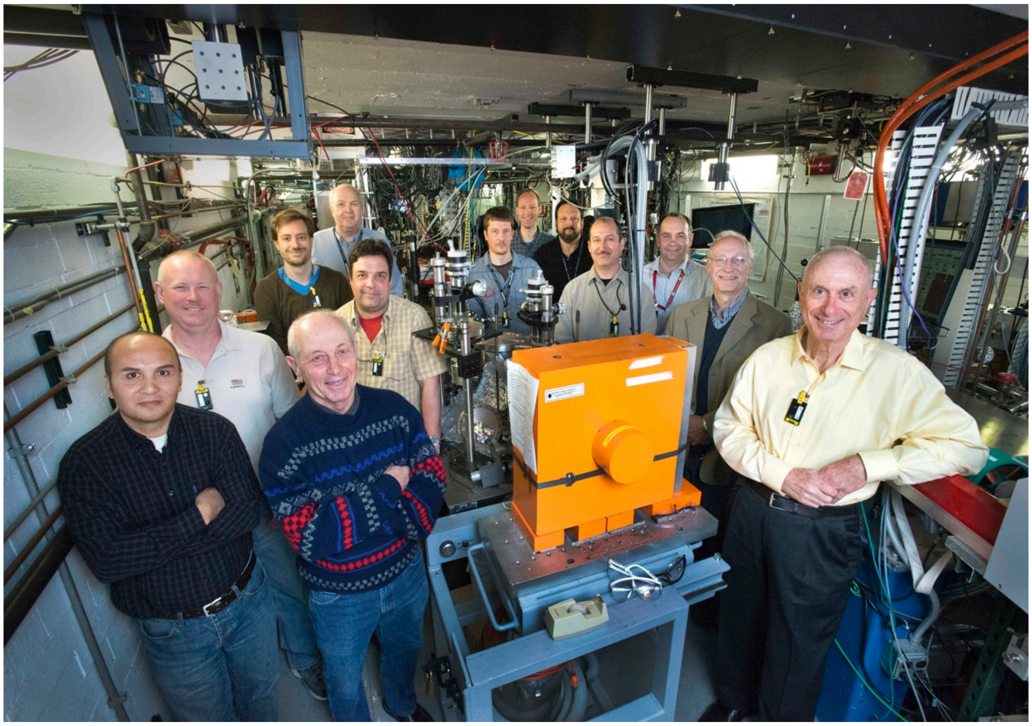

TEAM ATF

ATF
Newsletter

July 2013

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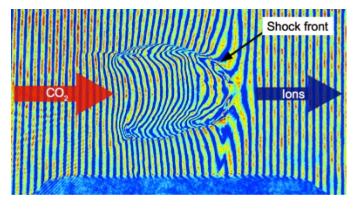

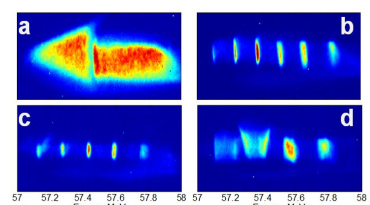

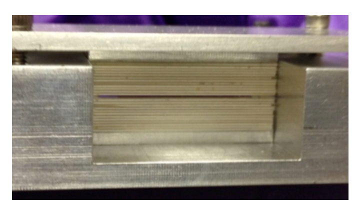

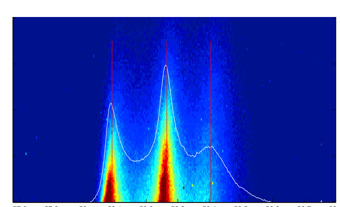

ATF Status Update

Edited by Christina Swinson

Welcome to the new look ATF newsletter containing a brief overview of ATF activities over the past year together with, user contributed, experiment reports.

Move to C-AD

On April 1, 2013, the ATF moved organizationally from the Physics Department to the Collider-Accelerator Department (C-AD), joining the Accelerator R&D Division. This move will give the ATF easier access to resources, particularly expertise in many accelerator physics fields.

ATF-II Proposal

The ATF is in the process of preparing an upgrade proposal to be submitted to the DOE. The main element of the proposal is a physical move of the ATF facility to a significantly larger building. The move will provide independently shielded experiment halls to enable setting up an experiment in one hall while running another experiment in the other hall. This arrangement will have a large impact on operations, allowing more hours of beam time. In addition, the space available for the ATF systems will triple in size and the infrastructure will be improved.

This year's meeting of the Program Advisory Committee will commence on July 11th for a review of the proposal. As a result there will be **NO User Meeting** this year.

Experimental Overview

The ATF has hosted 13 different experiments in the past year, along side our own beam studies and instrumentation programs.

Current Filamentation Instability – The subject of a USC PhD. thesis, this experiment was completed in 2012 after observing filamentation of the ATF electron beam traveling through plasma.

Self-Modulation Instability – The subject of a USC PhD. thesis, this effect was observed at the ATF in 2012 and is described in more detail on page4.

High-Brightness Picosecond Ion Beam Source – The most recent development in this experiment is the mono-energetic, 1.6 MeV proton beam generated only a few weeks ago. See expanded information on page 7.

High-Gradient, High-Field Dielectric Wakefield Experiments – This experiment continues to investigate different geometries of dielectric structure for acceleration. More details of this experiment can be seen on page 5.

RUBICON IFEL experiment – An IFEL experiment based around a tapered undulator, the most noted achievement of this experiment so far is the acceleration of electrons by almost 100% of their initial energy.

PWFA Holography – Still in its early stages, this experiment aims to achieve a direct measurement of a single electron beam driven wake using frequency domain holographic reconstruction.

Plasma Wakefields in the Quasi-Nonlinear Regime – Still in its infancy, this experiment has recently seen installation of a new chamber at ATF. Commissioning of the chamber is currently underway.

Beam Manipulation by Self-Wakefield – Consisting of three sub-experiments and most recently achieving observation of beam energy chirp correction this experiment is described on page 6.

AXIS 5μm Damage Test – The ATF laser system has been tasked for use in testing the resilience of optical materials. Some experiments, which were performed in air, will be repeated in vacuum in the near future.

Nonlinear Inverse Compton Scattering – The X-ray spectrum emitted during relativistic non-linear inverse Compton scattering is studied. This experiment, run by a group from UCLA, recently observed the 3rd harmonic of Compton backscattering. They will return after the summer to continue experimenting.

Single Electron Experiment – This year physicists from Columbia and Princeton Universities made use of the ATF electron beam for testing of a single electron time-of-flight detector. The group will return in August to continue their tests.

Coherent Noise Suppression – Published in Nature in 2012, this experiment successfully showed noise suppression by measurement of decreasing OTR power per unit bunch charge.

New Beginnings

We would like to extend congratulations to Vitaly Yakimenko on his new appointment at SLAC National Accelerator Laboratory.

Previously director of the ATF, he will be greatly missed. Fortunately the ATF will still benefit from his expertise as a member of the program advisory committee. All at ATF wish Vitaly good luck in his new role and welcome Igor Pogorelsky as interim director.

The ATF would also like to express gratitude for the 25 years of service given by Robert Palmer. As scientific program director to the ATF his guidance and expertise have made the ATF what it is today. We welcome Ilan Ben-Zvi as our new scientific program director and wish him luck in his new role.

Robert Plamer (left) has stepped down as Scientific Program Director for the ATF; his position is taken up by Ilan Ben-Zvi (right).

User Relations

A renewed effort to keep users informed of ATF activities has seen the introduction of our own twitter feed, you can follow us **@ATFatBNL** or see the feed on our home page. We have also introduced a proposal submission form, available from the ATF website, which should be completed and submitted to Ilan Ben-Zvi with a copy to Mikhail Fedurin, for all new proposals. Finally we look forward to keeping users informed via our new look website, to be launched at the end of this month.

PAC'13

Keep a look out for the following abstracts at this year's Particle Accelerator Conference:

- Shockwave velocity measurements in over-dense plasmas irradiated by 1 TW CO_2 laser pulses.
- Small beam generation at the Accelerator Test Facility.
- Electron beam diagnostics at the Accelerator Test Facility.
- Generation of electron bunch trains with small transverse size at the Accelerator Test Facility.

Safety

As a result of our move to C-AD, all safety documentation (including ESRs) will be transferred to that department. ESRs will still be generated as in the past, with Karl Kusche remaining as the primary safety contact for ATF staff and users. You many contact Karl at **kusche@bnl.gov** with any questions.

Noted Publications

A.Gover, A.Nause, E. Dyunin & M. Fedurin Beating the Shot-Noise Limit, Nature Physics **8**, 877-880, doi:10.1038/nphys2443
B. Allen,*et. al*. Experimental Study of Current Filamentation Instability , Phys. Rev. Lett. **109**, 185007
V. Yakimenko, M. Fedurin, V. Litvinenko, A. Fedotov, D. Kayran, & P. Muggli Experimental Observation of Suppression of Coherent-Synchrotron-Radiation-Induced Beam-Energy Spread with Shielding Plates, Phys. Rev. Lett. **109**, 164802
G. Andonian, D. Stratakis, M. Babzien, S. Barber, M. Fedurin, E. Hemsing, K. Kusche, P. Muggli, B. O'Shea *et. al*. Dielectric Wakefield Acceleration of a Relativistic Electron Beam in a Slab-Symmetric Dielectric Lined Waveguide, Phys. Rev. Lett. **108**, 244801
S. Antipov, C. Jing, A. Kanareykin, J. E. Butler, V. Yakimenko, M. Fedurin, K. Kusche, and W. Gai Experimental demonstration of wakefield effects in a THz planar diamond accelerating structure, *Appl. Phys. Lett.* **100**, 132910
F. H. O'Shea, O. Williams, G. Andonian *et. al*. Single Shot Diffraction of Picosecond 8.7 keV X-ray Pulses, *Phys. Rev. STAB* **15**, 020702
S. Antipov, C. Jing, M. Fedurin, W. Gai, A. Kanareykin, K. Kusche, P. Schoessow, V. Yakimenko *et. al*. Experimental Observation of Energy Modulation in Electron Beams Passing through Terahertz Dielectric Wakefield Structures, *Phys. Rev. Lett.* , **108**,144801
M. N. Polyanskiy and M. Babzien, Ultrashort pulses in: *CO2 laser - optimization and application*, D. C. Dumitras (ed.), InTech, ISBN 978-953-51-0351-6, pp 139-162
S. Antipov, C. Jing, P. Schoessow, A. Kanareykin, V. Yakimenko, A. Zholents & W. Gai High power terahertz radiation source based on electron beam wakefields, Rev. Sci. Instrum. **84**, 022706
R. Tikhoplav, M. Babzien *et. al*. High-power pulse recirculation in a stable pseudo-confocal geometry, *Optics Lett*. **37**, 22, 4717
B. Golosio, M. Endrizzi, P. Oliva, P. Delogu, M. Carpinelli, I. Pogorelsky & V. Yakimenko Measurement of an inverse Compton scattering source local spectrum using k-edge filters, App. Phys. Lett. **100**, 16, 164104

Operations

by Christina Swinson / Mikhail Polyanskiy

CO2 Laser Status

CO2 laser continues to provide terawatt 10-micron pulses for ATF user experiments. Using isotopic active medium for amplification of single ultra-short pulse without destroying its temporal clearness has proven to be a viable approach. It was implemented at ATF more than three years ago and is being routinely used without issue since then. Our current laser support and R&D activities are mostly concentrated on two main projects: 1) improvement of pulse diagnostics and 2) implementation of an all-solid-state laser system for sub-picosecond seed-pulse generation. The new, shorter seed pulse, will extract excitation energy from the active medium more efficiently than the 5-ps pulse used now. Increased pulse energy and its reduced duration will together ensure 5-10 fold increase in the peak-power. The diagnostics available now provide measurement of pulse energy, spectrum, and temporal profile with ~5-ps resolution. Single-pulse auto-correlator and new streak-camera will complement our system in the near future providing users with virtually complete information about the pulse. Implementation of frequency-resolved optical gating (FROG) planned for the next stage will complete the upgrade of the diagnostics system. Chirped-pulse amplification (CPA) apparatus are under active development and are planned for test and implementation in somewhat more distant perspective: we will start from a small-scale test system with compressor after the first amplification stage, and then will implement a full-scale, in-vacuum compressor for full-power output pulse. Our long-term plans include upgrading our system to 100 TW peak-power by adding one more amplification stage and exploiting self-phase modulation for post-compression of the amplified pulse.

2013 E-BEAM OPERATIONS STATS

60% Operations

34.5% User setup/installation

5.5% Maintenance

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Electron Beam Status

One notable upgrade to the ATF is the new experimental chamber on beam line #2. Developed for the Plasma Wakefield Acceleration in the Quasi-nonlinear regime experiment and installed in March of this year, the chamber has many useful features. These include multiple viewing ports, enough space for two permanent magnet quadrupole triplets (one before and one after the IP) and integrated connectors for motor control of stages.

One of many photos taken for the new website

As we continue to serve many experiments beam time is in short supply so see **www.bnl.gov/atf** for the current schedule and contact **fedurin@bnl.gov** to claim your spot.

KEY CONTACTS

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OPERATIONS COORDINATOR
Mikhail Fedurin **fedurin@bnl.gov**
For experiment scheduling and proposals

SAFETY OFFICER
Karl Kusche **kusche@bnl.gov**
For installations, training and hazards

Self-modulation Instability at ATF

by Yun Fang (USC)

The self-modulation of charged particle bunches experiencing self-modulation instability (SMI) in dense plasmas has emerged as a new scheme to drive large amplitude wakefields in plasmas. While many theory and simulation papers have been published recently, no experiment was performed. At the ATF we demonstrated for the first time that a long electron bunch (Fig. *a*) shaped with a sharp rising edge (Fig. *b* and *e*) drives periodic plasma wakefield with amplitude in the MeV range and wavelength one to one seventh of a bunch length. Thanks to the low charge chosen (50 pC), the longitudinal wakefields lead to periodic modulation in the energy spectrum of the bunch entering the plasma with a time-energy correlation, as shown in Fig. *c* and *d*. The wakefields amplitudes derived from these experimental results are in excellent agreement with 2D linear theory for plasma wakefields, as well as with PIC numerical simulation results. The transverse wakefields associated with these MeV/m longitudinal fields can effectively seed the SMI. The experimental results also show that the wakefields phase is determined by the rising edge of the bunch. This condition reached through seeding of the SMI is essential to be able to deterministically inject a witness bunch in the accelerating and focusing phase of the wakefields. Seeding of the SMI shortens the distance to reach saturation of the instability, determines the wakefields amplitudes and also contributes to the mitigation of a competing and deleterious instability, the hose instability. These first measurements of wakefields driven by long particle bunches in plasmas are important for large-scale experiments planed at SLAC (known as E209) and at CERN (AWAKE). These results will soon be submitted to Phys. Rev. Lett.

[1] R. A. Fonseca et al., Lect. Notes Comp. Sci. vol. 2331, Springer, 2002

FOR MORE INFORMATION

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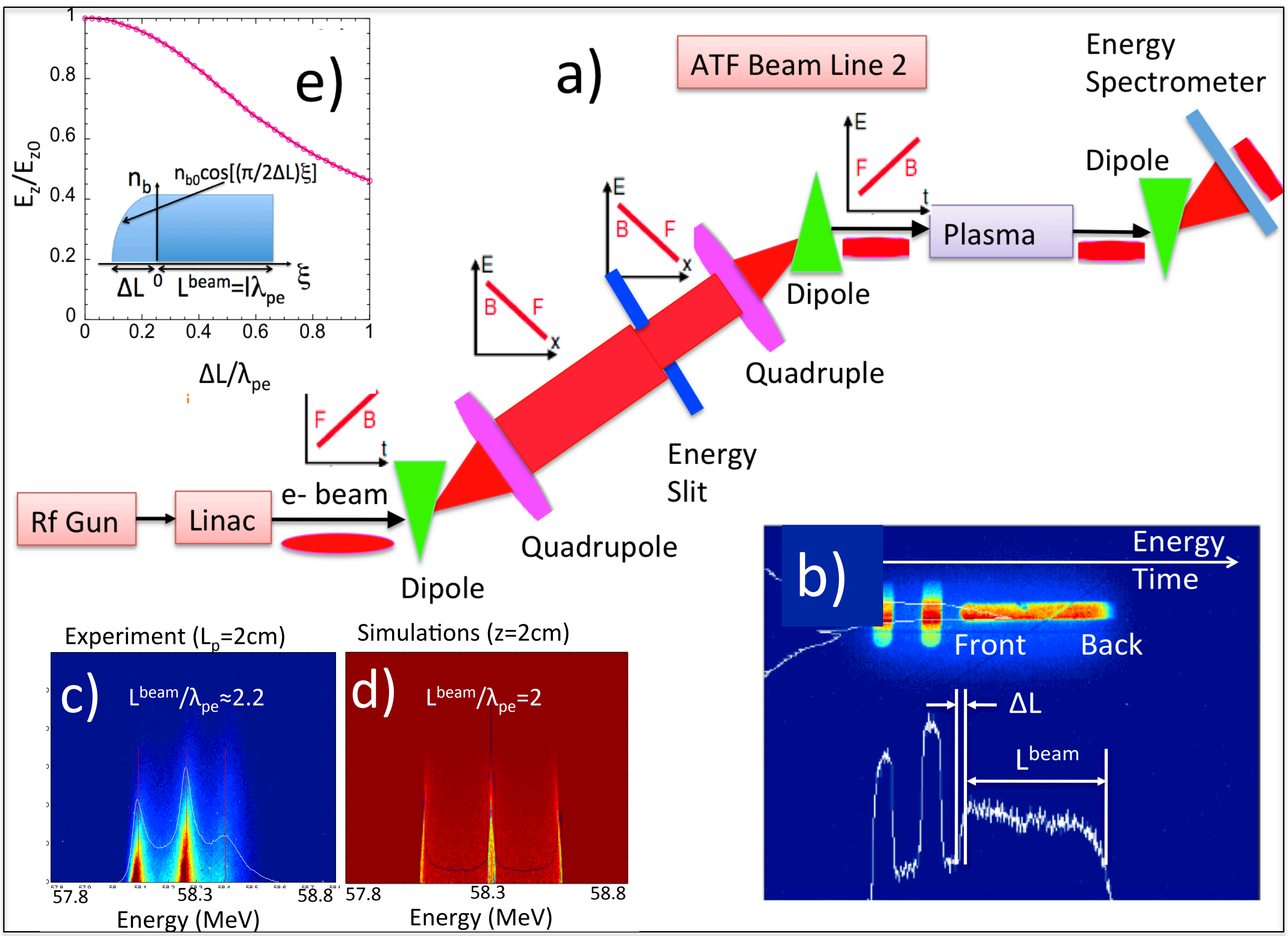

Dielectric Wakefield Acceleration in a Bragg-layered Slab Structure

by Gerard Andonian (UCLA) with contributions from S. Barber, P. Hoang, B. O'Shea, O. Williams and J. Rosenzweig

Advanced acceleration experiments employing dielectric wakefield acceleration (DWA) have produced significant results at the BNL ATF in conventional geometries (i.e. cylindrical and rectangular). However, the metallic outer lining of these structures is a limitation for achieving the high-gradient fields required for collider or light source applications.

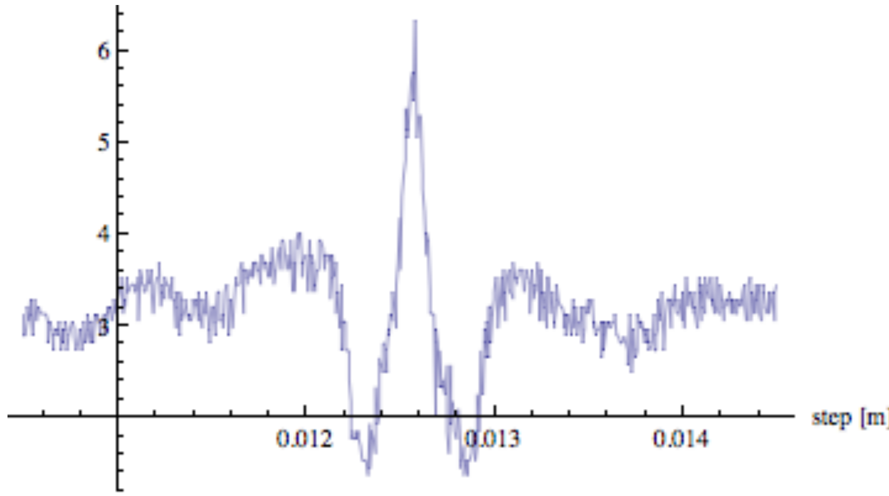

Figure 2: Raw interferogram of CCR emitted from Bragg structure. The central peak is due to beam effects from <100% transmission. The ringing in the tails is evidence of the excitation of a resonant mode in the Bragg structure.

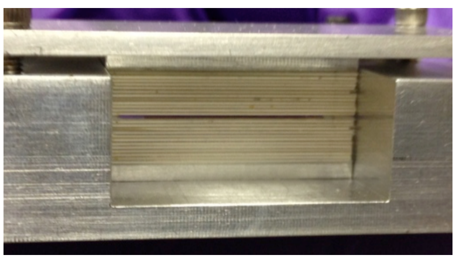

Figure 1: Photo Bragg layered DWA structure composed of quartz (SiO_2) and zirconia toughened alumina (ZTA). Gap is 240um.web

An alternative to metal boundary structures is a slab-symmetric Bragg-layered structure (alternating layers of different dielectric materials). Such a structure enhances modal confinement due to constructive interference between successive dielectric layers.

This experimental run is a follow on to the previous work performed at BNL ATF that characterized the accelerating modes of a DWA structure in a slab-symmetric configuration. In this experiment the Bragg-style boundary is composed of thin layers of alternating dielectric material (SiO_2 and ZTA).

The experimental goals for this study included characterization of the structure fundamental mode using a short electron beam (<1ps) and moderate charge (~100pC). The modes are investigated using Coherent Cerenkov Radiation (CCR) interferometry using the radiation emitted at these frequencies (<THz) with a Michelson-type interferometer and LHe bolometer detector.

Figure 2 shows the unprocessed autocorrelation curve of a CCR scan. The central peak is due to CTR from the beam. However, the ringing in the tails is due to resonant mode excitation of the structure. For the given dimensions, the fundamental mode of the structure is ~210GHz (λ = 1.4mm) which corresponds to the ringing in the tails.

The results of this experiment agree well with both 2D and 3D simulations (Figure 3) and form a foundation for exploration into beam driven, as well as laser driven, 3D photonic-like accelerating structures.

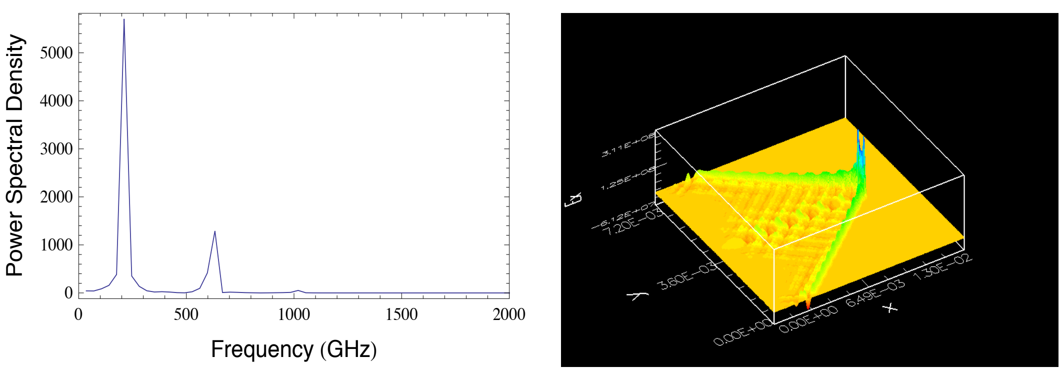

Figure 3: OOPIC simulations of the Bragg experiment at the ATF. Frequency spectrum showing first two modes (left) and longitudinal electric field (right).

FOR MORE INFORMATION

http://pbpl.physics.ucla.edu/

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Beam Manipulation by Self-Wakefield

by S. Antipov (Euclid Techlabs)

Compact, High Power, Narrowband, Tunable THz Source

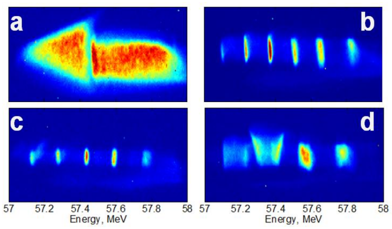

Figure 1: Spectrometer images of the full-size 1.6mm long "arrow" beam. a) Undisturbed beam, b) Beam passing through 0.95 THz, c) 0.76 THz and d) 0.615 THz structure.

In 2011 Euclid Techlabs and ATF demonstrated energy modulation by self-wakefield in THz wakefield structures (fig.1). In 2012 a chicane was added to the setup and energy modulation was converted into density modulation (fig.2), a second stage of the proposed 3-stage program. We also demonstrated a wide tuning range (0.5 – 1 THz) of the bunch train production scheme based on initial beam energy chirp.

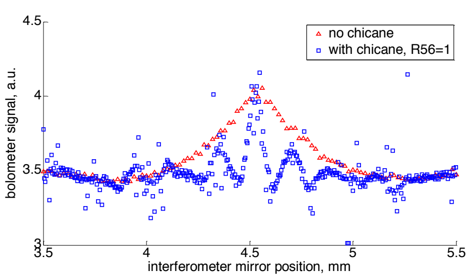

Figure 2: Energy modulation converted into THz bunchtrain and subsequently THz signal. Measured autocorrelation function: red – without chicane, blue: with chicane inserted into the beam line. Time structure shows periodicity of 850 GHz with 25% bandwidth (4-5 bunches in a bunch train).

Energy chirp compensation experiment

FELs are 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, high peak current, and low emittance. Sub-picosecond pulses are central to many of the next generation light source initiatives that are typical of linear accelerators. Compression leaves the beam with a small chirp to compensate for wakefield effects through the rest of the accelerating stage. It is required that this relatively small energy spread be compensated using a specially designed device. This compensation can be realized by a simple wakefield device. We now propose to test and demonstrate the first tunable energy chirp compensating system. Tunability is the key aspect for this proposal. We plan to demonstrate that in the case of beam parameter changes we can adjust the compensating structure accordingly to efficiently compensate the energy chirp.

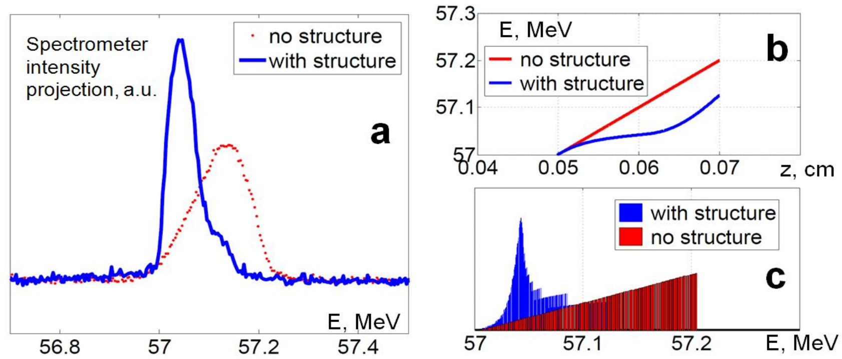

Figure 3: Energy chirp compensation: Left – experimental data, right – simulation; red – original, blue – compensated energy distribution.

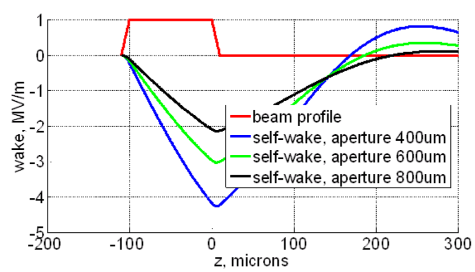

Figure 4: Self decelerating wakefield produced in a multimode rectangular dielectric loaded waveguide with variable aperture.

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. Aperture < 400 um gives rise to nonlinear self-deceleration wakes, which are also of interest.

Demonstration of high transformer ratio at the ATF

The transformer ratio is defined as the ratio of the maximum energy gain of the witness bunch to the maximum energy loss experienced by the drive bunch. It plays an important role in the collinear wakefield acceleration scheme. A high transformer ratio is desirable since it leads to a higher overall efficiency under similar conditions. The experiment that

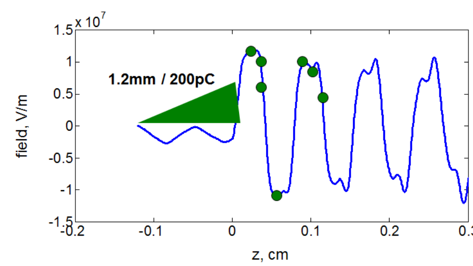

Figure 5: Wake produced by triangular drive beam, can be sampled by a small witness beam at variable distance from the drive. This measurement will show enhanced transformer ratio explicitly.

we propose, if successful, will be the first demonstration of enhanced transformer ratio from a triangular shaped beam. This experiment is similar to the diamond structure wakefield mapping done in 2011.

FOR MORE INFORMATION

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Ion acceleration using laser driven shocks

by O. Tresca with N. Cook, N. P. Dover, C. Maharjan, Z. Najmudin, M. Polyanskiy, P. Shkolnikov, I. Pogorelsky

Laser driven acceleration has been investigated in great detail in the last decade and has shown promising results. So far, most of the experiments have been conducted with solid foil targets which, when irradiated by a high intensity laser pulse (>10^{18} Wcm^{-2}), can generate ion beams of energies up to 70 MeV via the TNSA mechanism. The resulting ion beam has Maxwellian energy distribution that can be detrimental to some of the envisaged applications. Experiments conducted at the ATF in 2009 have demonstrated that the acceleration of mono-energetic proton beam was possible using the TW CO_2 laser incident on a gas target. In this regime, a shock wave is launch in the plasma by the radiation pressure of the laser pulse which then reflects ions to energy in the MeV range with a narrow spread, > 10% [1].

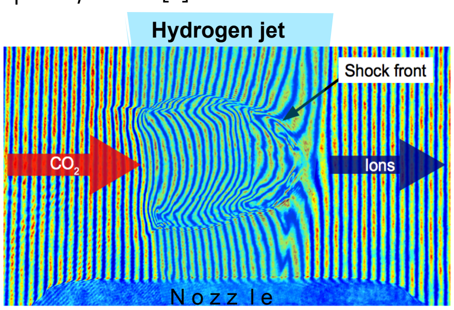

Figure 1. Time-resolved interferometry allows to observe plasma density distribution around the laser focus, hole-boring through the gas jet and measure the shock velocity.

A linearly polarized CO_2 pulse (λ=10 μm) is incident on a gas jet which consists of hydrogen at densities over the laser critical density (n_c~$1x10^{19}$ cm^{-3}). It is focused with and *f/3* off-axis parabolic mirror to a focal spot with a diameter of w_0=60 μm. The resulting on-target laser intensity I_L~6×10^{16} Wcm^{-2}. A frequency-doubled YAG laser is used to probe the laser-plasma interaction, at those densities the plasma is transparent to the short wavelength YAG (λ=532 nm), it is split into two channels one for shadowgraphy imaging the other for interferometric imaging. The interferometry image enables us to measure the plasma density profile during the interaction, an example is shown in Fig. 1. The resulting ion beam is characterized using a magnetic spectrometer, which dispersed the ions according to their momentum. The resulting ion track was then recorded using a scintillator and an EMCCD camera. Recent runs have seen the successful generation of proton beams with energies up to 3 MeV, as seen in Fig 2 (a). The energy spread of the beam has been found to be greater than 100%. This unexpected result has been investigated using 1D particle in cell simulations performed with the EPOCH code. The simulations were run for a slab of cold hydrogen plasma at a density of 2nC irradiated by a laser pulse of a0=1.45.

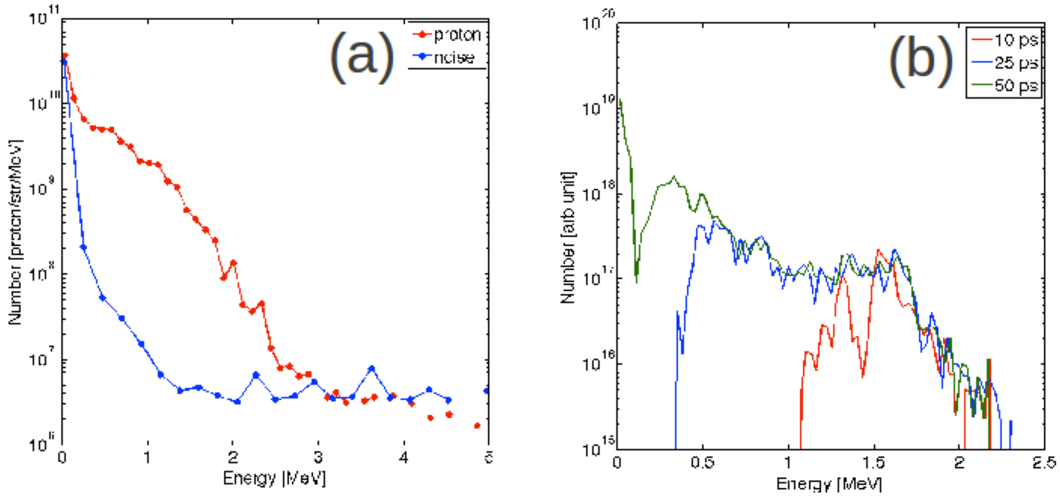

Figure 2. (a) Proton spectra measured experimentally. (b) Proton spectrum obtained from the 1D PIC simulations at different time during the interaction.

Fig 2 (b) shows proton spectrum extracted from the simulation results at different times during the laser-plasma interaction, 10 ps 25 ps and 50 ps. It is clear that the proton energy distribution starts with a somewhat narrow distribution centered around ~1.5 MeV with the low energy tail of the distribution appearing later in time. This is due to the laser-generated shock wave, responsible for the acceleration of the protons, slowing down as it propagates through the plasma. As it slows down, the shock reflects protons at lower energies creating the broad energy distribution observed experimentally. In addition the peak proton energy measured is found to be in good agreement with the simulation results.

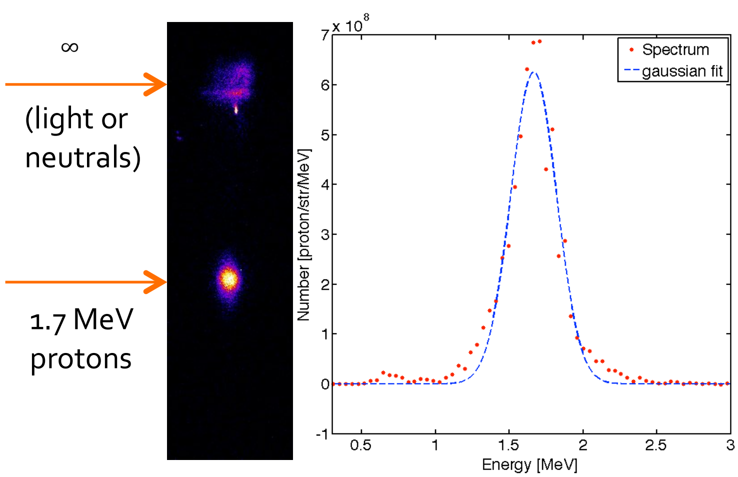

Figure 3. Example of a mono-energetic proton spectrum resulting from the Shock Wave laser acceleration experimentally observed with a magnetic spectrometer.

[1] C. A. J. Palmer *et. al.* , Phys. Rev. Lett.106, 014801 (2011).

FOR MORE INFORMATION

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Upcoming Beam Schedule

July

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
30	1	2	3	4	5	6
	AE43 - PWFA Holography Installation			Holiday		
7	8	9	10	11	12	13
	AE43 - PWFA Holography, BL2					
14	15	16	17	18	19	20
	AE43 - PWFA Holography, BL2					
21	22	23	24	25	26	27
	AE41 - RUBICON IFEL Installation					
28	29	30	31	1	2	3
	AE41 - RUBICON IFEL, BL2					

August

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
28	29	30	31	1	2	3
				AE41 - RUBICON IFEL, BL2		
4	5	6	7	8	9	10
	AE41 - RUBICON IFEL, BL2					
11	12	13	14	15	16	17
	Beam Studies					
18	19	20	21	22	23	24
	AE50 - PWFA in QNR					
25	26	27	28	29	30	31
	Beam Studies					

September

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
1	2	3	4	5	6	7
	Holiday	AE56 - Fiber Optic, BL2				
8	9	10	11	12	13	14
	AE56 - Fiber Optic, BL2				ATF BBQ	
15	16	17	18	19	20	21
	AE50 - PWFA in QNR					
22	23	24	25	26	27	28
	Maintenance		Beam Studies			
29	30	1	2	3	4	5
	NA-PAC'13					

Electron Beam | Electron Beam + Laser | ATF Operations | Maintenance/Installation