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Real time measurement of long parabolic optical similaritons

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Summary

We generate optical similaritons using a Raman fibre amplifier. Long pulses with a highly parabolic profile are monitored in real time on a high speed oscilloscope.

Introduction

Since their first experimental demonstration in 2000 [1], parabolic similaritons have stimulated a growing interest in the field of fibre amplification of high-power ultrashort pulses. This new kind of optical pulse is asymptotically generated in an amplifier as the result of the combined interaction of normal dispersion, Kerr nonlinearity and gain. The pulse can then experience temporal and spectral self-similar dynamics and can evolve without suffering from the deleterious effects of optical wave-breaking which usually deteriorates the pulse shape propagating in the normal dispersion regime [2].

Experimental demonstrations have been carried out both in rare-earth doped fibres (with ytterbium [1] and erbium dopants [2]) and in Raman fibre amplifiers [3]. The use of frequency resolved optical gating (FROG) technique based on iterative algorithms has enabled a precise but indirect intensity and phase characterization of the amplified pulses which exhibit a parabolic intensity profile combined with a strictly linear chirp. Parabolic pulse durations ranging from 500 fs to 50 ps have then been demonstrated.

In this contribution, we aim to generate and characterize long (> 200 ps) parabolic pulses. In this context, the use of an adiabatic Raman amplification is particularly well adapted. Thanks to the use of a high-speed oscilloscope and an optical spectrum analyser, we can then monitor in real time the parabolic pulse shape.

Experimental set-up

The all-fibred experimental set-up is sketched in Fig. 1 and relies only on telecommunication-ready devices. Initial pulses are delivered by an erbium fibre laser working at a repetition rate of 22 MHz. The pulses are transform-limited with a temporal duration of 12 ps and a central wavelength of 1550 nm. They are amplified in a 15-km Raman amplifier based on a normally dispersive fibre (dispersion $D = -13$ ps/km/nm and nonlinear coefficient $\gamma = 4$ /W/m). The amplifier is pumped by a continuous fibre laser with an output power up to 1 W. A counterpropagative pumping scheme is used in order to avoid deleterious depletion effects as well as detrimental noise transfer. Output amplified pulses are monitored in real time thanks to an optical spectrum analyser and a 50-GHz oscilloscope.

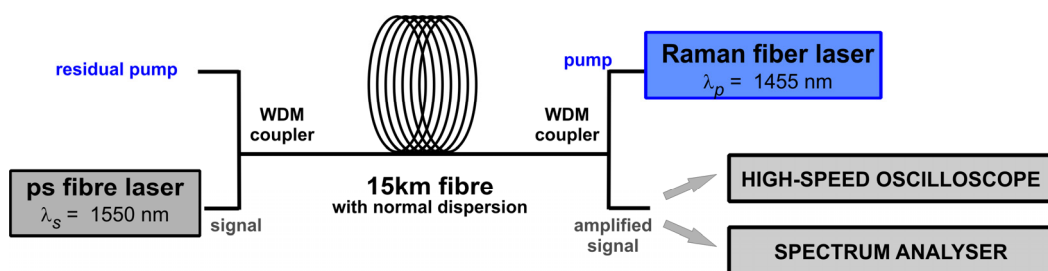


Figure 1 : Experimental set-up

Experimental results

Experimental results are summarized in Fig. 2 for an input pulse energy of 7 pJ and an integrated gain of 24 dB. Output intensity profile directly recorded by our high-speed photodiode (Fig. 2a) clearly illustrates the excellent agreement between the pulse shape (solid black line) and a parabolic fit (circles). The temporal broadening undergone by the initial pulse with an output temporal duration of 230 ps (full width at half maximum) is much higher than the one experimentally observed for a purely linear passive propagation (dashed line). The nonlinearity also leads to an enhanced spectral broadening as illustrated in Fig. 2b (a 15 times spectral broadening is recorded). Using a Gerchberg-Saxton algorithm and given the temporal and spectral intensity profiles, one can infer the temporal chirp of the pulse. Results are plotted in Fig. 2c and highlight the high linearity of the chirp of the amplified pulses.

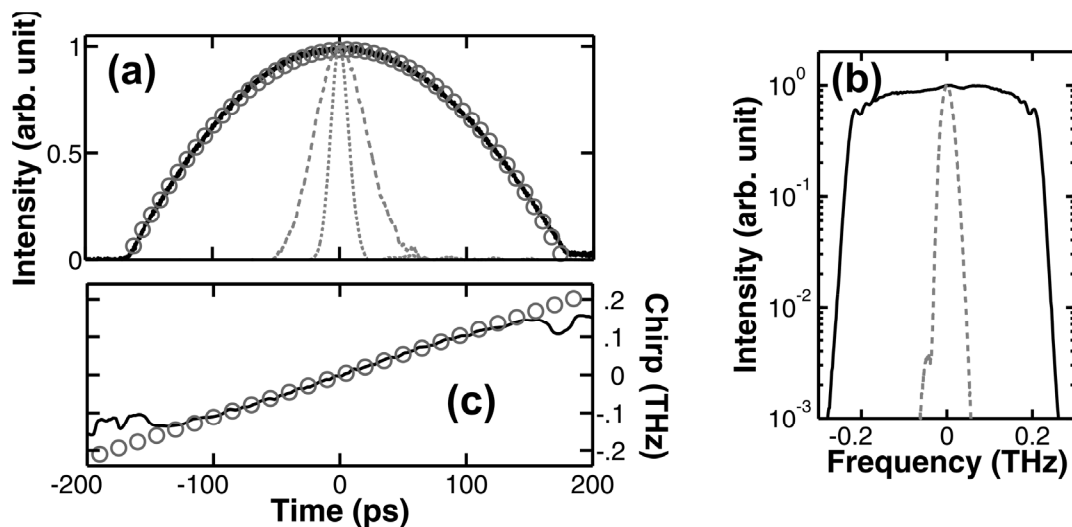


Figure 2 : Experimental properties of the initial pulse (dotted grey line), of the output pulse after passive linear propagation (dashed line) and of the output pulse after self-similar propagation (solid line) (a) Temporal intensity profiles recorded on the high-speed oscilloscope (b) Optical spectra (c) Frequency chirp. The temporal results obtained for a similariton are compared with a parabolic fit for the intensity profile and with a linear fit for the chirp (circles).

Conclusions

We have generated long 230-ps parabolic similariton pulses using an all-fibred device at telecommunication wavelengths. The parabolic profile has both been assessed by direct visualisation on a 50-GHz oscilloscope and by monitoring of the optical spectrum. The high quality of the profile will be a key element for future applications such as optical regeneration or retiming processes [2].

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