Probing Warm Dense Silica with Betatron Radiation

Jordan Kotick

Office of Science, Science Undergraduate Laboratory
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Abstract

Laser wakefield acceleration (LWFA) has been shown to produce short X-ray pulses from oscillations of electrons within the plasma wake. These betatron X-rays pulses have a broad, synchrotron-like energy spectrum and a duration on the order of the driving laser pulse, thereby enabling probing of ultrafast interactions. Using the 1 J, 40fs short-pulse laser at the Matter in Extreme Conditions experimental station at LCLS, we have implemented LWFA to generate and subsequently characterized betatron X-rays. A scintillator and lanex screen were used to measure the charge fluence and energy spectrum of the produced electron beam.

Warm Dense Silica

- Silica (SiO_2) is present in many optoelectronic components
- Development of many novel applications rely on better understanding of photoinduced structural changes
- Dynamic transition into warm dense matter requires simultaneous measurement of ionic and electronic structures

Probing Electron and Ion Structures Simultaneously

X-ray Diffraction

- Probes ion structure
- Requires monochromatic, fs

XANES at Oxygen K-edge (X-ray Absorption Near Edge Spectroscopy)

- Probes electron structures
- Requires broadband, fs

Novel broadband X-ray source necessary...

Betatron Radiation

X-rays produced through LWFA process

The following link shows a simulation made using Virtual Laser Plasma Lab PIC simulator. Credits go to Youtube user Taylor Ratliff.

[Laser Wakefield Acceleration LWFA of electrons](#)

Betatron Radiation

- X-ray pulses have short duration
- Synchrotron-like spectrum
 - broadband
 - exponentially decreasing tail

An example of a betatron spectrum (estimated from experimental values)

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Experimental Setup

■ Gas cell

← Gas Cell Probe

← Gas Cell Pump/
Betatron X-ray

← Target Pump
(~10 mJ)

← LCLS X-ray
Probe

Electron Detection

- Scintillators provide a preliminary diagnostic to confirm presence of electron beam
 - Electrons are bent by magnet into beam block
 - Bremsstrahlung radiation produces light in scintillator
 - Induces a voltage via a photomultiplier tube
 - Voltage measured by oscilloscope is proportional to number of electrons produced
- Wrote a Python script to compile all of a day's shots

Scintillator Results

Scintillator Results

Scintillator Results

Lanex Diagnostic

- Lanex screen used to measure charge fluence above saturation limit of scintillators
- Lanex screen also yields the energy spectrum of electrons by measuring their magnetic deflection
 - Displacement is less for particles with more forward momentum

Lanex Diagnostic

- Screen is hit by electrons bent by magnet, which scintillates and is imaged by a camera
- Results in energy spectrum represented spatially

Image shows Lanex screen scintillating due to electrons. Bright streak shows electron beam path, with higher energies to the right.

Lanex Readings

Lanex Readings

Lanex Readings

- Lanex screen provided valuable electron production diagnostic
- Spectrum gives qualitative analysis of energies
 - The current data is uncalibrated with respect to both energy and counts
 - With calibration, actual electron energy spectrum can be calculated

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