Abstract

In this paper, we describe the physics behind optical parametric chirped-pulse amplification (OPCPA), as well as the design of all-reflective pulse stretcher and compressor. By using concave mirrors, flat mirrors and gratings, we can achieve high stretching/compression ratio. The integration of this project and OPA into OPCPA combines the advantage of both techniques mentioned above, which enables the production of CEP controlled multi-millijoule ultrashort laser pulses in MIR spectral range.

Chirped-Pulse Amplification

- CPA first stretch the pulse in time domain by introducing a positive chirp. Then, it is possible to amplify the pulse to high energies without encountering nonlinear effects and the damage to the amplifier. Finally, the pulse are compressed back to the original one by opposite dispersive delay line.

Optical Parametric Amplification

- The signal beam propagates through the crystal together with a pump beam of shorter wavelength. Under certain phase-matching condition, photons of the pump can be converted into lower-energy signal and idler photons.

Pulse Compression

- Based on the grating equation: \( \sin \theta_2 (\lambda) = \sin \theta_1 (\lambda) + \frac{m \lambda}{L} \), the high-frequency components travel a smaller distance than the low-frequency components, which means grating pairs can provide anomalous dispersion.

- GDD of grating pairs = \( \frac{d^2 \sin \theta}{\cos \theta} \). By changing the separation G of two gratings, we can transform a chirped pulse into a transform-limited (TL) pulse.

Pulse Stretching

- The lenses are placed at a distance 2f from each other, acting as a 1:1 telescope. If L < f, the high-frequency components travel a longer distance and the whole setup supplies normal dispersion.

- GDD of pulse stretcher = \( \frac{d^2 \sin \theta}{\cos \theta} \). When L is smaller than the focal length, the system can stretch the TL pulse into up-chirped pulse.

Experimental Setup: OPCPA

- Ti:sapphire oscillator produces femtosecond pulses. They go through the nonlinear crystal and part of them are converted into MIR region (3.4μm), acting as the idler pulse in the setup.

- The residual laser pulses undergo self-phase modulation and play the role of pump pulses (1064nm) in the OPCPA setup.

- The idler pulses are stretched, amplified in three stages and compressed back.

References

1. Igor Jovanovic, "Chirped-Pulse Amplification", Optik & Photonik, NO. 4, December 2010, pp. 30-33