self-focused propagation in atmosphere at 800nm. The phenomenon unfailingly exhibits 1) light concentration in a long single or multiple filaments of the order of 150 μ m diameter and tens of meters in length, 2) conical emission associated with these filaments has a considerably wider spectral content than the original laser pulse. Conical emission became apparent after the filaments were formed. While the divergence angle of these conical emissions has been studied, unfortunately there is no reasonable model proposed that can qualitatively describe [1,2] even the most basic features such as divergence angles of the different colors. Furthermore, the color ordering of these conical emissions can be changed upon changing the chirp of the launched pulse. In this paper, we will present conical emission data to show its behavior as the pulse is chirped. In addition, we also present the spectral distribution of the conical emissions and how it depends on chirp. Finally, we compare our result with numerical result of Gaeta [3].

2. Laser source

The experimental data presented here uses a Ti:Sapphire system built by Continuum Corporation capable of delivering 4 TW of peak power. At full power, the laser produces 200mJ, 50fs pulses at 800nm with 4cm diameter beam. The laser system can also be configured to produce a 9mm-diameter beam, with tens of millijoules.

3. Spatial-spectral structure of conical emission

Using the laser at full power, we recorded the conical emission after propagating 55 m in air with a color CCD camera. Upon adjusting the compressor to produce a normally chirped pulse, the conical emission had a series of concentric rings with shorter wavelength (blue color) on the outside and progressively longer wavelength moving toward the center. This color order was changed when the laser pulse was anomalously chirped. The conical emission, decomposed into their RGB color for the two oppositely chirped cases, are shown in figure 1. The divergence angle of the conical emissions ranges from 2.5 – 4.6mrad depending on the chirp condition. The behaviors of both chirped cases are significantly different from the results of Chin et al. and Mysyrowicz et al. [1,2].

Figure 1a. The red (left), green (middle) and blue (right) components of the conical emission from a normally chirped pulse observed at 55m away from the pulse compressor. Notice the blue diameter is larger than the red diameter.

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Figure 1b. The red (left), green (middle) and blue (right) components of the conical emission from an anomalously chirped pulse at 55m away from the pulse compressor. Notice all colors have comparable diameters.

4. Spectral brightness of the conical emission

Using a laser beam with 9mm-diameter and pulse energy of 9mJ, we measured the spectral distribution of the conical emission scattered from a flat white diffusive surface 20m away from the compressor. A calibrated Ocean Optic S2000 spectrometer equipped with an optical fiber sampled the scattered light a distance 17.5cm from the scattering surface. The spectral distribution for the positive (normal) and zero chirped cases are shown in figure 2. We find qualitative agreement with the spectral distribution of the numerical simulation by Gaeta [3], which includes the shock contribution. The data supports qualitatively his conclusion that space-time collapse and self-steepening produce the temporal shock formation manifested in the spectral pedestal on the blue side of the laser wavelength. While this behavior has been observed in solid materials, this is the first experimental demonstration of temporal shock in air.

Figure 2. The left panel shows the spectral distribution of the conical emission from chirped and unchirped pulses. Significant difference in the blue region is noted. The right panel reproduces the spectral distribution published in ref. 3, the solid line represents the case when space-time collapse and self-steepening takes place causing the pedestal on the blue side. The x-axis has been re-labeled for easy comparison.

5. References

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