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Energy scaling of multi-pass cells for nonlinear optics

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Nonlinear spectral broadening based on self-phase modulation (SPM) followed by pulse compression is a well-established approach in high average power and ultrashort pulse duration systems [1,2]. One exemplary implementation uses free space propagation through a nonlinear medium (solid or gas) in a multipass arrangement [3]. Scaling this method beyond the 10 mJ-range is mainly limited by three detrimental effects: excessive self-focusing, laser-induced mirror damage and gas ionization [4]. Dominantly multipass cells are realized with a Herriott-cell (HC) arrangement comprising two concave mirrors (cav-cav). Here we suggest a different approach, a concave-convex geometry (cav-vex). No foci are present in these multi-pass cells, mitigating the ionization problem. The decreased intensity permits folding of the arrangement, e.g., as in fig 1a), which reduces the required footprint for practical applications. Based on these properties, we see potential to spectrally broaden 1 J picosecond pulses in a setup with less than 6 m length.

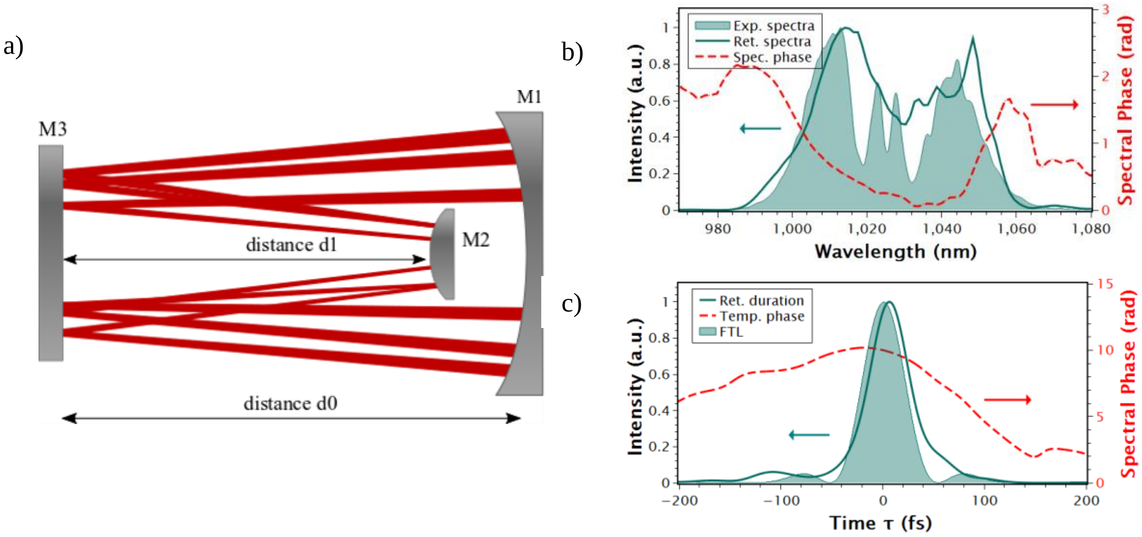

Fig. 1 a) Folding geometry for a convex-concave nonlinear multipass cell. b) Measured (shaded area) and FROG-retrieved (solid line) output spectrum and spectral phase (dashed line) for the Concave – Convex configuration at input energy of 15 µJ. The FROG error is 7×10^{-3} on a 256 × 256 grid. c) FROG-retrieved temporal profile (solid line), temporal phase profile (dashed line) and FTL reference (shaded area). The measured duration of 53 fs with FTL of 49 fs.

To prove the feasibility of this novel concept, we designed a HC broadening setup based on a cav-vex mirror arrangement and a fused silica plate for the nonlinear broadening medium. Pulses with 15 µJ of energy and 260 fs duration, from a commercial laser (Light Conversion PHAROS), are spectrally broadened to a spectrum spanning from 990 nm to 1070 nm (Fig. 1b, shaded area) with a corresponding Fourier-transform limit of 49 fs, which corresponds to a compression factor of 5.5. Compressed pulses are measured using a frequency-resolved optical gating device (APE GmbH), obtaining a pulse duration of 53 fs FWHM (Fig. 1c, shaded area) with a transmission efficiency of 91 %. The concave-convex arrangement delivers excellent spatio-spectral homogeneity with a weighted-average spectral overlap integral exceeding 90 % [3], as good as concave-concave cells. In conclusion, these findings show that using the convex-concave configuration is a viable option for external broadening and compression for a wide range of pulse energy, average power and durations. Moreover, they allow excellent performance in a reduced footprint, avoiding ionization of the media and the damage of the cell mirrors. As a result, the concept should allow energy scaling towards 1 J-level and TW-level input peak powers.

References

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