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High-energy coherent THz radiation from laser wakefield accelerated ultrashort electron bunches

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High-energy Coherent THz Radiation From Laser Wakefield Accelerated Ultrashort Electron Bunches

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Abstract: We report on the observation and characterization of intense pulsed coherent THz radiation. This radiation is generated by ultra-short multi-nC electron bunches passing the plasma/vacuum boundary. The electron bunches are produced through laser wakefield acceleration.

OCIS codes: (350.5400) Plasmas , (350.4010) Microwaves, (320.2250) Femtosecond phenomena

We report on the observation [1] of coherent THz radiation from femtosecond laser-accelerated electron bunches [2]. These multi nanoCoulomb bunches, concentrated in a length of a few plasma periods (several tens of microns) will experience a strongly reduced space charge force due to shielding by the background ions. The radiation, scaling We report on the observation [1] of coherent THz radiation from femtosecond laser-accelerated electron bunches [2]. These multi nanoCoulomb bunches, concentrated in a length of a few plasma periods (several tens of microns) will experience a strongly reduced space charge force due to shielding by the background ions. The radiation, scaling quadratically with bunch charge (see Fig. 1), is a combination of diffraction and transition radiation by the electrons passing the plasma/vacuum boundary [3,4]. If both a large collection angle as well as a large transverse plasma size are realized, theory [5] predicts energies on the order of 100 microJoule per THz pulse. Recent results on characterization of this source (energy and spectrum) will be discussed.

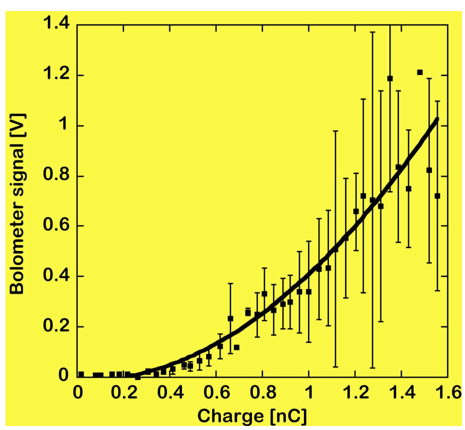

Fig. 1. The THz detector (bolometer) shows a quadratic dependence on bunch charge, indicating coherent radiation. For this limited collection angle (<30 mrad), pulse energies up to 5 nJ were measured.

At LBNL, we operate a 10TW Ti:Sapphire laser, with a pulse length of 50 fs and a repetition rate of 10 Hz. When such a pulse is focused (focal spot on the order of several micron) onto He-gas emerging from a gas-jet, a co-propagating plasma wave is set up. The longitudinal electric fields that are build up in this wave can reach 10-100 GV/m with a wave phase velocity close to the group velocity of the laser. In the regime we operate in, background electrons can get trapped by the plasma wave, and will be accelerated to relativistic energies. Experiments with such accelerators have demonstrated [2] the generation of multi-nanoCoulomb electron bunches, with a 100% energy spread (Bolzmann-like distribution with temperature of circa 5 MeV). Beam divergence can be as small as 10 mrad. Since in our lab the pulse-length is several times larger than the plasma period, the regime of acceleration is referred to as the self-modulated laser wakefield regime. In this regime, the growth of the plasma wave, and therefore the electron acceleration, is enhanced through an instability that causes the laser pulse envelope to be modulated at the plasma frequency.

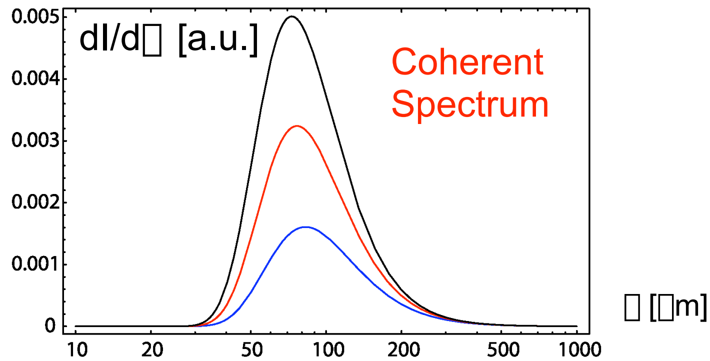

Fig. 2. This curve shows the theoretically predicted power spectrum dI/d□ of Coherent THz radiation emitted in a 100 mrad solid angle by a 15 □m long electron bunch (gaussian). The electron bunch is passing through a plasma/vacuum interface with a transverse radius of 100 □m and the bunch has Boltzmann temperatures of 3 (top), 5 (middle) and 10 (bottom) MeV.

As the electron bunch exits the plasma, transition radiation is emitted by the transverse currents at the boundary [1,3,4]. Modeling [5] indicates that the plasma/vacuum boundary can be treated as a metal/vacuum boundary. Since the plane of transition is finite, diffraction effects will influence the radiation properties, such as total energy, spectrum and cone-angle [5]. In Fig 2. a theoretical prediction of the power spectrum of the coherent radiation is presented. The wavelength cut-on comes from the bunch form-factor, while the cut-off originates from the diffraction limitation at higher wavelengths.
Our research focuses on the detection of coherent radiation, emitted in the THz regime. Recent results will be discussed. An improved collection system has increased the measured energy per THz pulse from several nJ to energies on the order of 100 nJ. This work is performed under DOE-contract DE-AC-03-76SF0098. C.G.R. Geddes acknowledges the Hertz Foundation.

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