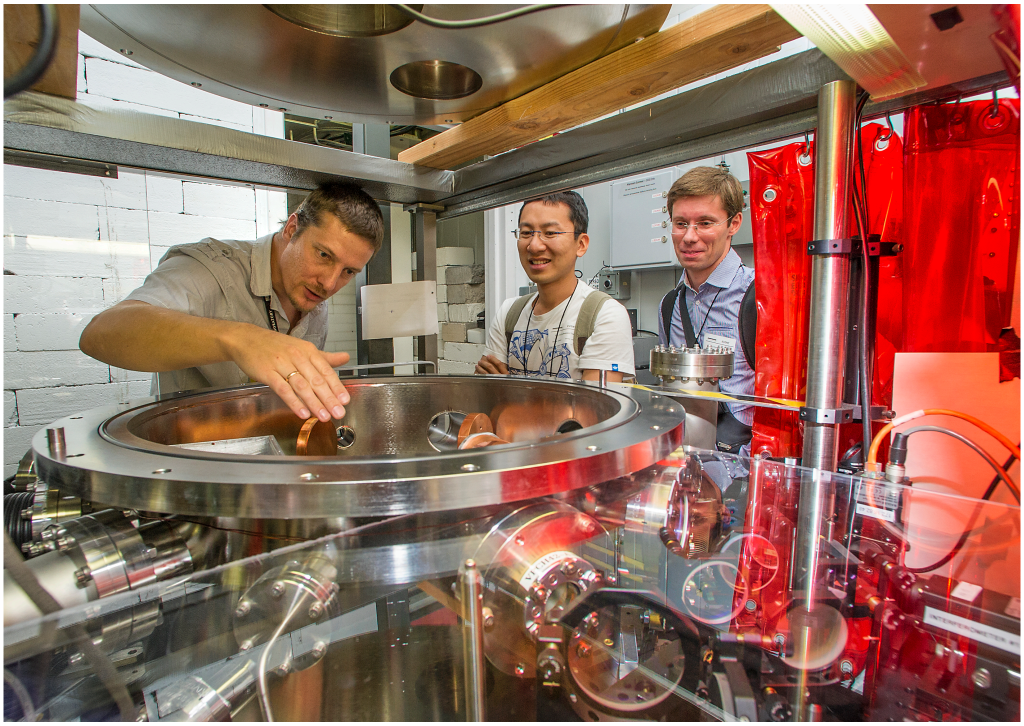

FEL'13 PARTICIPANTS AT THE ION GENERATION EXPERIMENT AT THE ATF

ATF Newsletter

Fall 2013

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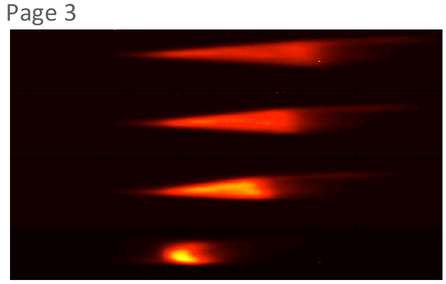
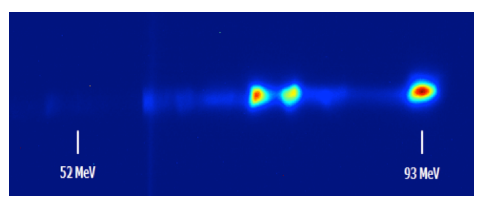
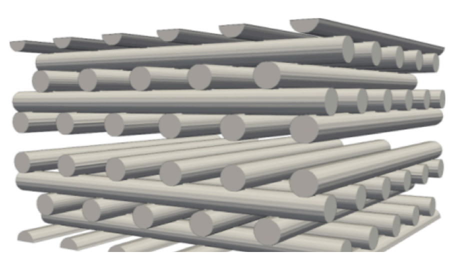
IN THIS ISSUE







ATF Status Update

by Christina Swinson

Welcome to the ATF Fall newsletter. The last few months have seen success in multiple experiments and completion of the ATF-II proposal, also first testing of the newly arrived X-band RF equipment (more about this next time). We also enjoyed playing host to FEL'13 participants, who took a tour of the ATF in August (see photo above).

Experimental Overview

The ATF has hosted 7 different experiments since the last newsletter; along side our own beam studies and instrumentation programs. Two new experiments (both Radiabeam) joined the fray; **High-resolution Transverse Diagnostic Based on Fiber Optics** and **Corrugated Plate De-Chirper**.

High-Brightness Picosecond Ion Beam Source – Work continues to try to characterize proton production by CO2 laser using a gas jet target.

RUBICON IFEL experiment – This IFEL experiment achieved great results this year. A more in depth view of the experiment and initial results can be seen on page 4.

PWFA Holography – This experiment aims to achieve a direct measurement of a single electron beam driven wake using frequency domain holographic reconstruction. This project uses both laser and e-beam and makes use of the ATF's new Ti:Sapphire laser. Recent work is for laser-ebeam synchronization.

Plasma Wakefields in the Quasi-Nonlinear Regime – Recent runs have ensured successful commissioning of the new experimental chamber, which was installed this summer. Data collection is scheduled to commence later this month.

AXIS 5μm Damage Test – The ATF laser system has been tasked for use in testing the resilience of optical materials. Some tests, previously performed in air, have now been repeated in vacuum.

Operations etc.

by Christina Swinson

Electron Beam Status

This quarter has seen beam studies in beam lines 1&2, including bunch length studies and edge radiation diagnostics. Most experimental beam time for users saw beam delivered to the new exprimental chamber, located on beam line #2. See right (fig. 1) for distribution of e-beam activities.

Typical beam parameters for this quarter ranged from 50 – 65 MeV in energy and 30 – 500 pC charge.

User experiments served:

AE41 – RUBICON (UCLA)

AE43 – PWFA Holography (USC/U. Tex Aust.)

AE50 – PWFA in Quasi-nonlinear Regime (UCLA)

AE56 – High-resolution Diagnostic Based on Fiber Optics (Radiabeam)

AE57 – Corrugated-plate De-chirper (feasibility study, Radiabeam)

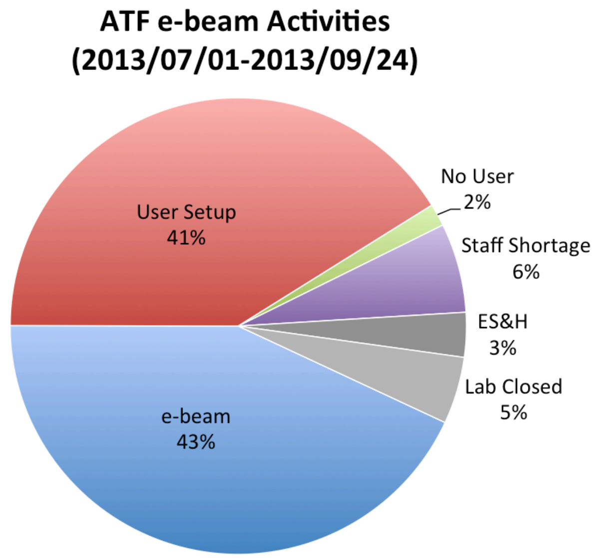


Figure 1: e-beam activities for the last quarter. The grey portions (ES&H and Lab Closed) represent times where beam running is unavoidably halted due, in this period, to tours, safety inspections and laboratory holidays.

Publications

Mikhail N. Polyanskiy, Marcus Babzien, Igor Pogorelsky and Vitaly Yakimenko, Ultrashort-pulse CO2 lasers: Ready for the race to petawatt? Proc. SPIE 8677, XIX International Symposium on High-Power Laser Systems and Applications 2012, 86770G (2013); doi:10.1117/12.2013389.

Sergey P. Antipov (Euclid TechLabs, LLC, Solon, Ohio) *et. al.* Experimental Demonstration of Energy Chirp Compensation by a Tunable Dielectric Based Structure arXiv:1308.56465646, Aug 26, 2013

NA-PAC

Dmitry Shchegolkov (LANL, Los Alamos, New Mexico) *et. al.* Beam Pulse Shaping Experiments for Uniform High Gradient Dielectric Wakefield Acceleration, NA-PAC, MOPAC24

Yun Fang (USC, Los Angeles, California) *et. al.* Seeding of the Self-modulation of a Long Particle Bunch in a Plasma, NA-PAC, MOPAC49

Sergey P. Antipov (Euclid TechLabs, LLC, Solon, Ohio) *et. al*. A Tunable Energy Chirp Correction, NA-PAC, MOPHO19

Sergey P. Antipov (Euclid TechLabs, LLC, Solon, Ohio) *et. al.* Subpicosecond Bu nch Train Production for High Power Tunable THz Source, NA-PAC, TUPMA08

IF YOU LIKE THIS NEWSLETTER

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Experimental Demonstration of Tunable De-chirper

by S. Antipov (Euclid Techlabs)

The free electron laser (FEL) is considered to be the main candidate for a short wavelength (UV to X-ray), short pulse (femto- to attosecond) light source. Demands on the electron beam needed to drive this class of FELs have become more and more challenging, including high repetition rate (~MHz), high peak current (a few kA), and low emittance (sub-micron normalized emittance). Short pulses (subpicosecond) are central to many of the next generation light source initiatives that are typical of linear accelerators. At the same time, at the output of the last compressor the electron beam will be left with a small chirp to compensate for wakefield effects through the rest of the accelerating stage. This residual chirp can be detrimental for the FEL performance and, thus, must be removed. This can be realized by a simple wakefield device. In 2011 we demonstrated energy compensation at the ATF.

The wake amplitude ~ $\eta \cdot q/a^2$, where η is the waveguide form factor, q (C) is the charge and a (m) is the characteristic size of the aperture. Hence tuning the transverse size of the aperture allows corresponding adjustment of the "strength" of the chirp corrector. Recently we demonstrated tunable chirp correction at the ATF. This is realized by a planar waveguide with tunable aperture (Figure 1).

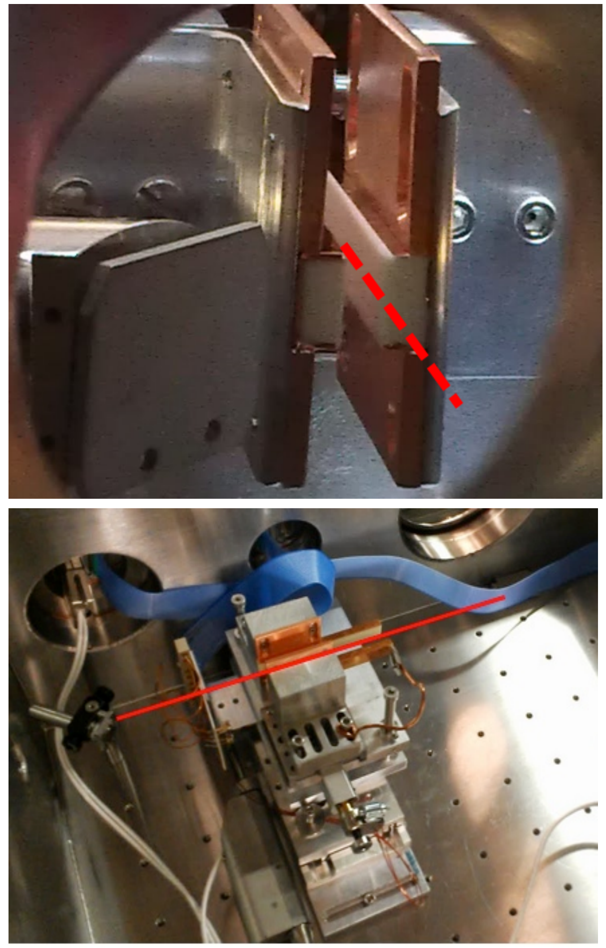

Figure 1: Photos of a planar tunable dechirper with the red line showing the electron beam trajectory.

The chirp corrector for ATF experiment is based on 1/2" x 1/4" x 4" long alumina bars and has tunable aperture. Tuning the aperture gives the ability to tune the strength of the chirp corrector. In the experiment we monitor the energy spectrum of the beam initially with the energy chirp. As we close the de-chirper aperture we observe that the energy spread gets reduced (Figure 2). Initial chirp of ~ 330 keV gets completely removed when the chirp corrector gap is 1 mm.

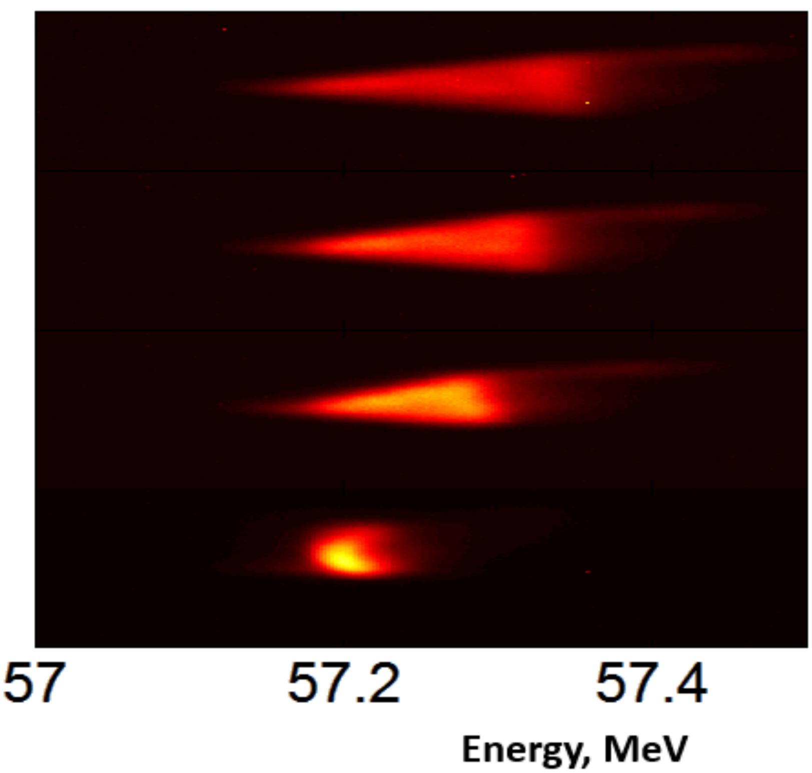

Figure 2: Measured energy spectra (57 – 57.5 MeV) of the beam passing through a chirp corrector with various gap sizes: 5.8, 2.8, 1.9 and 1 mm. The energy spread is seen to be significantly reduced as the gap size approaches its optimum value.

FOR MORE INFORMATION

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Helical IFEL acceleration at ATF

by J. Duris (UCLA)

The combination of ATF's linac and TW class CO_2 laser systems enables investigations into laser acceleration schemes such as the inverse free electron laser (IFEL). Past IFEL experiments utilized planar undulators to induce sinusoidal transverse motion in order to couple to the laser electric field. A drawback of this approach is that the electrons' transverse motion is reduced to zero two times per period, effectively halting energy transfer there. Introducing a circularly polarized undulator field improves this situation by causing the beam to move along a helix, thereby providing continuous energy transfer and improving the gradient by a factor of 2 or better.

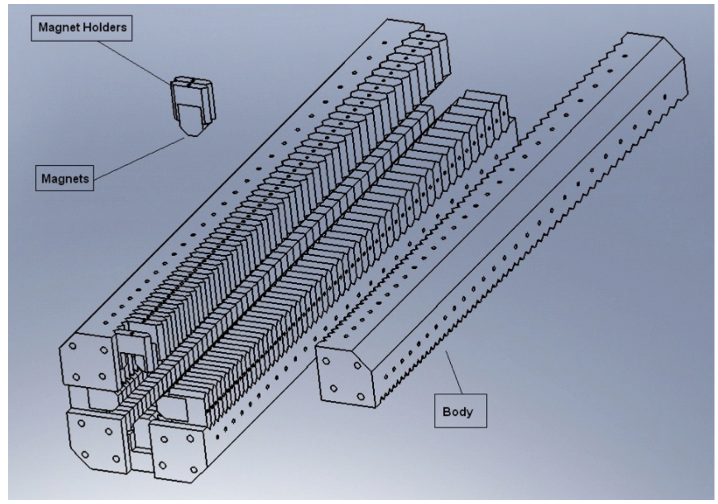

Figure 1: Engineering drawing of the helical Halbach permanent magnet undulator.

Experiments performed at UCLA set new records for IFEL accelerating gradients while experiments at ATF demonstrated high efficiency acceleration. The marriage of the two groups' experience through the UCLA-BNL helical IFEL collaboration at ATF allows the combination of high gradient and high efficiency acceleration through the use of helically polarized undulator and CO_2 laser fields.

The undulator, shown in Figure 1, is the first strongly field- and period-tapered undulator with a helical polarization. Work earlier this year lead to the observation of acceleration of 52 MeV electrons to 106 MeV with an average gradient of 100 MeV/m (see Figure 2), breaking IFEL energy gain and gradient records. More recently, the undulator was reconfigured to improve capture at the expense of final energy. This modification, along with improved laser diagnostics, lead to the transport of greater than 20% of a 110 pC beam from 52 to 93 MeV with an rms final energy spread of 1.8 %.

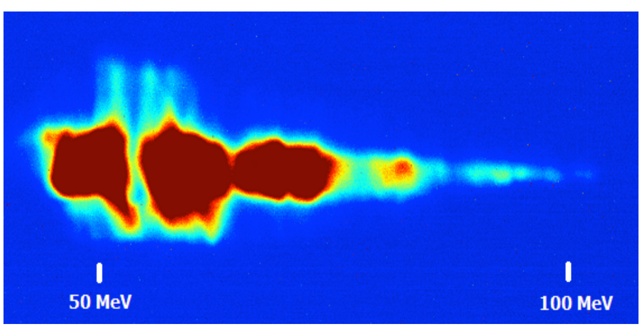

Figure 2: Raw spectra from early this year showing energy gain in excess of 50 MeV.

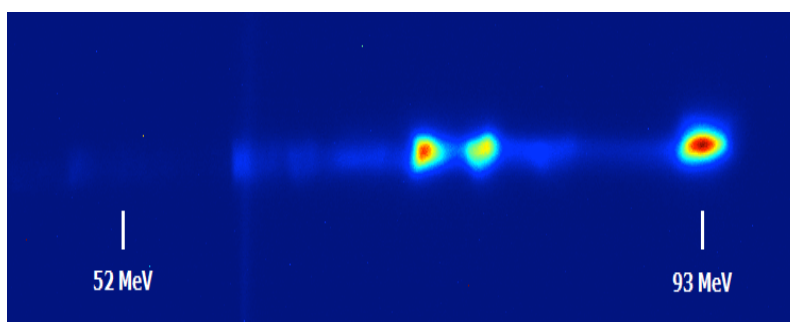

Figure 3: Recent raw spectra showing a significant fraction of captured beam.

These results demonstrate that the helical IFEL mechanism is a viable avenue for achieving compact accelerators and pave the way towards a meter-long GeV IFEL driver for compact light sources.

FOR MORE INFORMATION

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Wakefield excitation from a dielectric, 3D woodpile photonic structure

by P. Dinh Hoang with contributions from O. Williams, Y. Sakai, G. Andonian, B. Naranjo, and J. Rosenzweig (UCLA)

Studies in electron beam-driven, dielectric wakefield acceleration (DWA) have recently showed several experimental results in the terahertz range that affirm the viability of DWA as an advanced scheme to generate high-gradient accelerating fields. Recently, UCLA experimenters, in collaboration with the BNL ATF demonstrated mode excitation in a DWA structure with Bragg-reflector boundaries (i.e. alternating layers of dielectric materials to enhance the criterion of constructive interference for the excited mode). As a follow-on experiment, we have extended the principles of the 1D photonic "Bragg" structure to a fully 3D, all dielectric, photonic "woodpile" structure driven by the electron beam at the ATF.

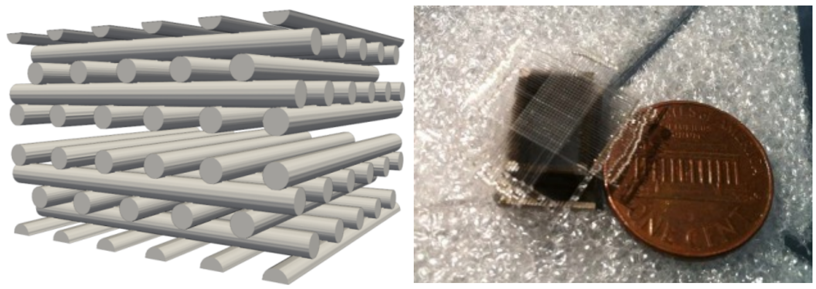

Figure1: device's conceptual design and realization

Generalization to lattices of more dimensions is difficult because of issues with micro- and nano-fabrication, and fragility of the dielectric material. Moreover, not all photonic lattices possess desirable confinement properties. The woodpile structure designed for this experiment is a full 3D lattice, which has a complete photonic bandgap. Figure 1 shows the conceptual design and the real device manually fabricated by UCLA. Each "log" in the device is made out of 125µm diameter, sapphire rods. The material is chosen for its relatively high dielectric constant and high breakdown threshold.

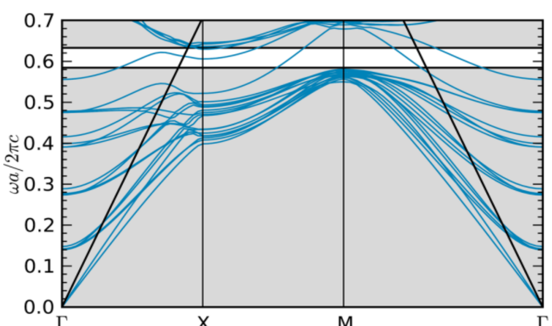

Figure 2: Theoretical bandgap and modes prediction

Although it is a finite-period device, frequency domain calculation predicts that some of the bandgap properties of the ideal lattice are still preserved. Figure 2 shows that for this structure, of only one lattice period on each side, formation of bandgap is still evident. Note that the penetration of a couple of modes into the bandgap is actually a commonly known feature of most lattices with defects. Under the Cherenkov condition, these trapped modes generate wakefields that are observable using diagnostic techniques developed by UCLA at the BNL ATF in previous DWA experiments. Our initial analysis of data has shown the presence of the "trapped mode" in the wakefield. In figure 3, the FTDT simulation (blue) is compared directly with the data (red). Indeed, the trapped mode is one of the prominent peaks in both the data and the simulation.

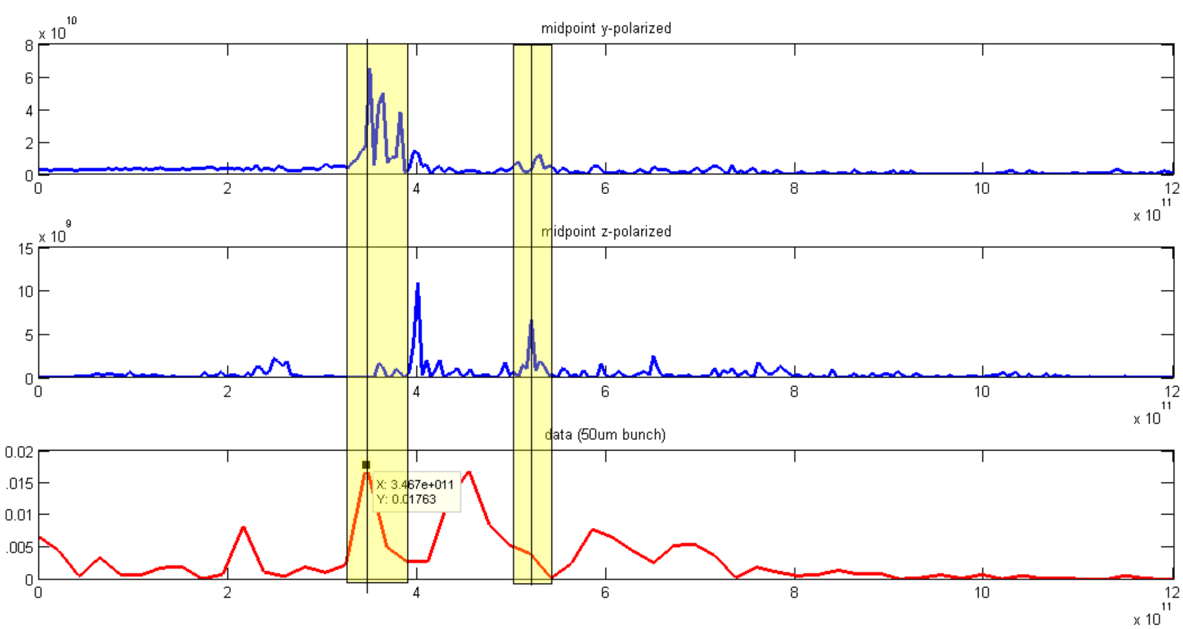

Figure 3: FTDT simulation (blue) and data (red)

The results are important for future beam-driven DWA studies, but also have relevance in laser-driven structures, which are inherently photonic structures, and permit achieving fields in excess of 10GV/m. Such structures have applications in the realization of fully coherent, table-top x-ray sources or as accelerating modules for future collider designs.

FOR MORE INFORMATION

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