Topic

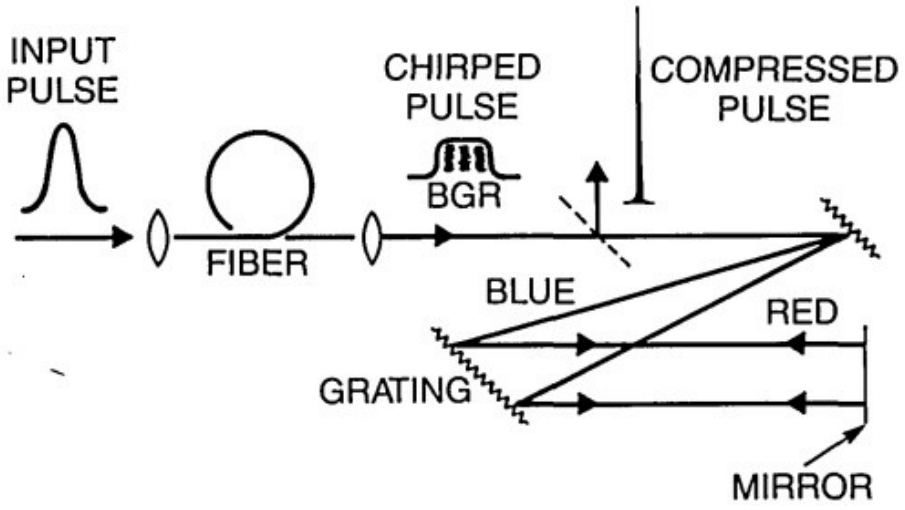
Ultrafast nonlinear optics in hollow-core photonic crystal fibers

- *Introduction*
- *Self-phase modulation / Pulse propagation*
- *Objectives / Literature review*
- *Experimental setup / Equipment / Work plan*
- *Applications*

Introduction

Ultrashort pulse lasers are important experimental tools for investigating fast-evolving atomic and molecular dynamics in physics, chemistry and biology.

Ultrashort pulses can be generated by extracavity compression techniques SPM(Self-phase modulation)+ODL(optical delay line). High energy pulse compression technique is based on hollow fibers or capillaries filled with noble gases. Hollow-core photonic crystal fibers are interesting medium for nonlinear spectral broadening and possible use for high energy pulse compression.



Self-phase modulation[1]

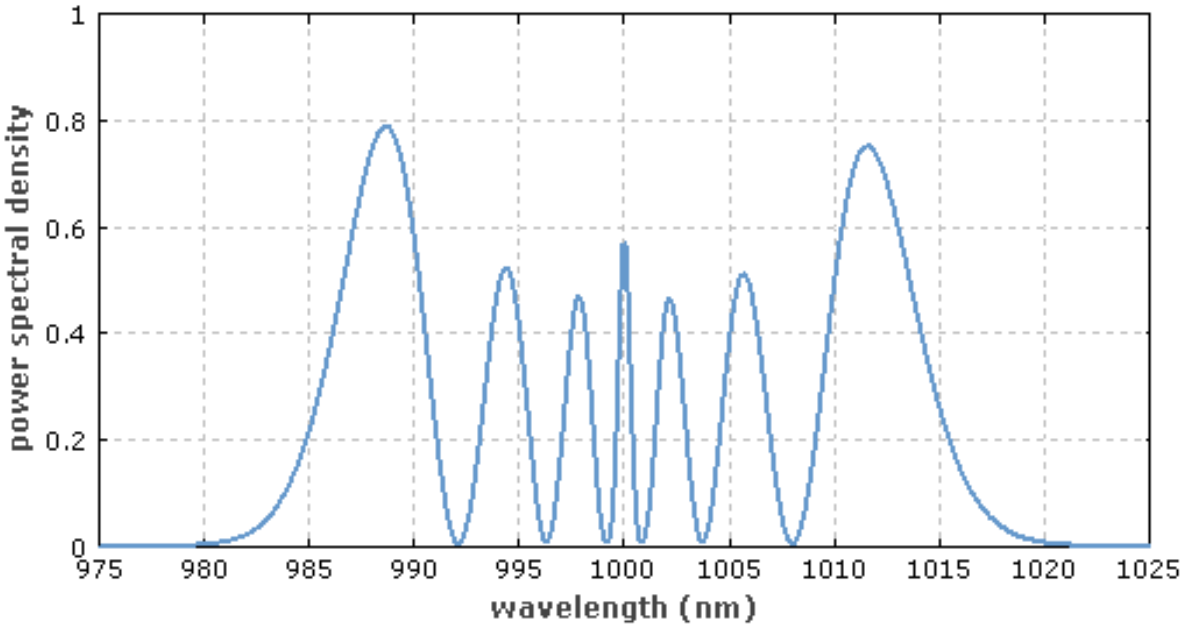
$$\vec{P} = \vec{P}^{(1)} + \vec{P}^{(2)} + \vec{P}^{(3)} + \dots$$

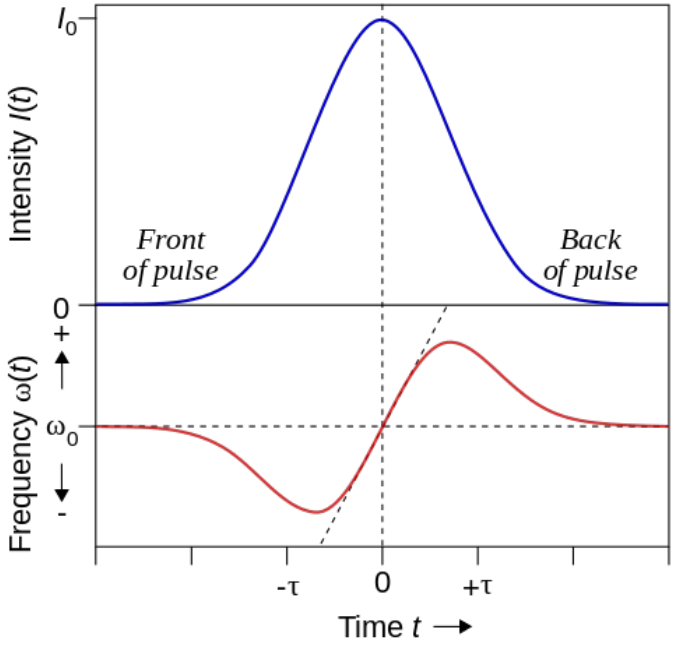
$$\vec{P}^{(1)}(\omega) = \varepsilon_0 \chi^{(1)}(\omega)\vec{E}(\omega)$$

$$\vec{P}^{(2)}(\omega_1 + \omega_2) = \varepsilon_0 \chi^{(2)}(\omega_1, \omega_2)\vec{E}(\omega_1)\vec{E}(\omega_2)$$

$$\vec{P}^{(3)}(\omega_1 + \omega_2 + \omega_3) = \varepsilon_0 \chi^{(3)}(\omega_1, \omega_2, \omega_3)\vec{E}(\omega_1)\vec{E}(\omega_2)\vec{E}(\omega_3)$$

$$n(I) = n_0 + n_2 \cdot I$$



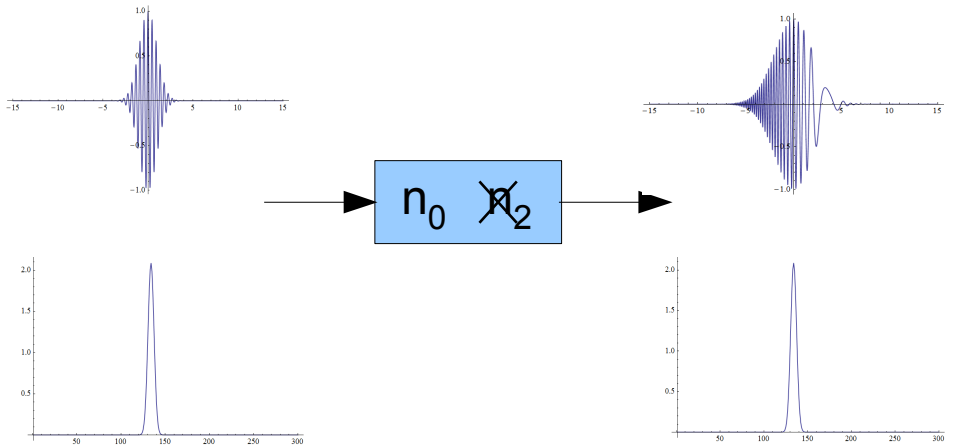


$$\omega(t) = \frac{d\phi(t)}{dt} = \omega_0 - \frac{2\pi L}{\lambda_0}\frac{dn(I)}{dt}.$$

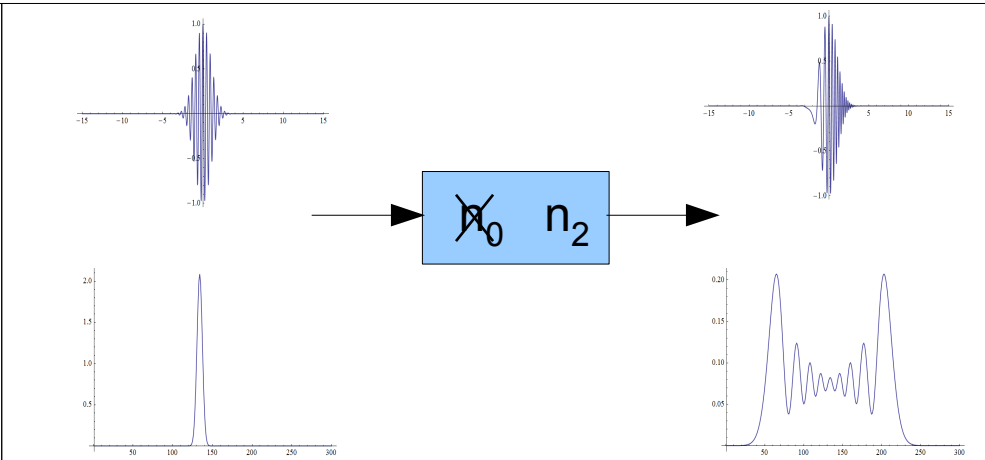
$$I(t) = I_0 \exp\left(-\frac{t^2}{\tau^2}\right)$$

$$\omega(t) = \omega_0 + \frac{4\pi L n_2 I_0}{\lambda_0 \tau^2} \cdot t \cdot \exp\left(\frac{-t^2}{\tau^2}\right).$$

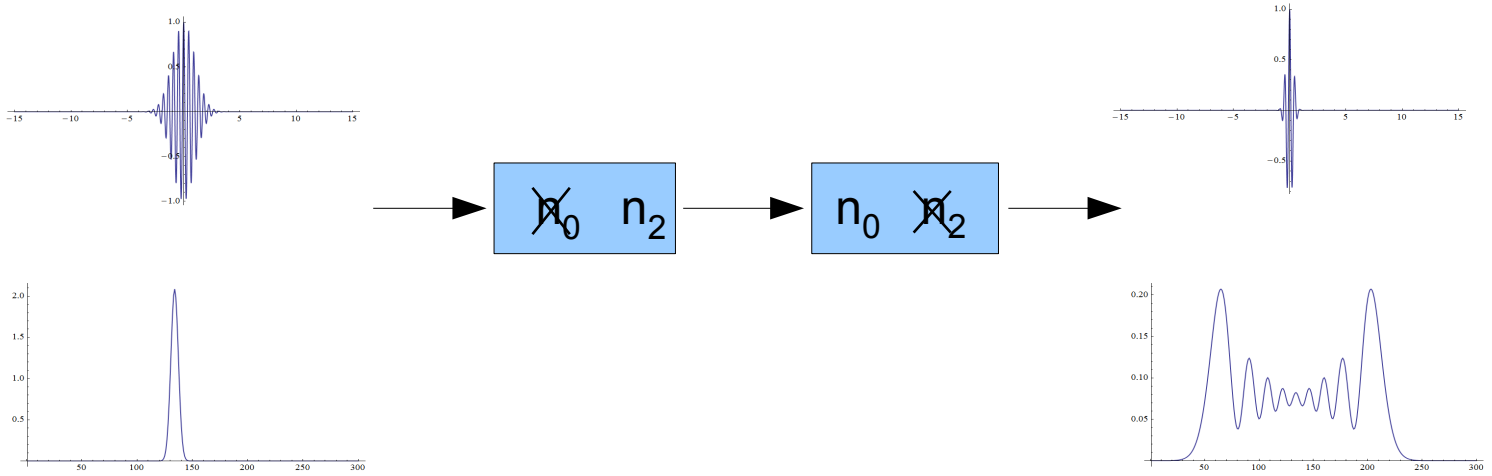
Pulse propagation



Linear medium (anomalous dispersion)



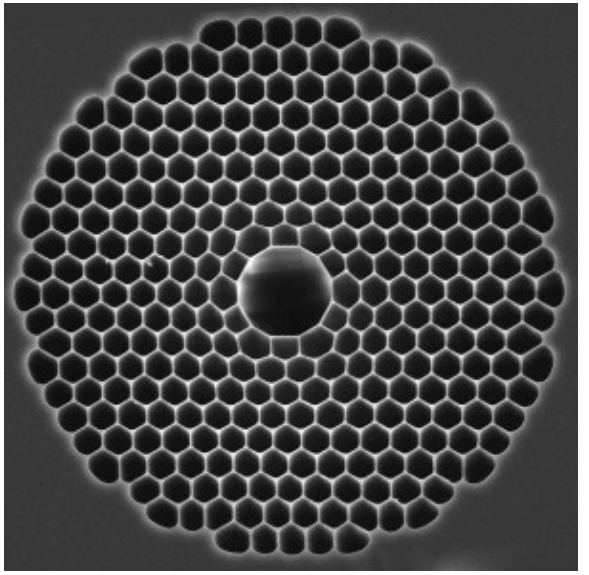
Kerr nonlinear medium

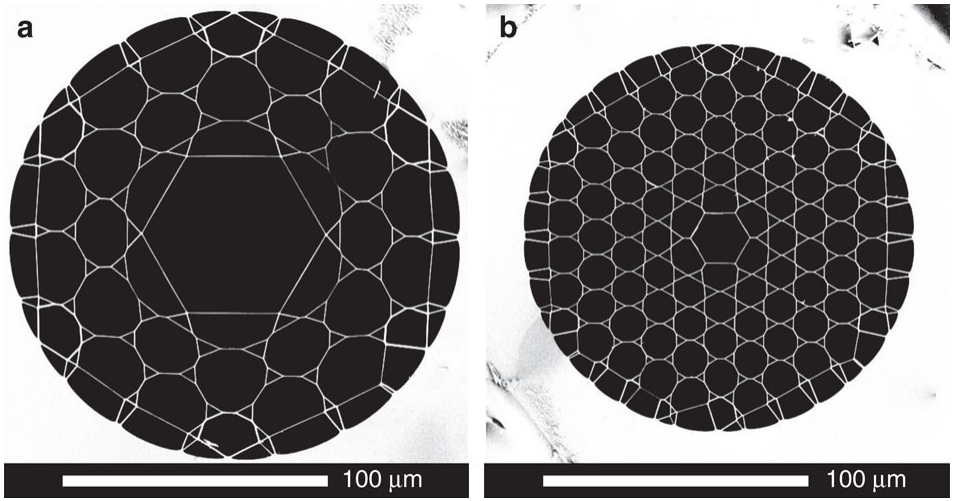


Kerr medium + Linear medium

Objectives

Self-phase modulation due to nonlinear optical Kerr effect in gas-filled hollow-core photonic crystal fibers[2] will be investigated and possible use for laser pulse shortening will be analyzed. Spectral broadening will be investigated in different gazes Ar,Kr...





and liquids under various (pressure and temperature) conditions. Also linear, circular and elliptic polarizations cases will be probed.

Literature review

3.Theoretical study of soliton-induced high-power supercontinuum generation by using kagome lattice HC-PCFs filled with a noble gas. [800nm 50fs 176 TW/cm^2]

4.Spectral broadening in Ar [800nm 140fs 450nJ 1-150bar]

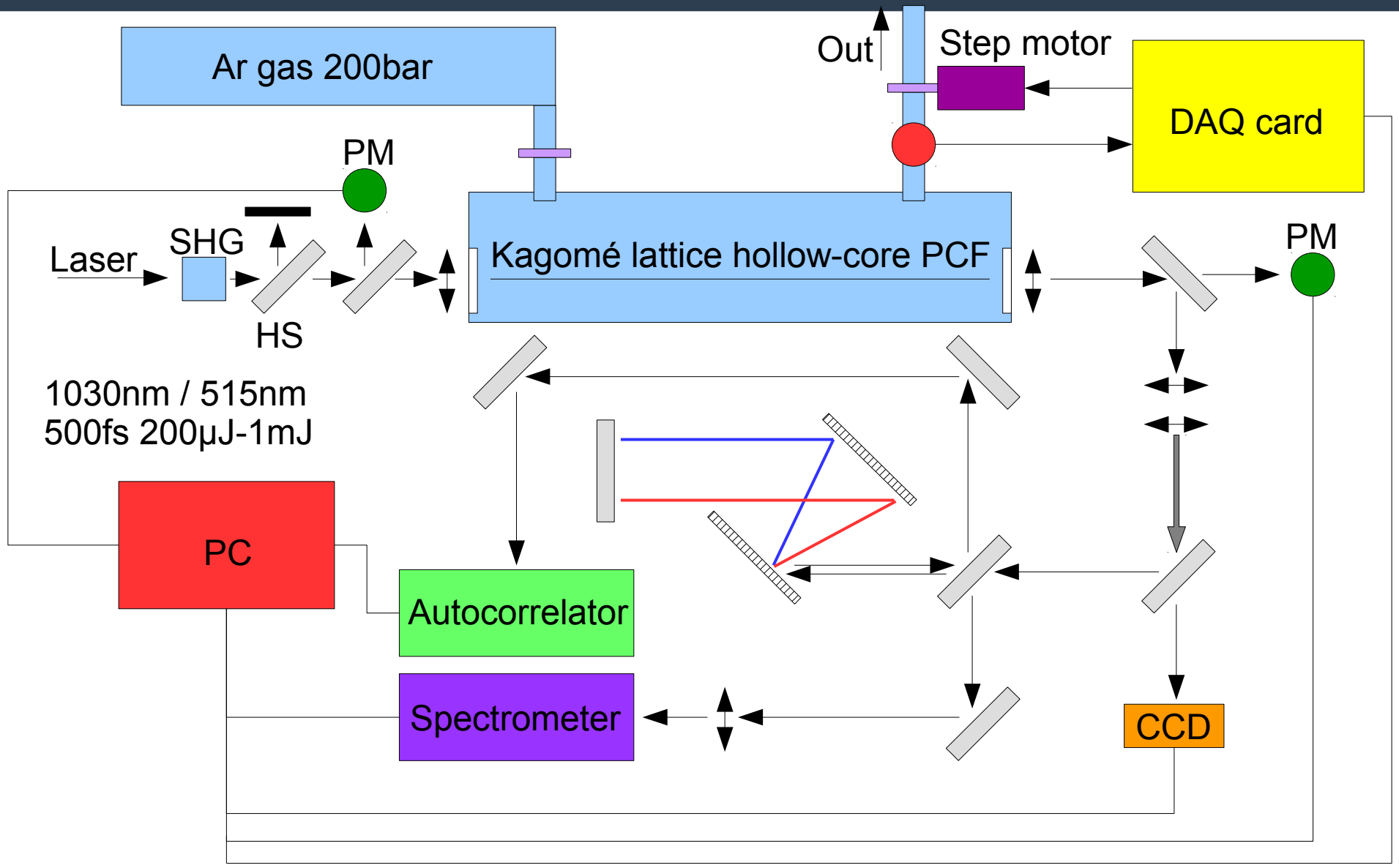
5.Pulse compression in Xe [1030nm 1ps-250fs 1μJ 8bar]

8.Compressing in inert gases [1053nm 1ps-100fs 1mJ 1-50bar]

9.Self-compression in Xe [1800nm 80fs-4.5fs 120μJ 4bar]

10.High energy ultrafast Ar [1030nm 740fs-88fs 18μJ 13bar]

Experimental setup



Equipment/Cost

- PC
- CCD
- Power meter
- Spectrometer
- Autocorrelator
- Optical elements/mounts
- Second harmonic crystal
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- High pressure chamber
- DAQ card /motors ~1000$
- PC fiber /m ~500$
- Diff. gratings pair ~300$
- 10x Al mirrors ~200$
- He,Ne,Ar,Kr,Xe,O_2,N_2
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Work plan

1. Concept/Idea formation
2. Literature review
3. Simulation software
4. Small proof of concept experiment
5. Compression module assembly and testing
6. Main experiment (He,Ne,Ar,Kr,Xe,O_2,N_2 1-100 bar)
7. Comparative analysis of results
8. Final pulse compression module assembly and testing

Applications

- Photonic-crystal fiber
- Ultrafast spectrometry
- Bright X-ray generation
- Multiphoton microscopy
- Particle acceleration
- Attoscience
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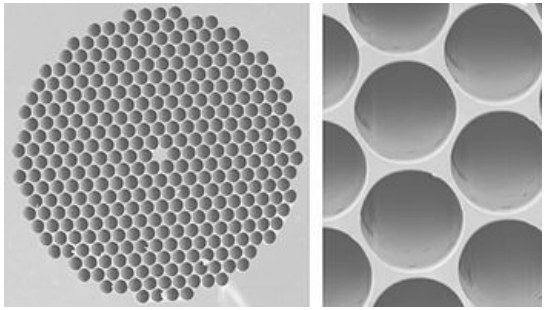

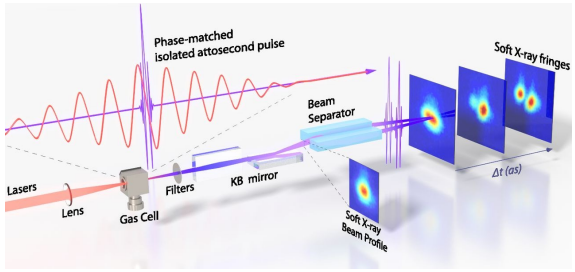

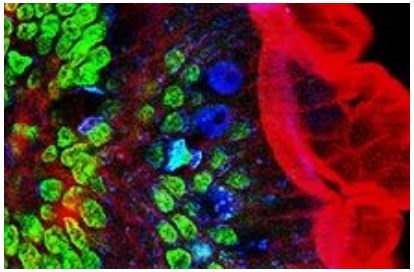

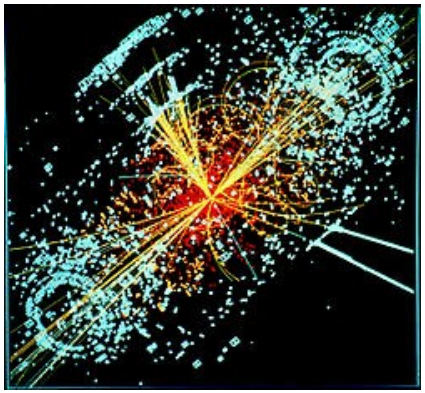

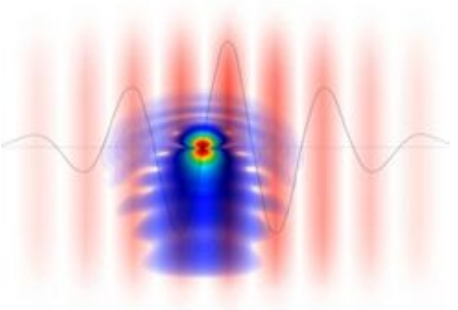

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