DAMOP12-2012-000107
Abstract for an Invited Paper
for the DAMOP12 Meeting of
the American Physical Society

Gigavolt-Energy Electrons and Femtosecond-Duration Hard X-Rays Driven by Extreme Light[1]

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The interactions of high-peak power laser light focused to extremely high intensity, or "extreme light," is at the core of high-energy laser-driven electron accelerators, and novel laser-synchrotron x-ray light sources. The hallmark of extreme light is its ability to cause the instantaneous electron quiver motion to become relativistic. We discuss recent progress in understanding the physics of extreme light, and the advanced electron and x-ray technologies that it drives. Through the mechanism of relativistic self-guiding, focused light from our 100-TW Diocles laser was propagated in plasma at relativistic intensity for distance of 1 cm [corresponding to over 15 vacuum diffraction (Rayleigh) ranges]. As a result of this extended propagation length, electrons were accelerated by a laser-wakefield to near GeV energy in a well-collimated beam. The electron beam was measured to be tunable over a wide energy range, 100 – 800 MeV, with 5– 25% energy spread, and 1–4-mrad divergence angle. The experimental results were found to be in reasonable agreement with the results of numerical simulation, which predict even higher electron energy (multi-GeV) with our recently upgraded peak laser power (>0.5 PW). These characteristics, along with their lack of any measurable amount of dark-current, make these electron beams good candidates for driving synchrotron x-ray sources. The development of one such x-ray source will also be discussed, one driven by inverse Compton scattering of laser light by laser-accelerated electrons. Its small radiation source size ($\sim$ 10 microns) and low angular beam divergence (< 10 mrad) make it quite promising for applications in radiology. By virtue of its ultra-short pulse duration (< 10 fs) and wide energy tunability (10 keV – 10 MeV), it can also be used to probe matter with atomic-scale spatial and temporal resolution—simultaneously.

[1]The following funding support is gratefully acknowledged: AFOSR FA9550-08-1-0232 and FA9550-11-1-0157; DOE DE-FG02-05ER15663; and DTRA HDTRA1-11-C-0001.