Generation of 3.7-fs, 1.2-mJ pulses using a hollow-fiber pulse compressor

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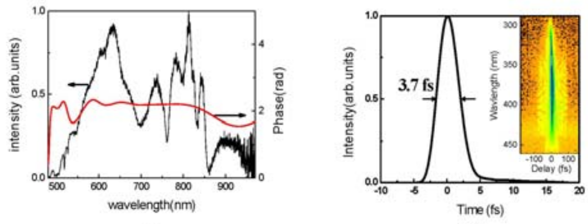
Synopsis: A differentially pumped neon-filled hollow-fiber pulse compressor was investigated to generate high-power few-cycle laser pulses. The pulse compression was optimized by adjusting neon pressure and laser chirp to produce the shortest laser pulses. Precise dispersion control enabled the generation of laser pulses with duration of 3.7 fs and energy of 1.2 mJ. This corresponds to an output of 1.5-cycle, 0.3-TW pulses at a 1-kHz repetition rate.

High-power few-cycle lasers have been developed for the investigation of ultrafast phenomena. The hollow-fiber pulse compression method has been utilized in compressing high power femtosecond laser pulses to few-cycle pulses [1]. While laser pulses are propagating through a hollow fiber filled with a noble gas, spectral broadening is induced by self-phase modulation due to Kerr and ionization effects. The spectrally broadened pulses can form few-cycle pulses after compensating for the chirp remained in output pulses.

For the generation of high-power few-cycle laser pulses, a differentially pumped hollow-fiber pulse compressor was utilized in a femtosecond Ti:Sapphire laser at 1 kHz. Laser pulses with 29-fs pulse duration and 5.0-mJ energy were launched into a neon-flowing hollow-fiber pulse compressor [2]. The residual laser chirp of the output beam was compensated by two sets of chirped mirrors. Temporal characterization of the compressed pulses was carried out using the second-harmonic generation (SHG) frequency-resolved optical-gating (FROG) method.

Spectral broadening of intense femtosecond laser pulses in ionizing gas is sensitive to the gas pressure and input laser chirp. The neon gas pressure in the hollow-fiber pulse compressor was adjusted to achieve wide spectral broadening while preventing self-focusing. Higher pressure leads to a broader output spectrum but too high gas pressure can result in propagation instabilities due to self-focusing effects. The output spectra changed very delicately to laser chirp. With negatively chirped pulses, spectral broadening was reduced, while the broadening was effective with positively chirped pulses. The broadest spectrum capable of generating 3.2-fs pulses was produced with positively chirped 33-fs pulses. Thus, appropriate gas pressure and positive chirp of initial pulses were needed for maximum spectral broadening.

The remaining laser chirp of spectrally broadened laser pulses was compensated to achieve near transform-limited pulses. The output laser chirp was precisely controlled by adjusting neon pressure and input laser chirp, together with 2-sets of chirped mirrors having total GDD of -170 fs^2. As shown in Fig. 1, the spectral phase of the output pulse indicates that the laser chirp was almost compensated. The shortest pulse of 3.7 fs with energy of 1.2 mJ, corresponding to 1.5-cycle, 0.3-TW output was generated in the conditions of positively chirped 33-fs pulse and 1.6-bar neon. CEP stabilized few-cycle high-power laser pulses will be applied to attosecond physics investigations.



(a) (b)

Fig. 1. (a) Spectral profile and phase of the laser output taken with 1.6-bar neon and positively chirped 33-fs laser pulse, and (b) temporal profile of the laser pulse measured using the SHG FROG method. The inset shows the FROG trace.

References

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