Pulse compression of multiple plate continuum at 1.55 μm

Chia-Lun Tsai[1], Yi-Hsun Tseng[1], An-Yuan Liang[1], Jhan-You Guo[1], Ming-Wei Lin[2], Shang-Da Yang[1], Ming-Chang Chen[1]
[1]*Institute of Photonics Technologies, National Tsing Hua University, Hsinchu 30013, Taiwan*
[2]*Institute of Nuclear Engineering and Science, National Tsing Hua University, Hsinchu, Taiwan*
tsaichalun@gmail.com

Abstract: We experimentally demonstrated nonlinear pulse compression at 1.55 μm from 80 fs to 28 fs by using multiple plate continuum generation and femtosecond pulse shaping.
OCIS codes: (190.4970) Parametric oscillators and amplifiers; (320.7110) Ultrafast nonlinear optics; (190.4410) Nonlinear optics, parametric processes; (190.4720) Optical nonlinearities of condensed matter; (320.6629) Supercontinuum generation; (320.5540) Pulse shaping.

1. Introduction

High-energy ultrashort laser pulses have been applied to high-harmonic generation (HHG) [1], attosecond science [2], and high-speed micro-machining of a variety of materials [3]. Powerful Ti:Sapphire lasers (0.8 μm) and Ytterbium lasers (1 μm) remain the workhorse of strong-field laser science. By pumping parametric down-conversion process with these lasers, central wavelengths of intense laser pulses ranging from 1.1 μm to 2.4 μm (Ti:Sapphire pump) [4, 5] or beyond 5 μm (Yb:KGW pump) [6] are available. Although optical parametric amplifier (OPA) or optical parametric chirp pulse amplifier (OPCPA) enables a wide range of wavelength tuning, the spectral bandwidth is limited by phase matching of the nonlinear crystal as well as temporal and spatial overlapping between pump and seed pulses. These effects tend to make pulse duration longer than the front-end solid-state lasers. It becomes highly desirable to compress the amplified pulses by spectral broadening and dispersion compensation to recover or further shorten the pulse duration in applications such as pump-probe experiments or isolated attosecond pulse generation.

In terms of spectral broadening, supercontinuum generation (SCG) by the use of photonic crystal fibers [7], microstructured fibers [8] and multiple-plate continuum (MPC) [9] has made tremendous progress in the last two decades. Among those methods, MPC has the advantages of easier optical alignment, economic cost, free from spectral distortion induced by beam-pointing fluctuation, and ability of spatial multiplexing. MPC has been carried out at 0.8 μm [9], 1 μm [10], and 1.5 μm [11], however, MPC plus dechirping at 1.5 μm remains undemonstrated. In this work, we demonstrate nonlinear pulse compression at the central wavelength of 1.55 μm. The 80 fs pulses from our OPCPA (primarily limited by the insufficient phase-matching bandwidth of KTP crystal) are spectrally broadened by passing through 9 quartz plates and de-chirped by a Fourier pulse shaper, delivering 28 fs (five carrier cycles) pulses at the output.

2. Experimental setup and results

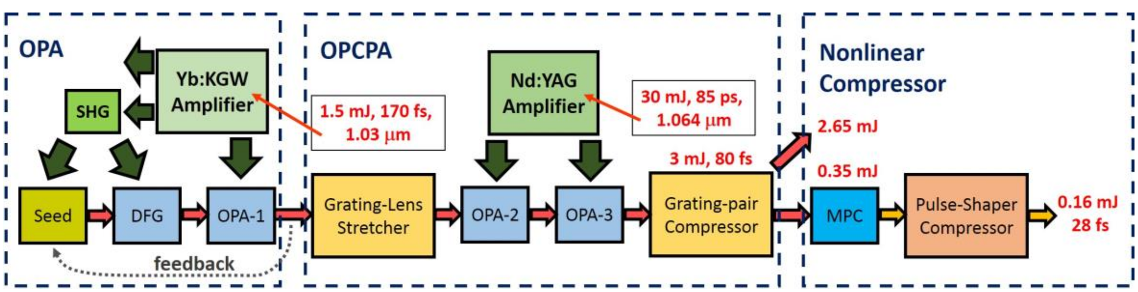

Fig. 1. Experimental setup. SHG, second-harmonic generation; OPA-#, optical parametric amplifier.

We perform MPC at 1.55 μm by a system consisting of three building blocks responsible for seed generation, OPCPA, and nonlinear compression, respectively. As shown in Fig. 1, A Yb:KGW amplifier (Light Conversion, Pharos PH1.5-06-200-CEP) emitting 1 kHz, 1.5 mJ (0.1 mJ is used), 170 fs pulses at 1.03 μm pumps white light generation (WLG), difference frequency generation (DFG) and the first OPA stage (OPA-1). The seed pulses at 1.55 μm come from the idler of the DFG (between the pump at 515 nm and the signal at 772 nm arising from the white light generation in a 10-mm YAG plate), therefore, are intrinsically CEP-stable. They are amplified to 10 μJ (44 fs) as the signal of OPA-1 before sent to the OPCPA. In order to stabilize the pulses, we implement a feedback loop (using a pico-motor-driven mirror mount, a CCD camera, and a home-made software) to lock the beam pointing of

OPA-1. In this way, the output power and bandwidth are greatly stabilized. Shot-to-shot noise pulse energy fluctuation is <1 %. The second building block is an OPCPA with two amplification stages (OPA-2 and OPA-3) pumped by a Nd:YAG amplifier (EKSPLA, APL 2003) that can produce 1 kHz, 30 mJ, 85 ps pulses at 1.064 μm. A Martinez stretcher (grating-lens pair stretcher) broadens the signal pulse from 44 fs to 50 ps by introducing a great amount of normal dispersion. OPA-2 and OPA-3 use 10-mm and 6-mm KTP crystals, respectively. After the grating-pair pulse compressor, we got 3 mJ, 80 fs pulses at 1.55 μm if the OPCPA is operated at full power. The third building block is a nonlinear pulse compressor containing MPC and a Fourier pulse shaper. For the lack of space for long focusing (to control the B-integral value in each quartz plate around 1.5π), we only tap 0.35 mJ from the OPCPA output for nonlinear compression. We focus the laser beam into the MPC stage by a lens of 0.5 m focal length such that the spot size on the first plate is 0.19 mm in diameter. After 9 pieces of 200-μm-thick quartz plates, a spectrum spanning from 1.35 μm to 1.7 μm (at -20 dB level) is generated [Fig. 2(a)]. Total transmission is 47% if the outer rings of the beam profile due to conical emission is blocked. A Fourier pulse shaper consisting of a 4-f zero dispersion stretcher and an array of liquid crystal spatial light modulator (SLM) (Jenoptik, SLM-640d) is used for all-order dispersion compensation. The spectral phase function of the de-chirped pulse is characterized by polarization-gating cross-correlation frequency-resolved optical gating (PG-XFROG). A loop of measurement-and-compensation is conducted until all the frequency components are nearly in-phased. The final result is shown in Figs 2(b) and 2(c), where 28 fs pulse width is achieved (transform limit is 27.4 fs).

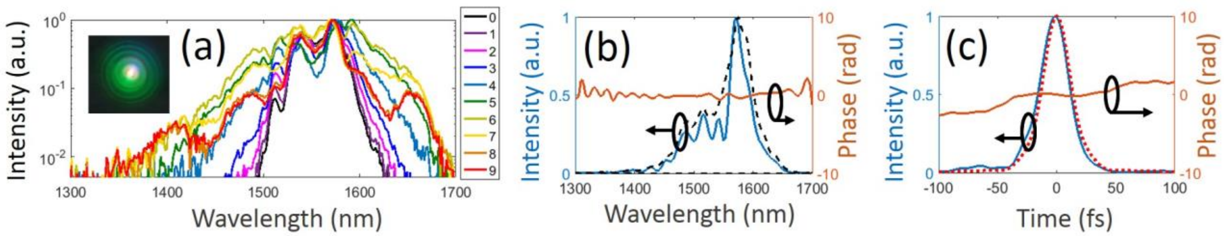

Fig. 2. Experimental results. (a) MPC spectra after insertion of different numbers of 200 μm-thick quartz plates. Subplot: MPC profile after 9[th]-plate. (b) Retrieved power spectrum (blue), and spectral phase (brown). Power spectrum acquired by a monochromator (black dotted) is shown for reference. (c) Retrieved temporal intensity (blue) and phase (brown). Transform-limited temporal intensity (red dotted) is drawn for reference.

3. Conclusions

We have demonstrated nonlinear pulse compression at 1.55 μm from 80 fs to 28 fs by using MPC and femtosecond pulse shaping. Energy up-scaling is possible by using looser lens focusing and chirp mirrors. Shorter pulse widths can be accomplished if more nonlinear phase shift is accumulated in plates. Such intense light source paves the way to generate water window soft x-ray for bio-imaging. Our work is supported by Ministry of Science and Technology (MOST) in 104-2112-M-007-012-MY3, 105-2112-M-007-030-MY3, and 107-2112-M-007-006. The authors acknowledge Dr. C. H. Lu and Prof. A. H. Kung for discussion of MPC.

4. References

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