THz Makes X-ray

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Within only a single decade, the energy of THz pulses generated by optical rectification of laser pulses increased dramaticall: by about eighth orders of magnitude, from the pJ level to over 100 ÂµJ (J. A. FÃ¼lÃ¶p et al.: Optics Lett. 37, 557-559 (2012)). According to model calculations, the application of the contact grating technique and high-energy half a ps long laser pulses will enable in the near future generation of 10 mJ near single-cycle or multi-cycl! e THz pulses in a few-cm diameter beam. By focusing these pulses, electric field strengths up to 100 MV/cm will be reached. According to model calculations, THz pulses with such extremely high fields will open up new possibilities for ultrashort light pulse generation from the visible to the X-ray spectral ranges. In my presentation I intend to show our results connected to improvement of attosecond pulse generation: enhancement of high harmonic generation around the cut-off frequency (K. Kovacs et al.: Phys. Rev. Lett. 108, 193903 2012)) and extension of the cut-off frequency (E. Balogh et al.: Phys. Rev. A 84 023806 (2011)) by extremely high field THz pulses. Another important application field of extremely intense THz pulses is the manipulation of relativistic electron beams (J. Hebling et al.: arXiv 1109.6852v1 (2011)). According to self-developed particle â€“ particle interaction calculations, using a laser gate (A. E. Kaplan and A. L. Pokrovsky: Opt. Express 17, 6194 (2009)) driven by THz pulses, it is possible to create a 20-nm-long sheet of 20 MeV electrons with a bunch charge of 30 fC. According to GPT simulations, a train of sub-20-nm-long sheets of 40 â€“ 80 MeV electrons with up to 400 fC bunch charge can be created by IFEL. Thomson scattering of THz pulses on these electron sheets can result in single-cycle (or temporally shaped) light pulses in the 50 nm - 400 nm wavelength range with up to a few tens of pJ energy. Thomson scattering of THz pulses on longer (100 fs) electron bunches will result in X-ray pulses in the 2.1 Ã· 0.8 Ã… range for 300 Ã· 500 MeV electron energy. Such electron bunches can be generated in modest-size linear microwave accelerators. It seems to be even more attractive to scatter THz pulses on ultrashort electron bunches generated by a centimeter-scale laser plasma accelerator. Scattering of 100 ps long pulses with 1 THz frequency on the reported 0.5 GeV electron bunch with 50 pC charge (W. P. Leemans et al.: Nature Physics 2, 696-699 (2006)) would result in X-ray pulses with 0.8 Ã… wavelength, 20 pJ energy and about 10 fs duration. Such a small scale ultrashort X-ray pulse source alone, or combined with the THz source could be an attractive device for investigation of structure and dynamics of condensed matter for example by THz pump â€“ X-ray probe measurements.