Final Scientific and Technical Report

Title: The Study of Advanced Accelerator Physics Research at UCLA Using the ATF at BNL: Vacuum Acceleration by Laser of Free Electrons

Institution: The Regents of the University of California
University of California at Los Angeles (UCLA)

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Period of Performance: 05/01/2012 to 09/30/2013

Objective and Major Goal of the Project:

The objective and major goal of the project was to demonstrate that a tightly focused laser on a vacuum can accelerate an electron beam in free space.

Scope of Work and Accomplishment:

An experiment was designed and data taken to show that a tightly focused laser on a vacuum can accelerate an electron beam in free space. The experiment was performed at the Brookhaven National Laboratory Accelerator Test Facility in collaboration with the BNL ATF support team and physicists from Fudan University, Shanghai, China. The BNL ATF is one of the few facilities in the world that can provide a high quality electron beam and a high intensity laser beam. The experiment used an electron beam having energy of 20 MeV. The CO_2 laser had energy of about 3 Joule. A high quality laser photo-cathode initiated beam of low emittance was accelerated to 20 MeV and the CO_2 laser was focused and brought into contact with the electron beam. The resulting electron beam was then passed through a magnet spectrometer and the results were recorded using a fast camera.

The experiment was carried out in March 2012. The CO_2 laser pulse delivered about 30 shots. The peak power of the CO_2 laser pulse was low for the first 10 shots, i.e. about 1 Joule. However, the laser pulse remained stable for the final 20 shots at 3 Joule. Every snapshot was a pair of laser-on and laser-off pictures. The laser beam and the electron beam had pulse duration of 5 ps and the synchronization resolution was about 1 ps. All 30 snapshot pairs showed two important features. 1) The electron beam profile shape remained stable and unchanged for two snapshots in one set with 2 seconds latency. 2) The energy spread always increased with the laser on. There was no exception to this feature through the entire experiment. From these two features, it was concluded that the interaction between the electron beam and the laser beam in vacuum was the only reason for increases in the energy spread distribution, and causes acceleration and de-acceleration on both energy spread ends simultaneously. This conclusion is consistent with the simulation results.

Conclusion:

This grant provided funding to support a successful proof-of-principle experiment to demonstrate acceleration of electrons by a laser in vacuum. The findings may have application in future laser fusion research. The project provided advances in particle accelerator technologies and provided additional knowledge and training to the UCLA postdoctoral and graduate student team engaged in the project. A complete description of the experiment and the results (to include the physics, a description of the experimental equipment, the experimental set-up, the experimental data, conclusions, acknowledgements and references) can be found in the Journal of Modern Physics, 2013, 4, 1-6.