DAMOP19-2019-020091

Abstract for an Invited Paper
for the DAMOP19 Meeting of
the American Physical Society

Nonlinear optical effects in all-bulk multipass cells and their applications

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Nonlinear optical phenomena involving ultrashort pulses such as spectral broadening, soliton self-compression and soliton Raman self-frequency shifting (SRSFS) are usually realized in solid-core photonic crystal, gas-filled photonic bandgap or hollow-core fibers. Implementations of these nonlinear effects strongly rely on extended propagation which, until recently, was only possible in fibers. A new method based on propagation in a periodic quasi-waveguide structure comprised of focusing elements and nonlinear media was lately demonstrated. Practically the scheme is realized by placing a nonlinear medium such as an anti-reflection coated fused silica plate inside a Herriott-type multi-pass cell (HC). In contrast to fibers, the sign of the overall net dispersion and its profile, including higher order dispersion terms, can be readily engineered by dielectric coatings tailored for the application. We show that this dispersion engineering enables the experimental demonstration of pure SPM spectral broadening, SRSFS and soliton self-compression. As main driving laser sources we use 100 W-level Kerr-lens mode-locked thin-disk Yb:YAG oscillators operating at 1030 nm central wavelength, 5-15 microjoules pulse energies and 200-300 fs pulse durations. For example, spectral broadening and subsequent pulse compression by means of dispersive mirrors in several HCs stages results in sub-15 fs pulses. Alternatively, self-compression of 300 fs pulses down to 30 fs is possible inside a single HC stage adjusted for a slightly negative net group delay dispersion. Additionally, for the first time to the best of our knowledge, SRSFS at high-energy (over 1 microjoule) is demonstrated. Generally, the overall losses strongly depend on the magnitude of the spectral broadening and are usually in the 5-30 percent range. HCs are known for being insensitive to the input laser beam pointing and for preserving this beam pointing at the output. These properties in combination with the dispersion engineering make this new method of exploring nonlinear phenomena highly interesting for research and industrial applications.