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Use of gas-filled multipass cells to generate clean supercontinuum spectra

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One of the most efficient nonlinear effects used to achieve ultrashort laser pulses is the self-phase modulation (SPM) [1]. Among the new post-compression setups which have been devised to generate large spectral broadening, multipass cells (MPC) are gaining relevance [2,3]. Multipass cells consist of a cavity formed by two mirrors and usually filled with gas, where a laser pulse travels during multiple roundtrips. To obtain short and clean pulses, one can let the pulse propagate in the enhanced frequency chirp regime, a regime introduced in optical fibers in the 1980s [4]. In this region, the spectrum is broadened with a clean spectral shape and phase because the dynamics is dominated by the nonlinearity, specially by SPM, but with the dispersion being non-negligible.

In order to study if this regime can be achieved in MPCs, we use a 3D numerical to simulate the propagation of a 177 fs full width half maximum (FWHM) Yb laser pulse with a central wavelength of 1030 nm. The propagation occurs along 20 roundtrips in a 40 cm confocal cavity filled with argon. The model calculates the evolution of the envelope of the pulse field affected by diffraction, dispersion, SPM and self-steepening.

We can delimit the enhanced frequency chirp regime by imposing the following three conditions: $L_{NL} < L < L_D$ and $1 < N = \sqrt{L_D/L_{NL}} < 20$, where L is the propagation length, L_{NL} is the nonlinear length and L_D is the dispersion length [5]. The third condition imposes that the maximum peak power reached during the propagation must be below its critical value. In these circumstances, we perform a scan in gas pressure and pulse energy looking for the best conditions of spectrum broadening while conserving a smooth shape.

An optimal region can be found for 10 bar and 100 μJ and its surroundings. In figure 1 we show the result obtained for this particular case. The spectrum obtained (Fig. 1(a)) presents a smooth spectral phase and a clean shape, far from the characteristic SPM oscillations. This shape assures a Fourier Limit compression factor of more than 12, with sidelobes less than 0.4 % of its peak intensity, entering in the few-cycle regime without showing any temporal secondary structure (Fig. 1(b)). This new regime opens a way to obtain clean ultrashort optical pulses using the multipass post-compression scheme

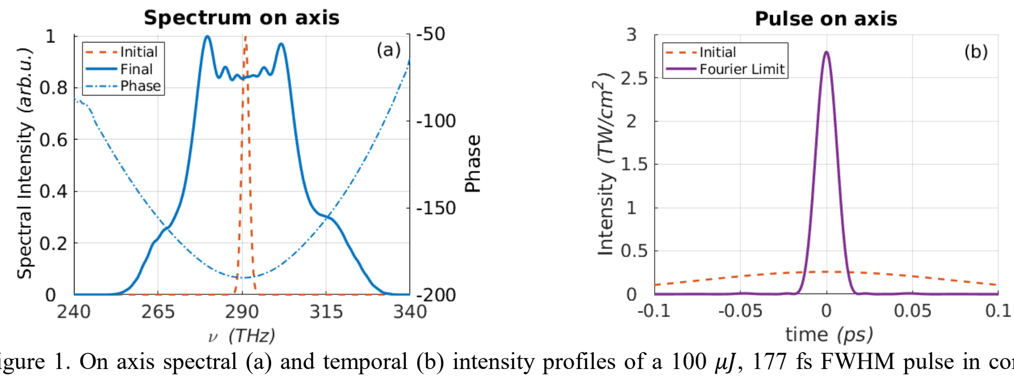

Figure 1. On axis spectral (a) and temporal (b) intensity profiles of a 100 μJ, 177 fs FWHM pulse in confocal cavity filled with 10 bar of argon. Temporal profile is plotted together with the Fourier Limit, reaching a compression factor of more than 12.

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