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Compression of laser radiation in plasmas using electromagnetic cascading[1]

SERGUEI KALMYKOV[2], Department of Physics and Institute for Fusion Studies, The University of Texas at Austin

We theoretically suggest an approach to generation of trains of few-femtosecond electromagnetic (EM) pulses in rarefied plasmas. The technique is based on the near-resonant laser beat wave excitation of electron plasma wave (EPW). The EPW modifies the refractive index of plasma thus inducing the periodic phase modulation of the driving laser (the modulation period being equal to the beat period). In spectral terms, the phase modulation is expressed as an EM cascading with the laser bandwidth proportional to the product of the plasma length, laser wavelength, and electron density perturbation in the EPW. In the case of beat wave downshifted from the Langmuir plasma frequency the longer-wavelength spectral components are advanced in time with respect to the shorter-wavelength ones near the center of each laser beat note. The anomalous group velocity dispersion of plasma compresses so chirped beat notes to a few-laser-pulse duration thus creating a train of sharp EM spikes with the beat wave periodicity. Depending on the plasma and laser parameters, chirping and compression can be implemented either concurrently in the same, or sequentially in different plasmas. Evolution of the laser beat wave and electron density perturbations is described in time and in two spatial dimensions (2D) in a weakly relativistic approximation. Using the compression effect, we demonstrate that the relativistic bi-stability regime of the EPW excitation [G. Shvets, Phys. Rev. Lett. 93, 195004 (2004)] can be achieved with the initially sub-threshold beat wave pulse. The effects of 2D evolution such as the relativistic self-focusing and cascade focusing are also addressed. We conjecture that this technique could be used for increasing the local power of sub- picosecond petawatt laser beams.

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[2]In collaboration with Gennady Shvets