Research on amplification of ultrashort laser pulses at 1.03 µm in gain-managed nonlinearity regime

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Ultrafast laser sources with and high pulse energy are a topic of interest both in science and industry, especially when their wavelength are not reachable in traditional way. Wavelengths that differs from conventional gain bandwidths for fiber lasers are a great basis for nonlinear effects such as different frequency generation or pumps for mid-infrared parametric oscillators. Recently the group of F. Wise reported a new regime of amplification called gain-managed nonlinearity (GMN) [1]. In this regime both pulse and gain spectra evolve and reshape one another, which allows to generate a bandwidth that exceeds the gain spectrum for Ytterbium-doped fibers. It is shown that the along with the amplification process of the self-similar pulse, it experiences nonlinear deformation and pulse shifts towards longer wavelengths [1]. This point is considered to be the beginning of the GMN regime. The pulse then continues to broaden in spectral and time domain and its energy increases. Here, we demonstrate a simple fiber amplifier setup which delivers pulses with energy up to 71 nJ, which corresponds to 2.17 W of average power, with a central wavelength of 1083 nm and 45 nm of width.

The experimental setup of the source is depicted in Fig. 1(a). As a seed laser we used fiber laser with a repetition rate of 30.44 MHz, working at the central wavelength of 1031 nm and 11 nm of width (Fig. 1(b)). The compressed pulse duration was 312 fs at average power of 68.3 mW. Pulses from the seed were directed into the amplifier, which consisted of 9-meter-long double-clad Ytterbium-doped polarization maintaining (PM) fiber with a 10-µm core diameter. It was pumped by a laser diode working at 918 nm. The spectra obtained after GMN amplification are depicted in Fig. 1(c). While increasing the pump power, the spectrum is broadening and spanning beyond the gain bandwidth of Yb-doped fibers. The maximal average output power of the amplifier of 3.25 W was achieved at 6.94 W of pump power, which corresponds to pulse energy of 107 nJ. The central wavelength of 1115 nm and width of 92 nm was achieved for this pulse. For the pulse energy of 46 nJ or higher, Raman scattering is observed. The last spectrum not affected by Raman scattering had the average power of 0.995 W (32 nJ) for 3.32 W of pump power. The central wavelength for this pulse was 1083 nm and the width was 45 nm. To the best of our knowledge, these are the broadest spectra achieved so far from a single-stage gain-managed amplifier.

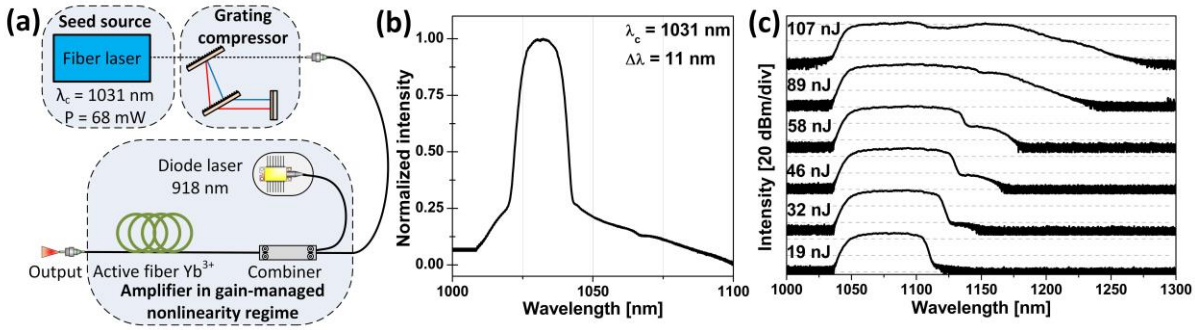

Fig. 1. Experimental setup of the GMN amplifier (a). Optical spectrum of the seed laser (b). Optical spectra of seed laser amplified in GMN regime (c).

Summarizing, we demonstrated an amplification process in a new gain-managed regime, which can deliver pulses with high energy and spectrum broader than a gain bandwidth. In the next step the presented source will be compressed with a grating compressor and used as pump for nonlinear processes [2], e.g. mid-infrared parametric generation. The work was funded by the Polish Ministry of Science and Higher Education (DG2018 006648).

References

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[2] A. Schliesser et al., "Mid-infrared frequency combs", Nat. Photonics **6**, 440-449 (2012).