Intra and extra-cavity beam shaping for post-compression of Yb:YAG picosecond high-energy pulses

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Post-compression by self-phase modulation (SPM) enables to overcome the spectral bandwidth limitation of most laser gain materials enabling shorter powerful pulses. SPM in hollow-core fibers or multi-pass cells driven by high power lasers sources have shown impressive results [1,2]. However, post-compression of >100mJ pulses requires few meters-scale devices [3]. On the other hand, SPM in bulk thin-plates is a table-top sized solution to broaden the spectrum of high energy short pulses [4]. However, contrary to the multi-pass cells or hollow-core fiber where the post-compressed beam is spectrally homogeneous [5], the spatial homogeneity of the nonlinearities is a direct footprint of spatial distribution of the energy on the thin plate. Then, compared to gaussian beams, high energy flat-top beams directly shaped in the power amplifiers have shown highly homogeneous thin-plate post-compressed pulses [6]. Here we propose a new approach to perform thin plate pulse compression of high energy Yb systems with homogeneous spectrum by providing flat-top beams with the help of phase mirrors.

From this perspective, we investigated the flat-top beam generation from Ytterbium systems in two directions. Firstly, we explored the direct production of flat-top pulses in a Yb:YAG thin-disk cavity by developing a low-losses phase mirror. The cavity and the phase mirror have been designed to support the regenerative amplification of >50 mJ pulses at 1 kHz with a 4 mm-diameter flat-top spatial profile on the disk. Secondly, we investigated the extra-cavity conversion of gaussian beams to flat-top beams. In particular, we will show experimental results of spectral broadening by SPM when we focused such shaped beam coming from a 1.6 mJ-400 fs Yb:KGW system at 1kHz on a silica plate. We will discuss about the spectral homogeneity obtained from this experiment.

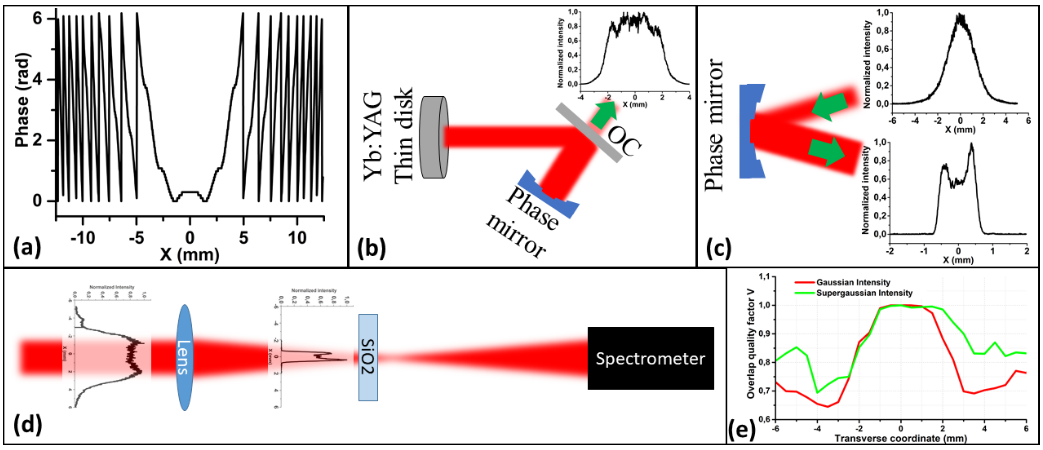

Fig. 1 : (a) Phase mirror phase designed for (b) intra-cavity and (c) extra cavity flat-top beam shaping. (d) Experimental setup for flat-top spectral broadening. (e) Gaussian versus supergaussian spectrum overlap quality factor

Finally, we will show how to apply this concept to the post-compression of higher energy pulses with HORIZON (1J-1kHz-1ps) currently under development. Starting from the Yb:YAG thin-disk regenerative amplifier front end delivering 50mJ pulses, we first designed a phase mirror to focus the compressed Gaussian beam in a flat-top beam at the intensity level of 1 TW/cm² on a 1-mm-thick silica plate. To post-compress the full 1J-pulses, we used another approach where we designed another phase mirror to shape the thin-disk regenerative amplifier beam in order to feed the final multipass power amplifier with an 8-mm-flat-top beam. In that case, the post-compression will be done just after the compressor without any further shaping. In both cases, the design of the phase mirror currently under manufacturing will be presented as well as the propagation and post-compression simulations. These results open the way to sub-100fs intense pulses from high energy powerful Yb:YAG systems.

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