Few-optical-cycle pulse generation based on a non-linear fiber compressor pumped by a low-energy Yb:CALGO ultrafast laser

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Pulse compression in a normal dispersion photonic-crystal fiber is investigated with an ultrafast Yb:$CaGdAlO_4$ laser. After a simple and power-efficient prism-pair compressor pulses as short as 14.9 fs with 29 mW average power are produced.
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Low-energy pulses shorter than 20 fs are interesting for several applications such as nonlinear microscopy, time-domain spectroscopy, and the synthesis of compact broadband THz devices for spectroscopy or imaging. Solid-state Yb lasers such as Yb:$CaGdAlO_4$ (Yb:CALGO) [1] pumped by a single mode laser diodes based on a single-prism cavity were provided to be a simple and effective source for generating pulses 36 fs short using a semiconductor saturable absorbers (SESAMs). To obtain even shorter pulses a reliable approach is to use a robust sub-100-fs compact source followed by a simple pulse compressor made by a nonlinear fiber and a prism pair compressor. We will present a few-optical-cycle pulse generation using a non-linear fiber compressor and a compact, robust Yb:CALGO single prism cavity, pumped by a readily available 400-mW single-mode telecom fiber-coupled diode. The oscillator is mode-locked with a SESAM and emits 70-fs Fourier-limited pulses at 60-MHz repetition rate, with 45-mW average power. As a non-linear fiber we use a commercially available zero dispersion fiber at around 1200 nm (LMA-PM-5, NKT photonics.inc). Fig.1 shows the SHG-FROG characterization of the generated pulses with the broadest spectral bandwidth, extended form 970 nm to 1180 nm. In this case the coupled laser pulse energy is of 0.52 nJ, that leads to a peak power of 7 kW. The reconstructed FROG pulse (fig. 1(d)) has a FWHM duration of 14.9 fs of the main peak where is contained the 62% of the total energy. After the compression the peak power is of 21 kW. Comparing the measured pulse temporal intensity profile with the Fourier transform limited one (continuous blue and dashed black lines in Fig. 2(d), respectively), it appears that there is a residual un-compensated higher-order dispersion. A clean, almost pedestal-free pulses were obtained reducing the injected pulse energy at 0.35 nJ with a peak power of 5kW. In this situation, the measured compressed pulse has a FWHM duration of 19,5 fs with the 90% of the total energy in the main lobe, corresponding to a peak power of 16 kW. To investigate the intensity stability of the ultrashort pulses we perform some relative intensity noise measurements (RIN) of the pump diode source, of the laser seeder and of the output of the PCF fiber that are shown in Fig.2. The RIN of the seed is equivalent to the one of the pump diode in the frequency range from 10 to 1000 Hz and it's mainly limited by the a flicker noise contribution. For higher frequencies the noise of the Yb:CALGO laser is lower than the pump diode; this is due to the fact that the laser cavity introduces a cut-off frequency corresponding to the upper laser level lifetime (440 μs that leads to a cut of frequency of ~360 Hz). The noise of both the supercontinuum (SC) radiation at higher and lower frequencies resembles the one of the seed apart from some acoustic noise acting at the frequencies of 100, 140, 650 and 800 Hz.

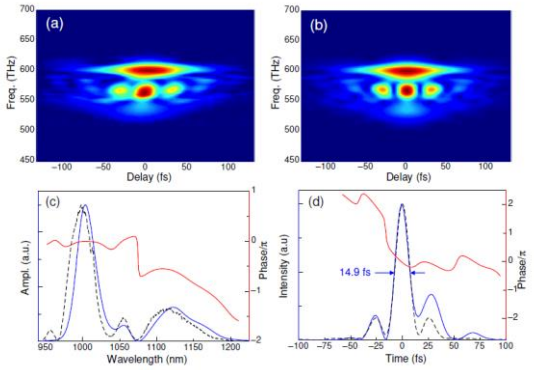

Fig. 1 (a) Measured and (b) retrieved SHG FROG trace. (c) Optical spectrum (black dashed line) at the output of the PCF. In blue are shown the reconstructed optical spectrum (d) and the intensity profile (d). In red are shown the reconstructed temporal (d) and spectral (c) phase in units of π. Black dashed line is the temporal intensity profile of the transform limited pulse corresponding to the measured optical spectrum.

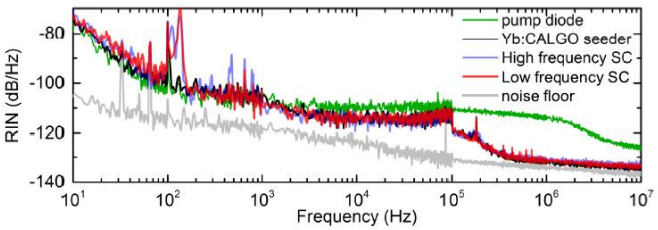

Fig. 2 Power spectral density of the RIN versus Fourier frequency of the low-power single-mode pump diode, Yb:CALGO seed laser, and SC radiation at the PCF output both at the high and low optical frequency tails.

References

1. F. Pirzio, M. Kemnitzer, A. Guandalini, et al. and A. Agnesi, Opt. Express 24, 11782–11792 (2016).