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Frequency domain nonlinear optics.

FRANCOIS LEGARE, INRS-EMT

The universal dilemma of gain narrowing occurring in fs amplifiers prevents ultra-high power lasers from delivering few-cycle pulses. This problem is overcome by a new amplification concept: Frequency domain Optical Parametric Amplification – FOPA [1]. It enables simultaneous up-scaling of peak power and amplified spectral bandwidth and can be performed at any wavelength range of conventional amplification schemes, however, with the capability to amplify single cycles of light. The key idea for amplification of octave-spanning spectra without loss of spectral bandwidth is to amplify the broad spectrum "slice by slice" in the frequency domain, i.e. in the Fourier plane of a *4f*-setup. The striking advantages of this scheme, are its capability to amplify (more than) one octave of bandwidth without shorting the corresponding pulse duration. This is because ultrabroadband phase matching is not defined by the properties of the nonlinear crystal employed but the number of crystals employed. In the same manner, to increase the output energy one simply has to increase the spectral extension in the Fourier plane and to add one more crystal. Thus, increasing pulse energy and shortening its duration accompany each other. A proof of principle experiment was carried out at ALLS on the sub-two cycle IR beam line and yielded record breaking performance in the field of few-cycle IR lasers. 100μJ two-cycle pulses from a hollow core fibre compression setup were amplified to 1.43mJ without distorting spatial or temporal properties. Pulse duration at the input of FOPA and after FOPA remains the same. Recently, we have started upgrading this system to be pumped by 250 mJ to reach 40 mJ two-cycle IR few-cycle pulses and latest results will be presented at the conference. Furthermore, the extension of the concept of FOPA to other nonlinear optical processes will be discussed. [1] B. E. Schmidt et al. *Nature Commun.* **5**, 3643 (2014).