Novel x-ray generation schemes based on electron cusps formed via intense laser plasma interaction

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We present the results of two kinds of experiments and theoretical description for generating coherent, ultrashort, tunable x-ray photons. Nonlinear interaction of intense laser pulses with plasma creates stable, specific structures such as electron cusps. For example, wake waves excited in an unerdense plasma by intense, short-pulse laser becomes dense and propagates along the laser pulse. This is called a relativistic flying mirror. The flying mirror can reflect a counter-propagating laser pulse and directly convert it into high-frequency radiation, with a frequency multiplication factor ~ $4\gamma^2$ and a pulse shortening with the same factor. We present the results of experiments in which a 9 TW laser pulse focused into a He gas jet generated the Flying Mirror, which partly reflected a 1 TW pulse, giving up to ~ 10^{10} photons, 60 nJ (~1.4×10^{12} photons/sr) in the XUV spectral region (12.8-22 nm).

Another mechanism of coherent x-ray generation is based on a single laser pulse irradiating gas jet target. In this case, bright high-order harmonics of both odd and even orders are emitted in the forward direction. We attribute this to the synchrotron or nonlinear Thomson scattering of a bunch of electrons in the cusp interacting with the laser. A 9 TW laser pulse produced harmonics with the photon energies up to 320 eV, with ~ 2×10^{11} photons/sr (~ 3 μJ/sr) in the 90-250 eV spectral region. The experimentally demonstrated harmonics cannot be explained by previously known mechanisms. We introduce a novel mechanism of harmonic generation by relativistic laser in underdense plasma. Favorable scalings allow straightforward extension of the harmonic generation into the keV spectral region.

Both methods use cusp structures formed by an intense, ultrashort laser pulse in a underdense plasma. The two methods presented here proved capabilities of compact convenient sources of ultrashort coherent XUV and X-ray pulses. Furthermore, radiation from these sources bears important information about the processes in the relativistic laser plasma, which can be used for diagnostics.