Filamentation control in temperature distributed argon gas filled tube

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Outlines

- **Background**
  - Temperature gradient and pressure gradient
- **Experimental setup**
  - system design and construction
- **Preliminary results**
  - multi-filament $\rightarrow$ single filament
- **Conclusions**

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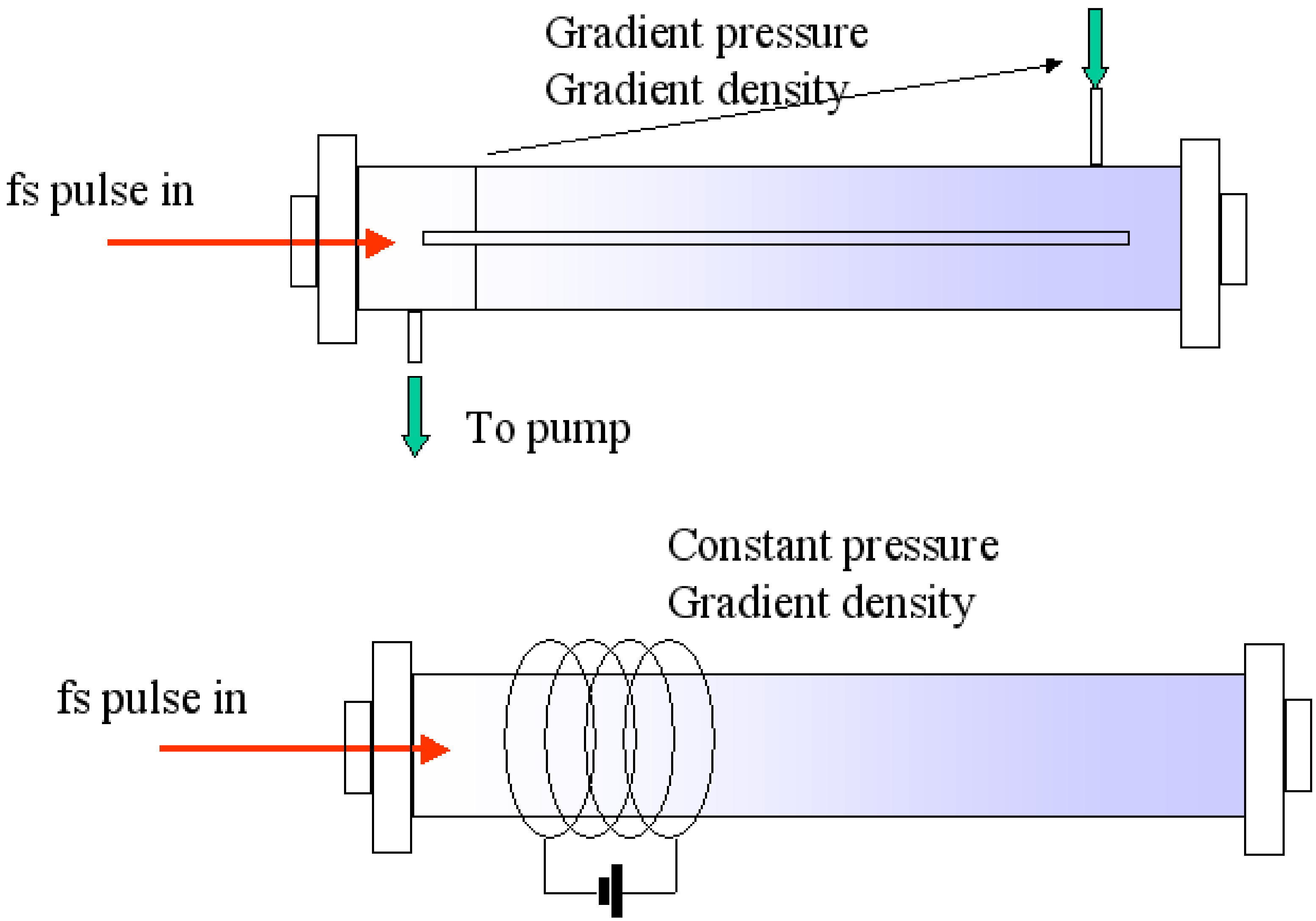
Research background

- Intense monocycle pulses (sub-5-fs) play an important role in many scientific and technological research fields,
  - the production of single attosecond pulses by high-order harmonics,
  - time-resolved measurements of electron dynamics in atoms and molecules.
- Intense mono-cycle pulse generation:
  - Hollow fiber (tapered hollow fiber)
  - Filamentation,
  - OPCPA
  - ……
- In hollow fiber, the pulse energy is limited to sub mJ by damage threshold and self-focusing.
- In filamentation, pulse energy is limited to several mJ by multi-filament and beam pointing instability.
- How to increase the pulse energy beyond mJ is our research target.

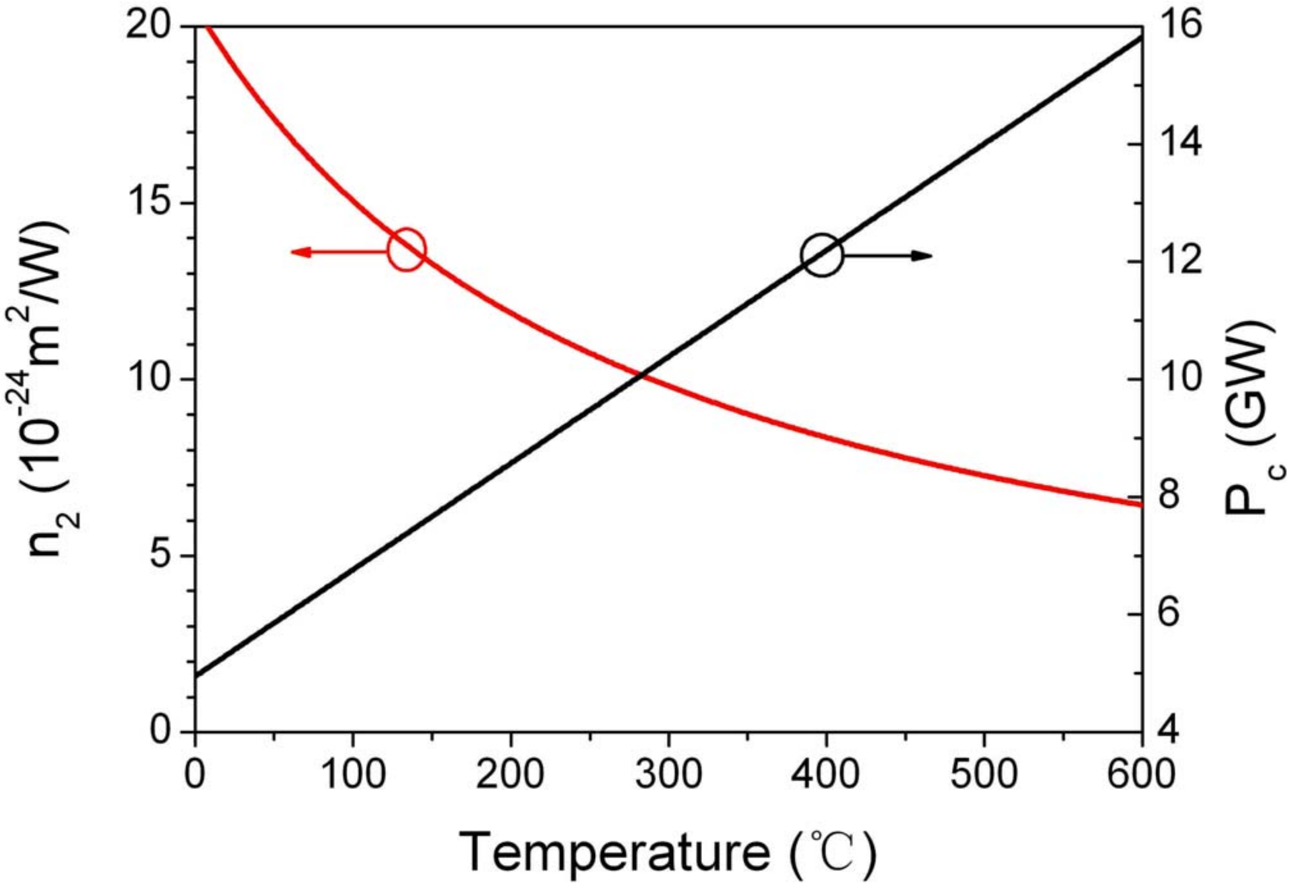
Gradient pressure & gradient temperature

- Gradient pressure was proposed as a method to allow more input pulse energy.
- The essence of Gradient pressure is the Gradient density.
- Gradient pressure results not only in large consumption of noble gas, but also a gas flow that disturbs the spatial beam stability.
- Proposal: if one end of the tube is cooled and the opposite end is heated, such that the temperature gradient is formed, the effect will be similar to that of pressure gradient.
- The gradient temperature along the tube

Gradient pressure & gradient temperature

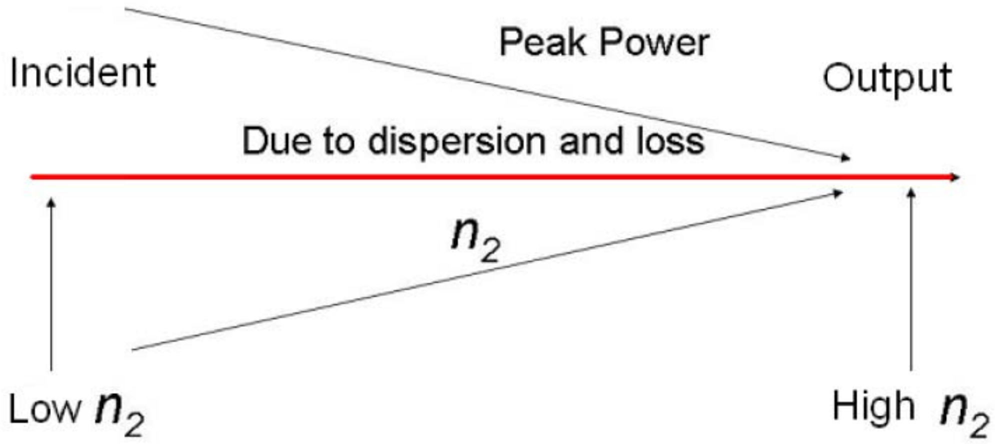


Temperature Vs n_2, P_c



How to reduce P_c

- To maintain a high nonlinear interaction while avoiding self-focusing, we want a gas density gradient, with the following scheme



High temperature or low pressure → Low temperature or high pressure

$$P_c = \lambda^2 / 2\pi n_2$$

Low density — High density

Temperature ↑ → n_2 ↓ → P_c ↑ → **Filamentation control**

→ **Spectrum broadening**

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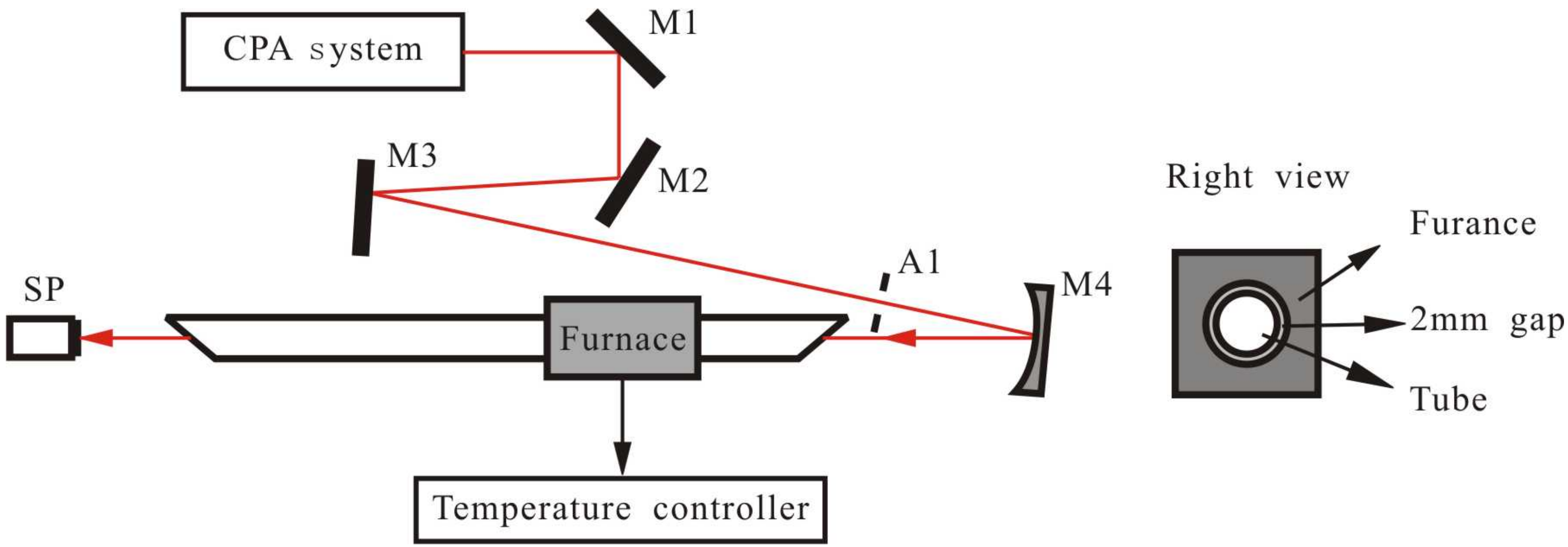
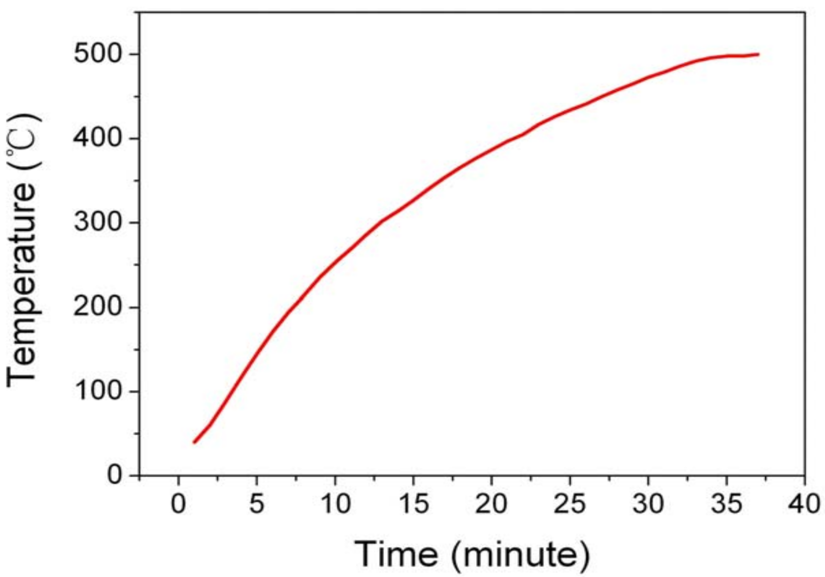
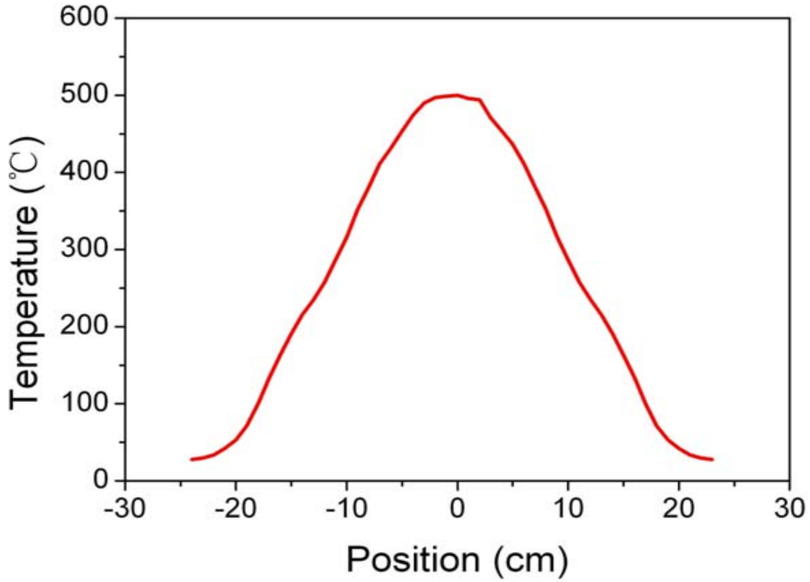
Experimental setup



- **Light source: SIOM**
- **Repetition rate: 1kHz**
- **Central wavelength: 800nm**
- **Pulse duration: ～37fs**
- **Maximum pulse energy: 2.0mJ**
- **Gas: Ar**
- **Gas pressure: <3atm**
- **Gas length: 1m**
- **Heating length: 20cm**
- **temperature: < 500℃**

Heating device





- **500℃ can be obtained in 35 minutes**

- **Temperature distribution along the tube**
- **The temperature gradient is about 2403 ℃/m**

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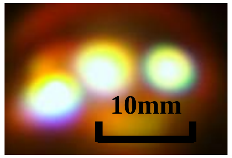
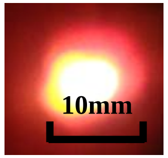
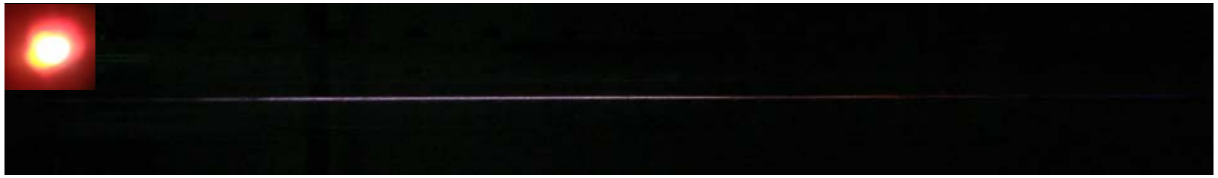
Filament pattern at different temperature

T= 25℃

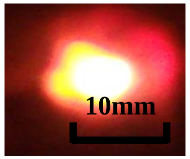


T=200℃

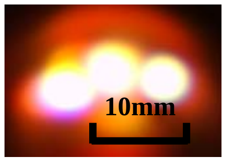




T=300℃

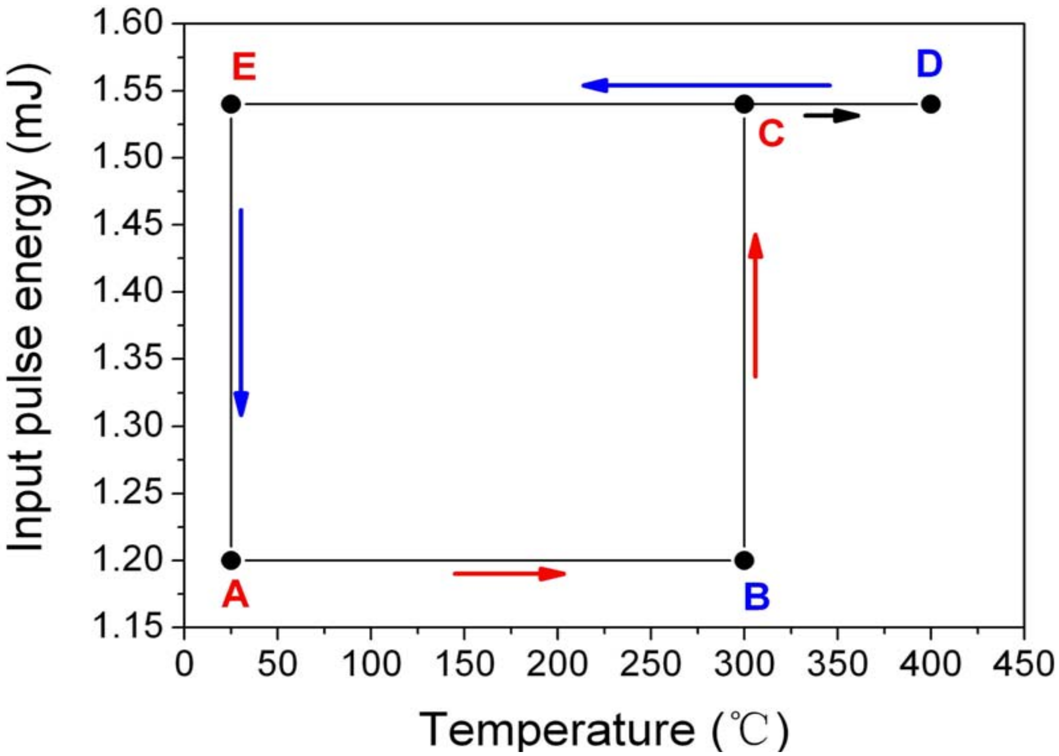


T= 25℃



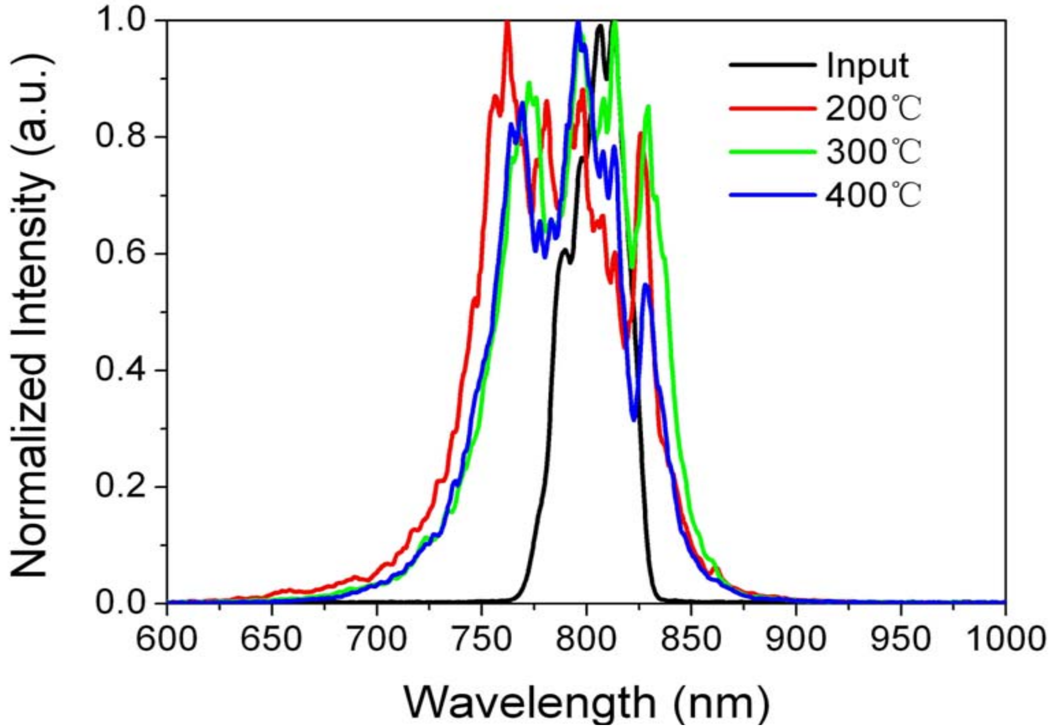
- **Input pulse energy: 1.2mJ**
- **Initial gas pressure: 2.1atm**

Filamentation Vs temperature and pulse energy



- **Filament appears: A, C, and E**
- **Filament disappears: B, and D**

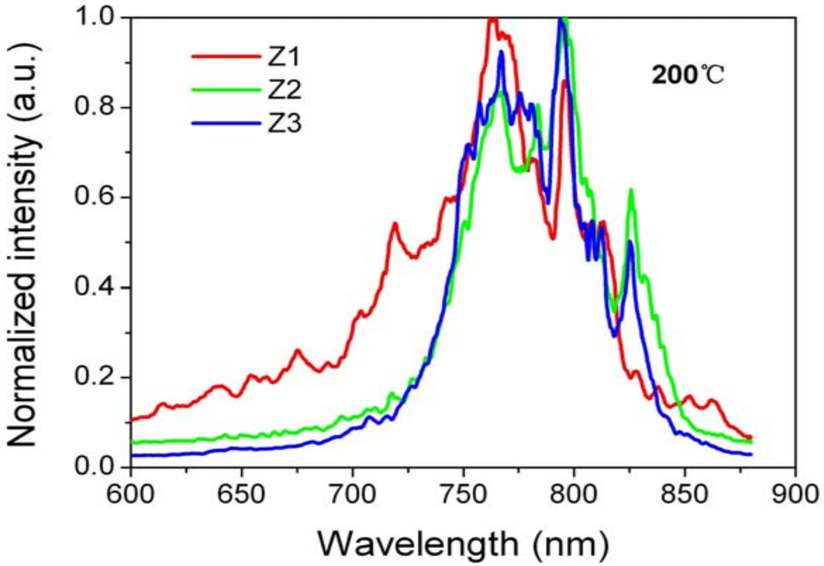
Broadened spectrum Vs gradient temperature

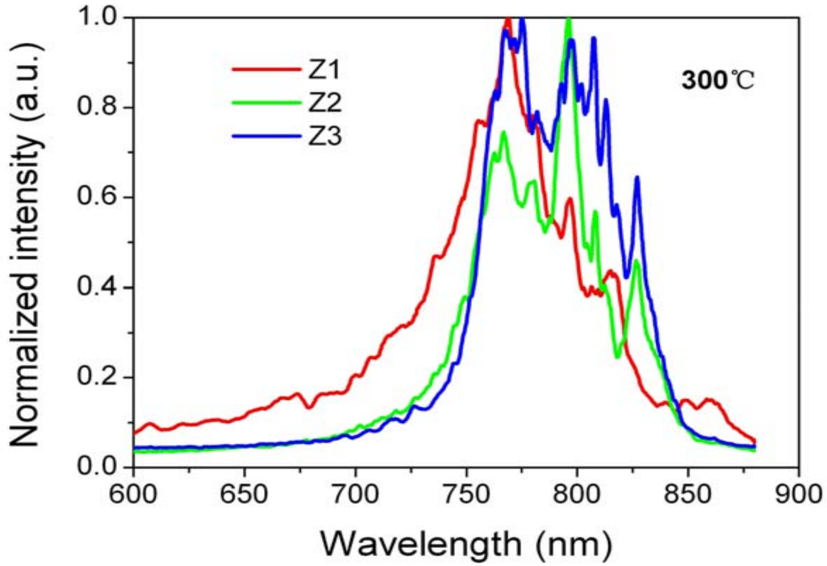


➢Pulse energy: **1.2 mJ**
➢Gas pressure: **2.1atm**

Broadened spectrum will be narrow with the increasing of the temperature.

Broadened spectrum Vs heating position





- **Z1: 28.5cm before the focus point**
- **Z2: 3.50cm before the focus point**
- **Z3: 3.50cm after the focus point**

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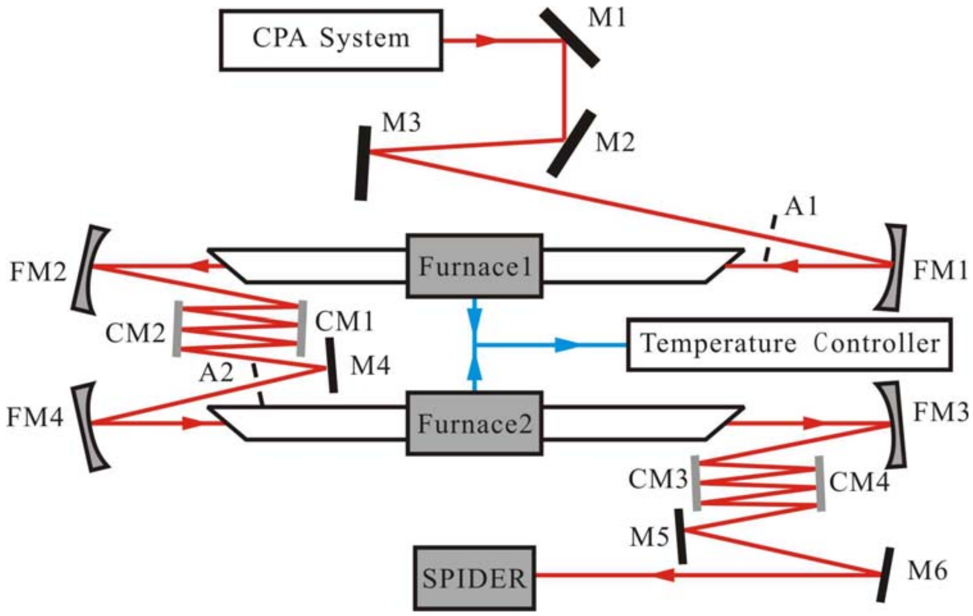
Conclusions

- Temperature could be another degree of freedom to control the filamentation.
- Multi-filaments at room temperature merged into a single filament at a higher local temperature. Further higher temperature led the filament collapse.
- Broadened spectrum will be narrow with the increase of the temperature.
- This technique offers a new way of controlling filamentation in gas-filled tube for multi-mJ level few-cycle pulse generation without the gas consumption and turbulence.

Further experiment

- Further expansion of the pulse spectrum is expected by sending the through pulse back to the tube for the second pass, after compression, by sending the pulse to another tube with individual control of the temperature and the pressure.



Thank you!