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Prospective Studies for Combining Multi-PW Pulses

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Extreme Light Infrastructure –Nuclear Physics (ELI-NP) under construction in Romania will host a laser system with two parallel 10PW arms make possible power powers in excess of 10PW, once the synchronization of the two beams is demonstrated at a jitter level below the pulse duration.
A short review of ELI-NP laser specifications is presented. The rough monitoring of the synchronization can be performed using the plasma mirror technique reported in [1], with temporal resolution down to 2 ps. The overlap of the pulses can be achieved using nonlinear processes such as second order autocorrelation. In order to reach coherent combination of the pulses, the jitter of the two pulses shall drop below a quarter of period of the pulse, which is ˜0.5fs in the ELI-NP case. Further, the proposed path to follow for the pulse duration reduction and peak power boost is spectral combination of ultrashort laser pulses. A collinear combination method was proposed, based on the spectral combination of parallel laser pulses, with complementary spectra, in chirped pulse amplification (CPA) laser systems. In a proof-of-principle experiment, it was demonstrated that two long pulses of 330 fs can be overlapped in a collinear way, to produce a shorter pulse, of 190 fs. As a consequence, it is shown that the power for the combined pulse obtained is up to a factor of 1.7 larger than the sum of the peak powers of each individual pulse. The spectral phase of the combined pulse was characterized with lambda/10 accuracy, using spectral interferometry. A way to implement the method at parallel CPA laser facilities, such as ELI-NP, using no transmission optics, was indicated [2].
However, the collinear spectral coherent combination method proposed is complex in terms of hardware use, using 6 large gratings. An alternative way towards a simpler combination is to synthesise the ultrashort pulse directly in the interaction point.
Hence, non-collinear spectral coherent combining (NCSCC) of ultrashort pulses is analyzed 2D modeling of the electromagnetic field is performed in case of NCSCC using two or three pulses with different wavelengths. In the case of two pulses, a potentially unwanted spatio-temporal structure of the field appears, corresponding to spatial and temporal modulation of the pulse. By using NCSCC of three 62 fs long pulses with different spectral composition, such spatial-temporal coupling is eliminated and the combined pulse duration in the focal region drops to less than half. The method is scalable to a large number of ultrashort pulses. Increasing the number of beams, the pulse duration drops accordingly [3]. The results are relevant for projects such as ICAN [4].
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