# 液体媒質におけるベッセルモードのフェムト秒パルス誘起フィラメント
# Femtosecond Bessel beam filament in liquid

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(Abstract)

Femtosecond filament induced by the laser beams with different transverse modes is compared for the liquid medium (water). Laser spectra are measured for each beam under different transverse mode conditions. Our preliminary results show that the laser spectra after the propagation in water are different for the different incident transverse modes.

Key words: femtosecond filament

## 1. Purpose:

Based on the previous calculation we did [1], compared with a single Gaussian beam, the combination of two Gaussian beams with different diameters can result in some advantage under certain conditions in terms of the lengths of filament and plasma channel during the propagation in argon gas. This is because the outer part of the combination beam takes more energy, and it serves as a reservoir from which energy flows into the inner part during the propagation. This study is to verify our previous calculation experimentally.

## 2. Method:

The generation of the combination of two Gaussian beams with different diameters is achieved by inserting a telescope in one arm of a Michelson interferometer. To protect the optics, we chose a low energy, less than 100 μJ to begin with. This low energy is insufficient to have filamentation in gas. For this reason, the filament experiment is done in water. The setup of the experiment is shown as Fig.1. The laser beam from the Ti:Sapphire amplifier is centered around 800 nm, and has a spectrum width of about 30 nm. The pulse duration of the laser is about 50 fs. After passing through a spatial filter, the beam has a Gaussian profile, and the beam diameter is about 2 mm. After the Michelson interferometer, two Gaussian beams with different diameters ($d_1 \approx 4$mm, and $d_2 \approx 2$ mm) are combined together and focused into a 100 mm long liquid cell filled with water by a f=100 mm focusing lens.

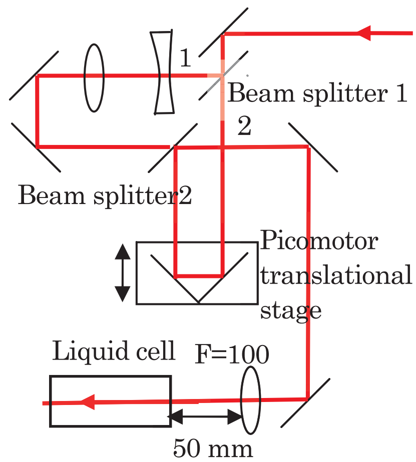


Fig.1. Experimental setup in which two Gaussian beams with diameters 4mm and 2mm are combined and focused to the liquid cell.

Laser Spectra are measured under the conditions shown in Table 1. . Arm1 means the arm with the telescope, and arm 2 means the other one. The beam diameters of arm 1 and arm 2 are 4mm and 2 mm.

| | A | B | C | D | E | F |
|---|---|---|---|---|---|---|
| Energy in arm 1 (μJ) | 23 | 0 | 23 | 12 | 0 | 12 |
| Energy in arm 2 (μJ) | 0 | 23 | 23 | 0 | 12 | 12 |
| Total energy (μJ) | 23 | 23 | 46 | 12 | 12 | 24 |

Table 1. Experiment conditions under which the laser spectra are taken.

3. Result:

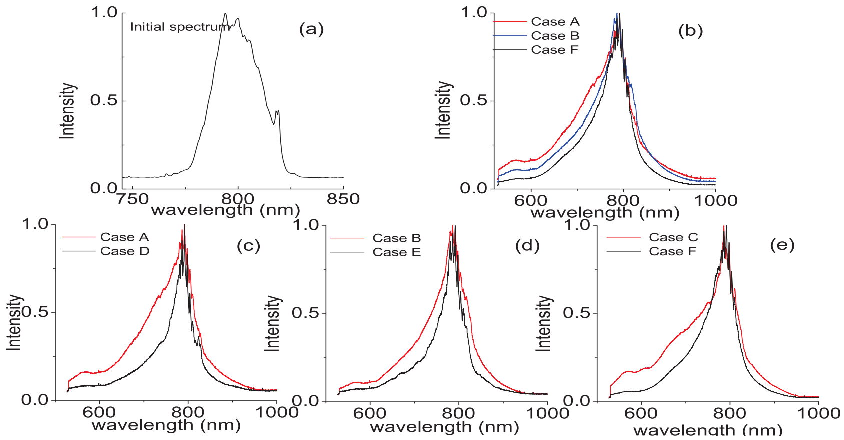


Fig.2. Laser spectra measured in the experiment. (a) Initial spectrum from laser. (b) Laser spectra for different modes at 24 μJ. (c)-(e) Laser spectra of each mode at different pulse energy.

The measured spectra in each case are shown in Fig.2. Fig. 2(a) is initial spectrum from the laser; Fig. 2(b) is the spectral of different mode (d≈2mm, 4mm, and combination) after filament for the same pulse energy 24 μJ. Figs. 2(c)-(e) are spectral after filament for each mode but at different energy (Fig. 2(c) is for d≈2mm, Fig. 2(d) is for d≈4 mm, and Fig. 2(e) is for combination). From Figs. 2(c)-(e), we can find that for each mode, the spectrum will be broader if pulse energy is higher. This is simply because the peak intensity is higher for higher energy. From (b), we find that the large diameter beam (d≈4mm) has a broadest spectrum. This is because it can be tighter focused, thus has higher peak intensity. Comparing case B and F, although the combined beam should have higher peak intensity, the spectrum is narrower. This is consistent with our calculation result, and can be explained by the reservoir effect.

4. Conclusion:

We experimentally studied the femtosecond filament by the beams with different incident transverse modes. Our preliminary results show that, for the given total energy, the combination of two Gaussian beams with different beam diameter results in the different laser spectrum after the propagation in water. As a next step we plan to find the optimal laser power for the maximum transverse mode effects.

5. References:


1. Z. Song, and T. Nakajima, "Formation of filament and plasma channel by the Bessel incident beam in Ar gas: role of outer part of the beam," Opt. Express **18**, 12923-12938 (2010).