



FRONTIERS IN OPTICAL COHERENT AND ULTRAFAST SCIENCE

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A nugget from FOCUS:

Title: Compression of laser radiation in plasmas via electromagnetic cascading

Investigators: Gennady Shvets, Serguei Kalmykov

The near-resonant beat wave excitation of an electron plasma wave (EPW) can be employed for generating trains of few-femtosecond electromagnetic (EM) pulses in rarefied plasmas. The EPW produces a co-moving index grating that causes laser phase modulation at the difference frequency. The bandwidth of the phase-modulated laser is proportional to the product of the plasma length, laser wavelength, and amplitude of the electron density perturbation. The laser spectrum consists of a cascade of red and blue sidebands spaced by integer multiples of the beat frequency.

When the beat frequency is lower than the electron plasma frequency, the red-shifted spectral components are advanced in time with respect to the blue-shifted ones near the center of each laser beat note. The group velocity dispersion of the plasma compresses the chirped beat notes to a few-laser-cycle duration thus creating a train of sharp EM spikes with the beat periodicity (THz repetition rate). Depending on the plasma and laser parameters, chirping and compression can be implemented either concurrently in the same or sequentially in different plasmas [S. Kalmykov and G. Shvets, *Phys. Rev. Lett.* **94**, 235001 (2005)].

Evolution of the laser beat wave and electron density perturbations is studied theoretically in time and one spatial dimension (1D) in the weakly relativistic approximation, and in time and three spatial dimensions (in the axi-symmetric cylindrical geometry) via fully relativistic PIC simulations. Using the compression effect, we demonstrate that the relativistic bi-stable regime of the EPW excitation [G. Shvets, *Phys. Rev. Lett.* **93**, 195004 (2004)] can be achieved with the initially sub-threshold beatwave pulse in the 1D geometry. PIC simulations indicate that the cascade compression effect persists in a realistic 3D axi-symmetric geometry and helps to maintain high laser intensity in the plasma over a few Rayleigh diffraction lengths (a few centimeters) [S. Kalmykov and G. Shvets, to appear in *Phys. Plasmas* in April 2006]. The EPW driven by the electromagnetic cascade in the 3D geometry can accelerate injected electrons to GeV energy.

This work has been selected as the Research Highlight in the July 14, 2005 issue of *Nature*.