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Short-pulse optical parametric chirped-pulse amplification for the generation of high-power few-cycle pulses

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In the quest for a way to generate ultrashort, high-power, few-cycle laser pulses the discovery of optical parametric amplification (OPA) has opened up the path towards a completely new regime, well beyond that of conventional laser amplification technology [1]. The main advantage of this parametric amplification process is that it allows for an extremely broad amplification bandwidth compared to any known laser amplifier medium. When combined with the chirped-pulse amplification (CPA) principle (i.e. OPCPA), on one hand pulses of just 10 fs duration and 8 mJ pulse energy have been demonstrated [2]. On the other hand, pulse energies of up to 30 J were also achieved on a different OPCPA system [3]; the pulse duration in this case, however, was 100 fs.

In order to combine ultrashort pulse durations (i.e. pulses in the few-cycle regime) with high pulse energies (i.e. in the Joule range) we propose to pump an OPCPA chain with TW-scale short pulses (100 fs–1 ps instead of >100 ps of previous OPCPA systems) delivered by a conventional CPA system. This approach inherently improves the conditions for generating high-power ultrashort pulses using OPCPA in the following ways. Firstly, the short pump pulse duration reduces the necessary stretching factor for the seed pulse, thereby increasing stretching and compression fidelity. Secondly, also due to the shortened pump pulse duration, a much higher contrast is achieved. Finally, the significantly increased pump power makes the use of thinner OPCPA crystals possible, which implies an even broader amplification bandwidth, thereby allowing for even shorter pulses.

We carried out theoretical investigations to show the feasibility of such a set-up. Alongside these studies we will also present preliminary experimental results of an OPCPA system pumped by the output of our Ti:Sapphire ATLAS laser, currently delivering 350 mJ in 43 fs. An insight into the planned scaling of this technique to petawatt levels (i.e. the Petawatt-Field-Synthesizer project at the MPQ) will also be given.

References

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