Femtosecond pulse self-compression in second-order nonlinear media: Surfing soliton and polariton waves

Valdas Pasiskevicius
Royal Institute of Technology, KTH, Roslagstullsbacken 21, 10691 Stockholm, Sweden

High-peak power solid-state ultrashort pulse lasers and chirped pulse amplified systems based on Yb^{3+}-doped hosts offer high wall-plug efficiencies owing to relatively low quantum defect. That is also advantageous for average power scaling. As a result, such systems are finding widespread use in scientific and industrial applications. The spectral gain bandwidth in the most popular Yb^{3+}-doped hosts typically limits the pulse length to hundreds of femtoseconds. Further spectral broadening is achieved by self-phase modulation in suitable Kerr media with subsequent pulse post-compression [1] or exploiting pulse self-compression using soliton propagation [2]. In the standard dielectric Kerr media with a positive Kerr coefficient, self-compression can happen only in the net anomalous dispersion regime. In the near-infrared spectral range, the net anomalous dispersion propagation can be realized using suitably designed chirped mirrors or exploiting dispersion control in gas-filled hollow-core waveguides. Alternatively, soliton propagation and pulse self-compression can be realized in net normal dispersion regime in second-order nonlinear interaction where the effective Kerr nonlinearity can be designed to be negative [3, 4].

This work investigated pulse self-compression and supercontinuum generation in second-order nonlinear crystals pumped in the net normal dispersion propagation regime. Two different pulse self-compression methods were realized. The first method relies on the design of the effective Kerr coefficient in quasi-phase-matched second-order ferroelectrics [5]. The structures were designed so that the effective Kerr nonlinearity was negative in the normal dispersion spectral range and positive in the anomalous dispersion regime. Pulse self-compression and supercontinuum exceeding one octave have been obtained. The second spectral broadening and self-compression method relies on pulse interaction with self-generated phonon polariton shock waves in polar second-order nonlinear crystals. It is known that femtosecond pump pulses generate Cerenkov-type radiation in the THz spectral range in a second-order nonlinear medium due to optical rectification [6]. When associated with the phonon resonances, we found that this shock wave can back-act very efficiently on the original pump pulse, causing pulse spectral broadening and self-compression in the normal dispersion regime. These projects were performed in close collaboration with groups from Vilnius University Laser Center, Lund University, and Light Conversion Ltd.

References

[1] V. Hariton, A. Bin Wahid, G. Figueira, K. Fritsch, O. Pronin, Opt. Lett., 47, 1246 (2022).
[2] L. F. Mollenauer, R. H. Stolen, J. P. Gordon, W. J. Tomlinson, Opt. Lett., 8, 289 (1983).
[3] S. J. Holmgren, V. Pasiskevicius, F. Laurell, Opt. Express, 13, 5270 (2005).
[4] J. Moses, F. W. Wise, Opt. Lett., 31, 1881 (2006).
[5] A.-L. Viotti, R. Lindberg, A. Zukauskas, R. Budriunas, D. Kucinskas, T. Stanislauskas, F. Laurell, V. Pasiskevicius, Optica, 5, 711 (2018).
[6] D. A. Kleinman, D. H. Auston, IEEE J. Quantum Electron., 20, 964 (1984).