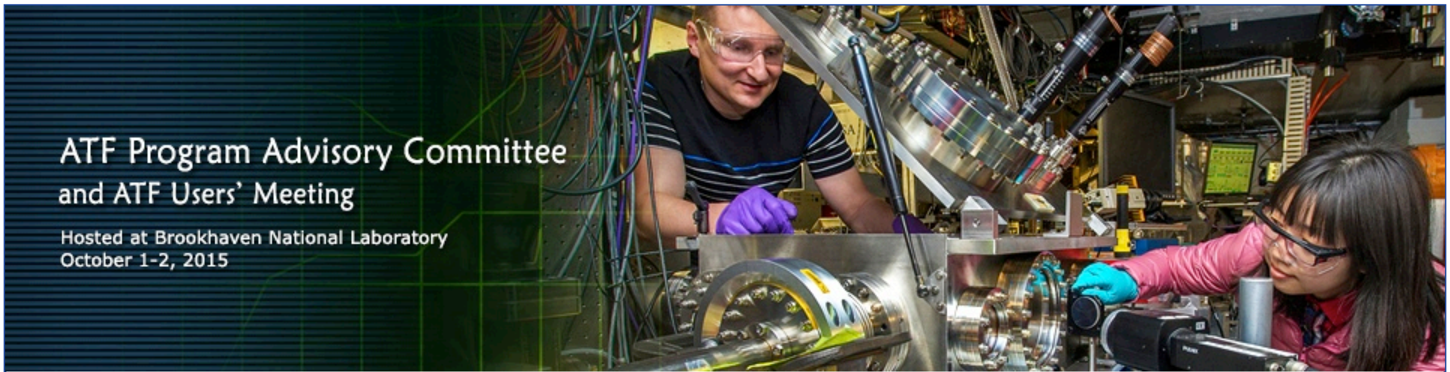

ATF Newsletter

Summer 2015

ATF Status Update

Welcome to the Summer 2015 edition of the ATF newsletter. It is that time of the year when we are open to accepting new proposals in preparation for the annual users' meeting, to be held on October 1-2. During this two-day summit, the ATF Program Advisory Committee (APAC) will review users' reports on ongoing and completed experiments and newly proposed projects. Researchers who wish to bring new experiments to the ATF in FY16 must have submitted their proposals online by September 1 and present their plans in person at the meeting on Oct. 1-2. This year we implement a new online proposal submission system that will streamline user experiment review and reporting. To submit your proposal go to pass.bnl.gov and sign in with a Google account.

After completing the regular business of reviewing active user experiments and new proposals, we will culminate our meeting with reports from the ongoing ATF-II upgrade project and round table discussions on fitting the new facility to cutting-edge Accelerator R&D and Accelerator Stewardship missions. The main objective of this discussion is to provide constructive interaction between future ATF-II users and the facility engineers and managers, about the optimum design of the experiment areas, to facilitate a smooth and productive start to user experiment programs at the new facility. The first stage of ATF-II should come on line in the next two years; this will include a 9-11 mm CO_2 laser with unprecedented parameters, 25-TW@ 2-ps or 100-TW @100-fs; a 160 MeV electron beamline with laser interaction capability and; a separate experiment hall for "laser only" experiments. We welcome users' opinions regarding the desired configuration and parameters for experiment areas. Collecting this information at an early construction stage will ensure that our laser and e-beam systems and beamlines are designed to accommodate user requests in the best way. You can see a draft agenda for the meeting at http://go.usa.gov/3GKDC

In this Issue

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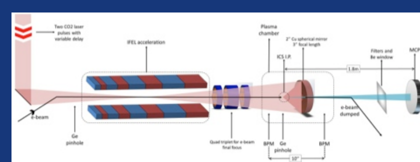
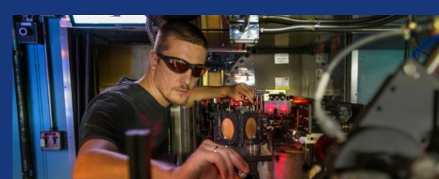


Confirmation of double pulse ICS for realization of IFEL driven ICS using re-focusing optics, p.5



First-ever chirped-pulse amplification in a CO_2 laser demonstrated at ATF, p.6

Important Dates

Sept 1 proposal submission deadline

Sept 25 users' mtg. registration deadline

Oct 1 - 2 users' meeting

Registration for the users' meeting is now open at www.bnl.gov/atfusersmeeting. We look forward to seeing our seasoned users alongside some new faces.

In Memoriam

Photo courtesy of UCLA

Sadly, as some of you may already have heard, Dave Cline, Distinguished Professor Emeritus of UCLA Physics and Astronomy Department, died on June 27, 2015 of a heart attack at the age of 81. Dave's work is internationally recognized and admired, spanning elementary particle physics and accelerator science.

Dave was one of the founding members of the ATF Users community and a staunch supporter of the ATF. He participated in the design of the ATF and in groundbreaking experiments such as the Inverse Cerenkov accelerator, the first generation and measurement of microbunches, the Staged Laser Accelerator (STELLA) and many others. You can read more about his life and work here.

Dave will be greatly missed by all of us.

Ilan Ben-Zvi

Operations etc.

Operations, this quarter, included providing laser/ebeam for the following 6 experiments.

AE52 – Beam Manipulation by Self-wakefield, Euclid Techlabs

AE59 – ICS for Extreme Ultraviolet Lithography, Radiabeam

AE65 – NOCIBUR: an IFEL Decelerator Experiment, UCLA

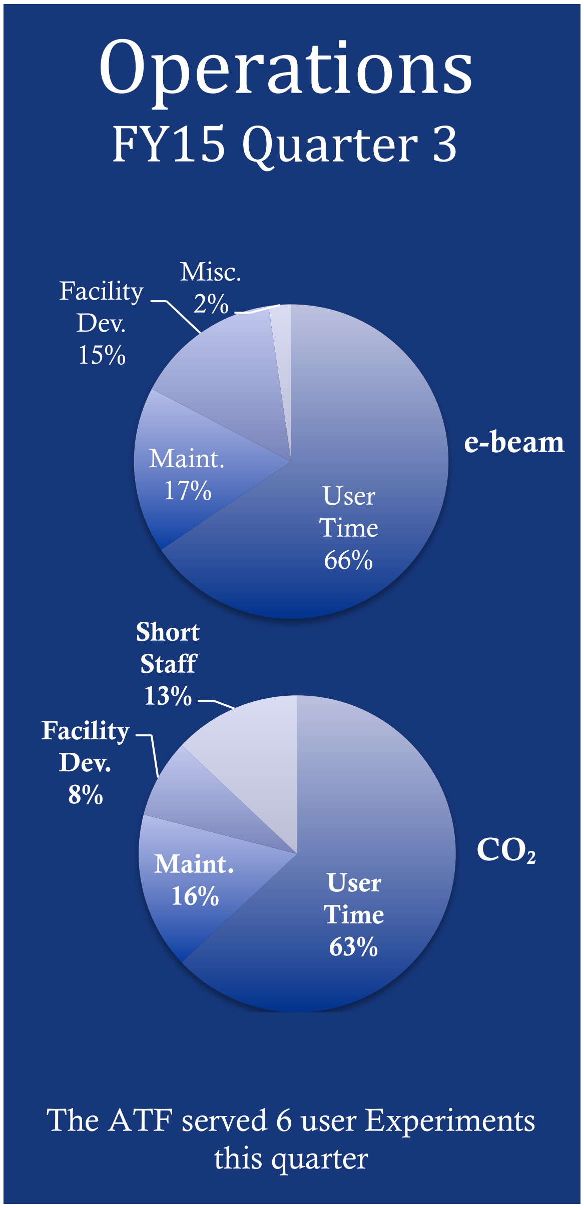
AE66 - Modification of Gas Jet Density Profile for CO_2 Ion Acceleration, NRL/Imperial College

AE67 – Space Radiation Effects, NASA/JPL

AE70 – Nonlinear Inverse Compton Scattering, UCLA

On the ebeam facility development side: installation of an x-band RF system, to support Radiabeam's deflector cavity and for x-band electron gun R&D, is well under way. A new solenoid was also installed at the gun with the intent of investigating the feasibility of using emittance mixing at the ATF to generate flat beams suitable for use in experiments such as those that use slab-shaped structures.

The CO_2 laser part of the facility development is also diverse and rich with innovations. This activity is aimed to benefit our current users and a long-term strategic goal of constructing a next-generation ultra-fast CO_2 laser BESTIA. Along these lines, the ATF laser support staff develops and implements double-pulse regime and the contrast enhancement for our current users' experiments (NOCIBUR, Ion Acceleration) and strategically important CPA technique, a corner stone for BESTIA. This last advancement is highlighted in this Newsletter as well as in a paper accepted for publication by the OPTICA journal.



Publications

Y. Sakai, I. Pogorelsky, O. Williams, F. O'Shea, S. Barber, I. Gadjev, J. Duris, P. Musumeci, M. Fedurin, A. Korostyshevsky, B. Malone, C. Swinson, G. Stenby, K. Kusche, M. Babzien, M. Montemagno, P. Jacob, Z. Zhong, M. Polyanskiy, V. Yakimenko, and J. Rosenzweig, **Observation of redshifting and harmonic radiation in inverse Compton scattering**, *PR-STAB* 18, 060702 **2015**

M. N. Polyanskiy, ***co2amp*: A software program for modeling the dynamics of ultrashort pulses in optical systems with CO2 amplifiers**, Appl. Opt., 54, 5136-5142, **2015**

M. N. Polyanskiy, M. Babzien, and I. Pogorelsky, **Multi-terawatt CO2 laser with chirped-pulse amplification**, *Conference on Lasers and Electro-Optics (CLEO)*, San Jose, CA (USA), May 10-15, **2015** [*abstract*]

I. V. Pogorelsky, I. Ben-Zvi, J. Skaritka, M. Babzien, M. N. Polyanskiy, Z. Najmudin, N. Dover and Wei Lu, **New opportunities for strong-field LPI research in the mid-IR**, *Relativistic Plasma Waves and Particle Beams as Coherent and Incoherent Radiation Sources*, Prague (Czech Republic) April 15-16, **2015** [*proceedings*]

Upcoming IPAC'15 proceedings

MOPMN028 – **Design of a CSR suppression bunch compressor for ultra short pulse at ATF upgrade**, Y. Jing *et. al.*
TUPMA042 – **THz radiation generation in multimode wakefield structures**, S. Antipov *et. al.*
TUPWA020 – **BNL ATF II beamlines design**, M. Fedurin *et. al.*
TUPMA043 – **Experimental test of semiconductor decirper**, S. Antipov *et. al.*
WEPJE006 – **Dielectric wakefield acceleration experiment at ATF**, Shchegolkov *et. al.*
WEPJE018 – **Ramped bunch generation using beam self-wakefields in dielectric structures**, G. Andonian *et. al.*

Important Contacts

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NEWSLETTER CONTRIBUTIONS
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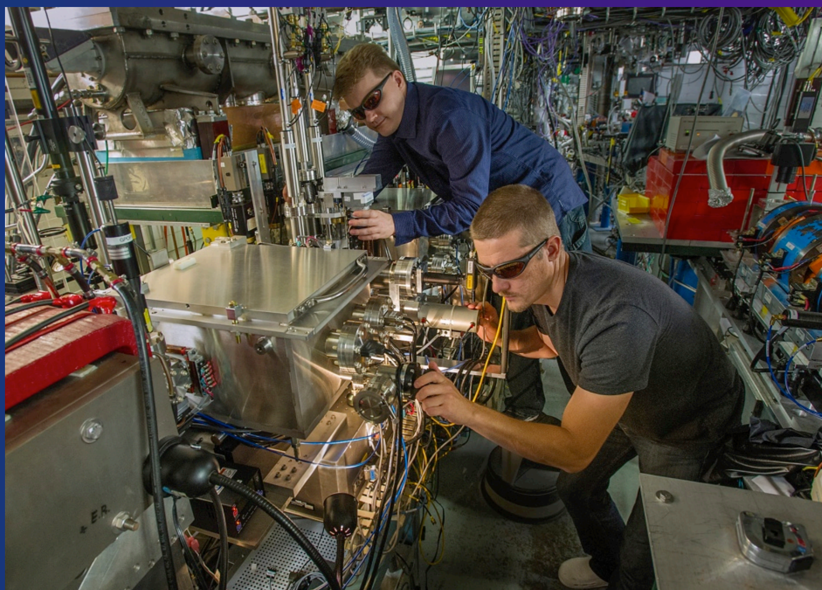
The emergence of trains of intense x-rays pulses from an infra-red laser



Photograph of ATF and Radiabeam staff working on the ebeam-CO_2 interaction chamber, designed and built by Radiabeam and installed in the ATF experiment hall.

In our previous Spring 2015 issue of the ATF Newsletter, we reported instalation of an intra-cavity Inverse Compton scattering (ICS) SBIR experiment by RadiaBeam Technologies in the ATF's beamline 1 as well as their first success in demonstrating trains of CO_2 laser pulses matched to the repetition rate of the ATF electron beam.

Since then, in several experiment runs, RadiaBeam and ATF researchers progressed on their path towards achieving proper co-alignment and synchronization of multiple electron- and laser- bunches at the Compton interaction point integrated into the laser amplifier's ring cavity. Then, strong bursts of x-rays emerged from the interaction point to be measured and imaged by the variety of the x-ray diagnostics. Increasing the number of interacting pulses from one to five, and then to fifteen resulted in a nearly proportional increase in the x-ray yield that clearly demonstrates the viability of the approach aimed towards development of compact light sources for multi-disciplinary applications. These fresh from the pot results are being digested, now to be materialized in a high-profile journal publication and a more comprehensive report for our future ATF Newsletter issue.

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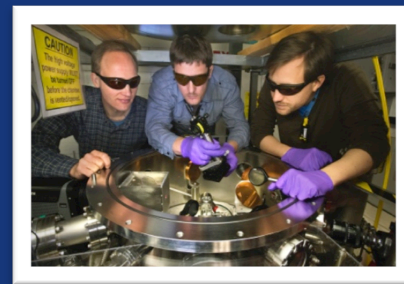
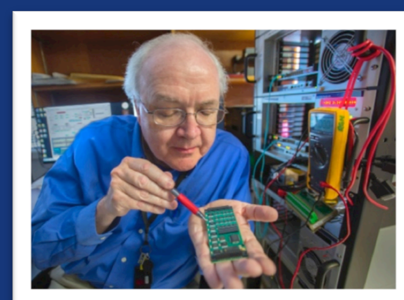
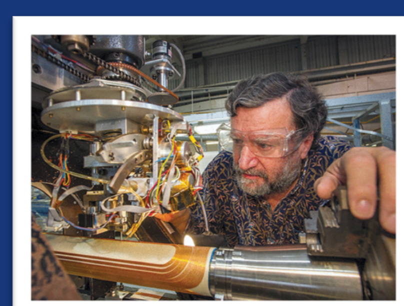
ATF in the News



In BNL News: Brookhaven Lab's Accelerator Test Facility Named a DOE Office of Science User Facility
Link

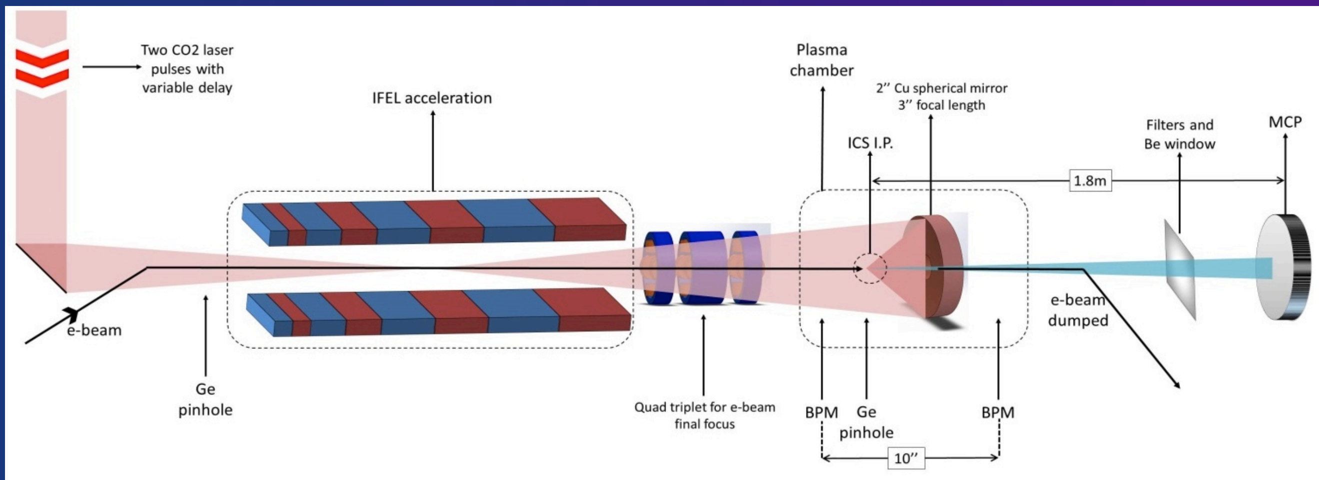


In BNL News: Lab Employee Robert Malone Helps U.S. Air Force Get Ready for Take-Off
Link



In Physics Today: DOE: Let's move accelerator technologies to commercial markets
Link

Confirmation of double pulse ICS for realization of IFEL driven ICS using re-focusing optics



Schematic of the IFEL driven ICS experiment: The e-beam is synchronized with the second pulse of the double pulse CO_2 laser in order to be accelerated inside a tapered undulator. The first CO_2 pulse then meets the e-beam head-on at the ICS I.P.

A photon that is Compton (or Thomson) back scattered from a relativistic electron with energy, $U_e = \gamma m_e c$, has its energy increased by a factor of $4\gamma^2$. This scenario is commonly referred to as inverse Compton scattering (ICS) and can be developed into a compact quasi-monochromatic source for x-rays. There is a vast gap in intensity, bandwidth, and energy between the powerful undulator x-ray facilities and the commercially available x-ray sources based on x-ray tubes. ICS x-ray sources can bridge this gap by becoming the high-brightness, narrow bandwidth x-ray source available to researchers at the university level. Such an x-ray source will find applications in nuclear resonance fluorescence (NRF), medical computed tomography (CT), materials research, and transistor manufacturing. As a scientific tool, it will grow and deepen the field of x-ray science as it relates to astronomy, biology, and chemistry.

We propose to couple the technique of electron beam acceleration through the Inverse Free Electron Laser (IFEL) process to an ICS interaction point. UCLA and ATF have had great success in implementing both IFEL and ICS experiments at the ATF. This past experience will significantly aid the proposed integration of the two. ATF has the required beam-line infrastructure and optical setup. The figure above shows a schematic of the proposed IFEL driven ICS experiment. The CO_2 pulse is split into two pulses and delivered to the experimental hall. The electron beam and CO_2 laser are co-propagating at the entrance of the undulator and the e-beam is synchronized with the second CO_2 pulse. The leading pulse is ahead by 2 focal-lengths of the Cu mirror and collides head-on with the accelerated e-beam at the ICS I.P. The e-beam is then dumped and the ICS x-rays are K-edge filtered by appropriately chosen metallic foils and collected with an MCP detector.

In June, a 50-50 ZnSe beam-splitter along with a delay stage was installed before the main CO_2 amplifier. The objective of the initial experiment (planned for September) is to deliver two TW CO_2 pulses to BL2 and observe ICS x-rays. At this point, the IFEL undulator will not be installed, as we would like to first characterize the back-reflected ICS in BL2. Using 65 MeV electrons, we expect to generate 7.7 keV x-rays on axis and a 1 nC electron bunch should yield ~10^8 x-ray photons per CO_2 pulse. The successful coupling of an IFEL accelerator to an ICS light source will shift the x-ray energy to >20 keV and simultaneously serve as a new diagnostic for IFEL beam quality.

Contact: Ivan Gadjev (ivangadjev@gmail.com), UCLA

First-ever Chirped-pulse Amplification in a CO_2 Laser Demonstrated at ATF

ATF laser physicists, Mikhail Polyanskiy, works on alignment of the first ever mid-IR CPA compressor.

Development of BESTIA (Brookhaven Experimental Supra-Terawatt Infrared at ATF), a CO_2 laser that will deliver up to 100-TW peak-power mid-infrared pulses for user's experiments, is in progress. A major milestone has been recently reached by the ATF's team who implemented, for the first time, a chirped-pulse amplification (CPA) scheme in a CO_2 laser.

In CPA, an ultrashort seed pulse is stretched (or *chirped*) by a special dispersive device ("stretcher") before being injected into an amplifier and is re-compressed by another dispersive device ("compressor") after the amplification. This simple trick allows to reduce, often by many orders-of-magnitude, nonlinear interaction between the laser pulse and the elements of the amplifier, and to correspondingly increase the extracted energy.

The majority of modern ultrahigh-power lasers use a solid-state active medium with inherently high nonlinearity that dictates the need for stretching the pulse. *All* petawatt-class lasers now thus use a CPA scheme. The active medium of a CO_2 laser, however, is a low-density, low-nonlinearity gas that makes the need for CPA not so obvious. Indeed, the multi-terawatt 10-micron pulses were achieved at UCLA [1] and Brookhaven ATF [2] by direct amplification of picosecond pulses in high-pressure CO_2 amplifiers. Computer simulations using a comprehensive model of the dynamics of picosecond pulses in optical systems with CO_2 amplifiers developed at ATF [3] showed, however, that further increase of the pulse's power is hindered by the nonlinear interactions with *transmissive optical elements* of the amplifier. This theoretical conclusion was irrefutably confirmed experimentally by the implementation of a CPA scheme at the first amplification stage of the ATF's CO_2 laser. Stretching a 9.2-µm 1.6-ps (FWHM) seed pulse to 50 ps resulted in an order-of-magnitude increase of the energy extracted from the amplifier, while an intra-cavity germanium switch was found to be the main element limiting the pulse energy *via* nonlinear absorption and refraction [4]. Preliminary testing of the full-power CPA setup with both power-amplifiers of the ATF's CO_2 laser is currently underway.

[1] D. Haberberger, S. Tochitsky, and C. Joshi, Optics express 18, 17865-17875 (2010)
[2] M. N. Polyanskiy, I. V. Pogorelsky, and V. Yakimenko, Optics Express 19, 7717-7725 (2011)
[3] M. N. Polyanskiy, Appl Optics 54, 5136-5142 (2015)
[4] M. N. Polyanskiy, M. Babzien, and I. V. Pogorelsky, "Chirped-pulse amplification in a CO_2 laser," Optica 8 (2015) - *accepted for publication*

Contact: Mikhail Polyanskiy (polyanskiy@bnl.gov), BNL-ATF