ATF Newsletter

Spring 2014

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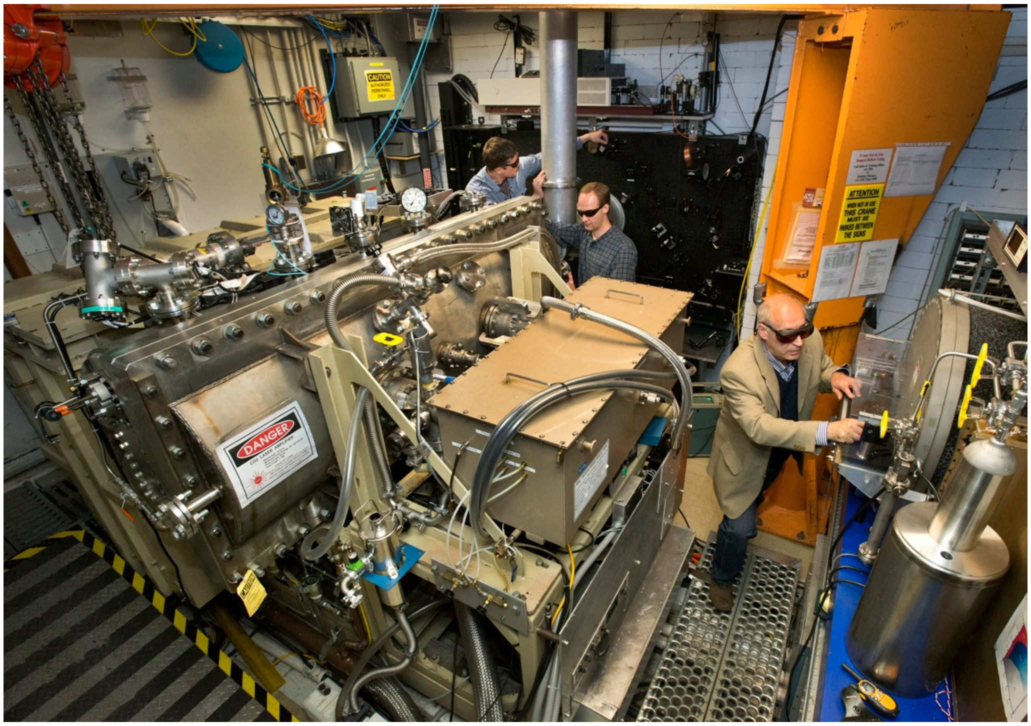

ATF STAFF IN PREPARATION FOR PLANNED UPGRADE OF CO_2 LASER FROM 1 TO 100 TW

ATF Status Update

Welcome to the ATF spring newsletter. 2014 has already proved to be a great year for the ATF with the approval of the planned facility upgrade (see page 3). The ATF will benefit from a big increase in experimental space, accelerator energy and laser power.

This year's User Meeting will take place on 14-15th October 2014. The meeting will address operations, current experiments and new proposals. **Proposals are due by 15th September**; visit **http://www.bnl.gov/atf/access.php** to begin the proposal submission process. Please email, **fedurin@bnl.gov**, for more information. The User Meeting will be followed by a two-day workshop, 16-17th October 2014, dedicated to the upgrade of the ATF. Please see the final page of this newsletter for the announcement of the user meeting and upgrade workshop.

There follows a brief overview of this quarter's experimental work:

Beam Manipulation by Self-Wakefield – Measurement of a narrow-band THz radiation generated by passing an electron bunch train through a quartz tube (see page 4 for a full report). Experiments will continue with a study of transformer ratios in dielectric wakefield acceleration.

Nonlinear Inverse Compton Scattering – A new run is underway. The experiment continues towards observing harmonics and their spectra beyond those previously achieved.

EUVL experiment (high-repetition Compton source) – The first important milestone, experimental demonstration of CO_2 active cavity, and 30 J pulse trains generation, is reached; see page 5 for more info and plans.

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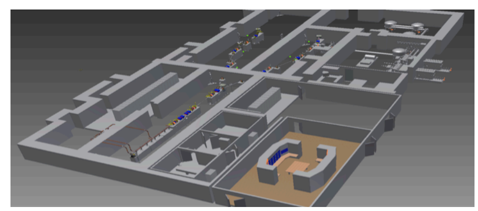

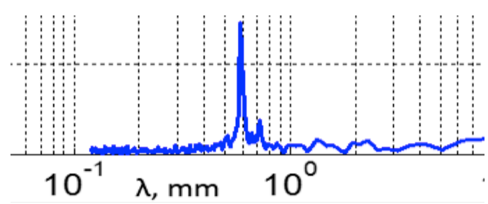

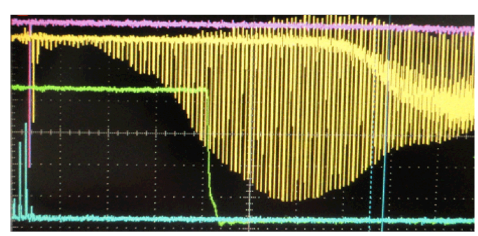

Operations etc.

by Christina Swinson

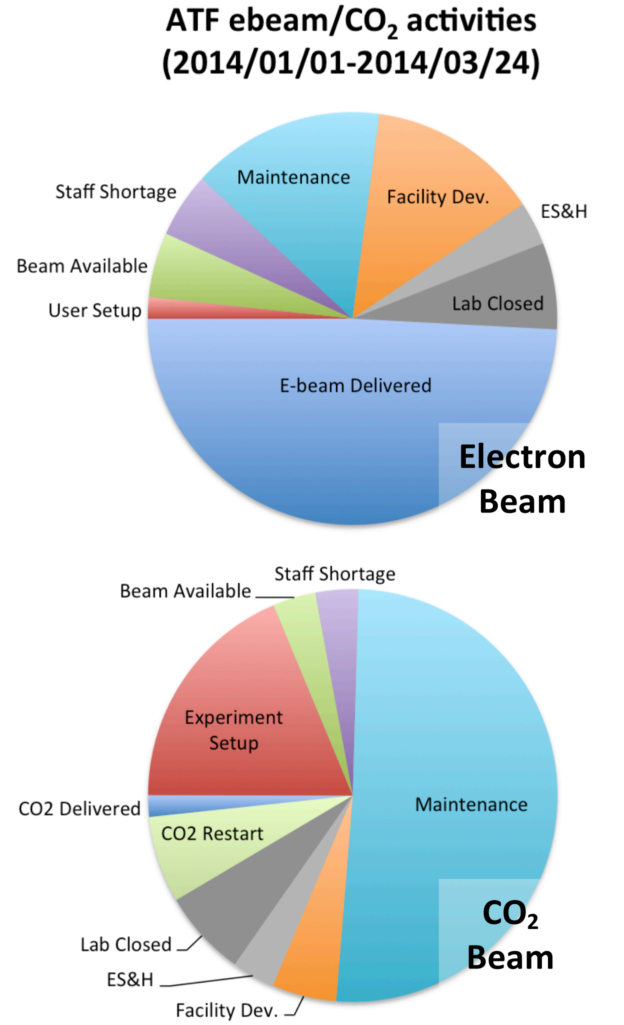

Figure 1: Operations for the last quarter. The grey portions represent times where beam running is unavoidably halted due to bad weather, safety inspections etc.

Electron Beam and CO_2 Laser Status

The first quarter of the year accommodated the ATF's annual maintenance and upgrade activities with time spent on RF and photocathode laser maintenance, repositioning of a bunch-selector mask used to produce fs bunch trains and specially shaped electron bunches. This will allow much more flexibility in manipulating electron bunch structure. The move was prompted by user interest and will be of particular use to wakefield experiments. Bunch length studies and beam tests for the newly positioned bunch selection mask was followed by two user experiments. See right (fig. 1) for distribution of e-beam and CO_2 laser activities.

The following user experiments were served with typical ebeam parameters ranging from 50 – 65 MeV in energy and 30 – 500 pC charge and CO_2 laser of 1 TW peak power:

AF53 – Non-linear Inverse Compton Scattering (UCLA), *feasibility study*

AE52 – Beam Manipulation by self-wakefield (Euclid Techlabs)

CO_2 laser activities focused on rebuilding the front end that supplies a seed picosecond 10-μm pulse for amplification. An old multi-component pulse forming system based on gas lasers and YAG:laser-controlled optical switches has been decommissioned and a new Ti:Sapphire-pumped Optical Parametric Amplifier (OPA) put on-line. This move improved both seed pulse duration and energy by an order of magnitude. Most recently, ebeam-laser synchronization for nonlinear Compton experiment was achieved and the experiment is now moving towards attempting new scientific results.

Noted Publications

Y. Fang, V. E. Yakimenko, M. Babzien, M. Fedurin, K. P. Kusche, R. Malone, J. Vieira, W. B. Mori, and P. Muggli, Seeding of Self-Modulation Instability of a Long Electron Bunch in a Plasma Phys. Rev. Lett. 112, 045001, 28 Jan 2014

S. Antipov, S. Baturin, C. Jing, M. Fedurin, A. Kanareykin, C. Swinson, P. Schoessow, W. Gai, and A. Zholents, Experimental Demonstration of Energy Chirp Compensation by a Tunable Dielectric Based Structure Phys. Rev. Lett. 112, 114801, 18 March 2014

M. Babzien, I. Pogorelsky and M. Polyanskiy, Design and Application of the Brookhaven CO_2 laser to be in proceedings of 2014 OSA conference on High-intensity Lasers and High-field phenomena

IF YOU LIKE THIS NEWSLETTER

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Facility Upgrade – ATF-II on the Horizon

by Christina Swinson

As an accelerator and laser user facility, it is the mission of the ATF to provide the best possible experimental resources to our community. This drive, together with increasing demand and complexity of experiments led the ATF to pursue an upgrade of those facilities. Most notably, an increase in experimental space, and laser and electron beam energies. The upgrade to ATF-II will occur in two stages, the first of which is already under construction.

The upgrade will see the ATF move to a larger building, with space to accommodate multiple experiment halls. Stage 1 includes the construction of a linac and four beam lines in two separate experiment halls with an increase in beam energy from the present 80 MeV to 150 MeV. In parallel, there will be an upgrade of the CO_2 laser to increase power from 1 TW to 100 TW. The aim for Stage 2 will be construction of a 300 MeV beamline with space remaining available for an even larger energy increase at a later date.

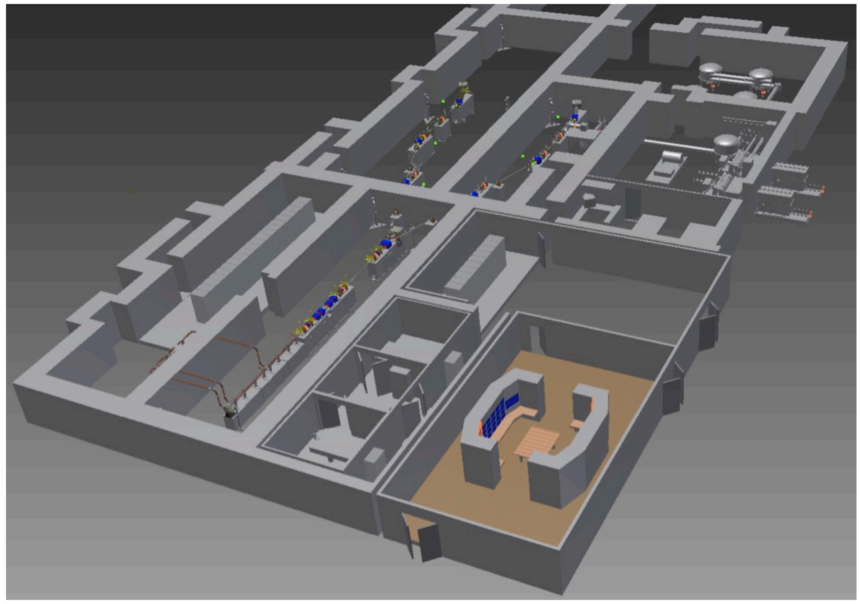

Figure 1: 3D rendering of the planned upgrade. When complete ATF2-II will boast 4 separate experiment halls, one of which will be dedicated to ion generation by CO_2 laser. The other halls will contain electron beamlines for multiple energies, up to 300 MeV, with electron beam and laser-ebeam interaction points.

Accelerator Upgrade

The new facility will have multiple, radiation isolated, experiment halls, which will allow experiment setup in parallel with operations. This arrangement ought to increase scientific throughput and allow users to install/modify experiments, without having to sacrifice beam time. The second motivation is that an increase in the electron beam energy, from the present 80 MeV to a future 300 MeV, will significantly broaden the experimental landscape at the ATF.

CO_2 Laser Upgrade

The CO_2 laser upgrade to 100 TW peak power in sub-picosecond pulses will open the first-time opportunity to explore strong-field physics in in the mid-IR spectral domain. Upgrade of the CO_2 system will be achieved through adding stages to the laser's amplification chain, implementing the Chirped Pulse Amplification (CPA) technique and installing a high-power Optical Parametric Amplifier (OPA), and by implementing femtosecond pulse compression. This will greatly expand the experimental capabilities offered to the ATF's users. Most notably, a significant increase in laser power will allow ion generation at radiotherapy relevant energies and will also lead to further development of high luminosity laser wakefield accelerators.

Construction of the new facility has already begun and is being handled in such a manner as to minimize disruption to operations. It is planned that the first experiment hall (with two 150 MeV beam lines and CO_2 laser interaction capability) be fully commissioned at the time of shutdown of the current ATF. We look forward to hosting your experiments for many years to come.

FOR MORE INFORMATION

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Measurement of a Narrow-band THz Radiation at the ATF

by S. Antipov (Euclid Techlabs)

We used a mask method to produce a train of 3 bunches at the ATF. The spacing between bunches was determined to be 500 microns by means of CTR interferometry (Figure 1). Three bunches correspond to 5 peaks in the autocorrelation function. Naturally the bandwidth of the spectral content carried at the fundamental frequency by the beam is wide, 33%.

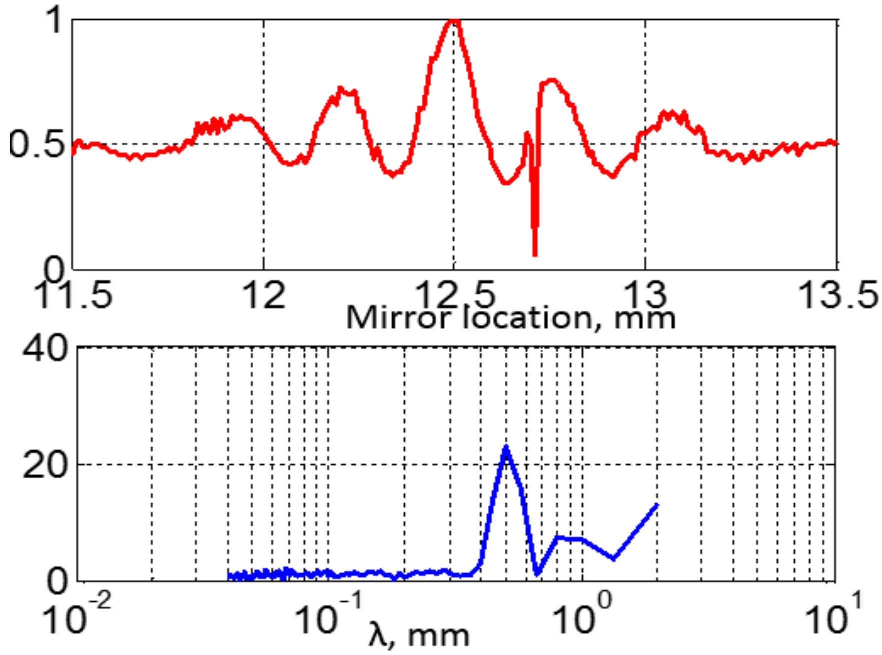

Figure 1: Autocorrelation function for the bunch train and its Fourier transform.

When this bunch train passed through the quartz tube with ID ≈ 400 µm, ID ≈ 550 µm it generated a narrowband signal due to a low group velocity of the generated mode. The interferometer measurement (one half of the symmetrical autocorrelation function) is shown in figure 2. The measured bandwidth of the autocorrelation signal is 2.38%. The traveling range of the interferometer's mirror, however, limited this measurement. The theoretical bandwidth for this 2 inch long structure with group velocity = $0.58c_0$ is about 0.7%. The frequency of the signal generated in the capillary is ~ 500 GHz, which is less than the central frequency of the bunch train (600 GHz). However the signal is excited because the bandwidth of the bunch train is rather large. If we managed to overlap the central frequency of the bunch train with the frequency of the synchronous mode we would gain more power in THz signal. In this case we calculate, based on the amount of charge in the bunch train, the total length of the 500 GHz signal to be 290 ps. The wakefield amplitude excited inside the capillary was 40 MV/m which corresponds to 350 kW peak power and 58 µJ energy per pulse.

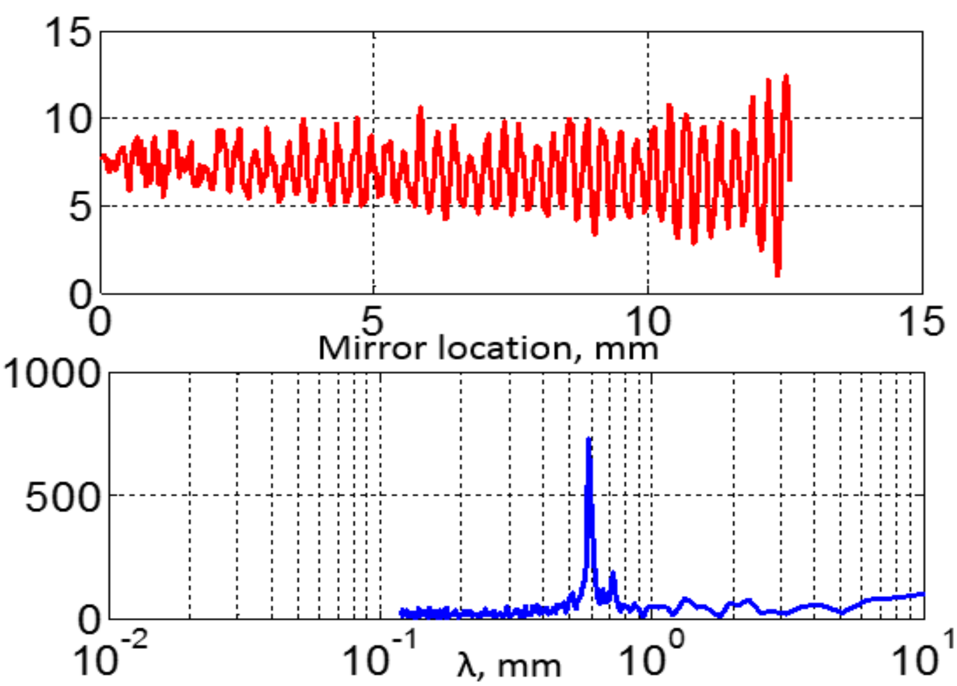

Figure 2: Autocorrelation function of the THz signal and its Fourier transform showing a narrowband signal.

FOR MORE INFORMATION

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Experimental demonstration of CO_2 active cavity, and 30 J pulse trains generation at ATF

A. Murokh, A. Ovodenko (RadiaBeam), I. Pogorelsky, M. Polyanskiy (ATF BNL)

Inverse Compton Scattering (ICS) technology carries a promise to obtain “Light Source” quality quasi monochromatic directional X-rays from moderate energy compact linacs, by replacing centimeter-period undulators and wigglers with intense lasers. The resulting reduction of size and cost makes such systems attractive for a host of applications in medicine, industry, research, and homeland security. However, one important obstacle to the practical realization of ICS sources is low average power, even when the system is fully optimized, it is hard to extract more then 1 X-ray photon per interacting electron, and any practical ICS configuration requires 1000s of interacting nano-Coulomb electron bunches and multi-Giga-Watt laser pulses per second. This is a major challenge for ICS technology, and RadiaBeam, in collaboration with the ATF and UCLA, has been actively involved in developing a recirculated ICS system, where the intra-cavity laser pulse circulation enables interactions with electron bunch trains.

In this project we develop an active CO_2 amplifier cavity, to enable multiple laser interactions with an electron beam pulse train at ~40 MHz repetition rate (Fig. 1 Left). In December 2013, for the first time we demonstrated a successful operation of the 3-atm CO_2 laser amplifier in the regime of long trains of 60-80 laser pulses, of several picosecond duration each, circulating inside the cavity, with a total 30 J pulsed energy achieved. As the active cavity is the most challenging element of the recirculated ICS, this result is an important milestone.

The initial pulse was generated with the ATF CO_2 laser oscillator and a picosecond semiconductor optical switch, reaching several mJ in the ATF’s regenerative amplifier, and injected into an amplification optical ring cavity through a partially reflecting NaCl window. A big part of the recirculating amplifier testing included the effects of gas composition, cavity alignment, and optimization of the shot-to-shot stability. Fig. 1 (right) shows a typical scope trace recorded for each laser shot using a set of fast photovoltaic detectors. Here, the blue trace shows the pulse buildup inside the regenerative amplifier. It is terminated at the moment when a pulse is extracted from the regenerative amplifier cavity with the help of an active optical switch. This single extracted pulse, shown on the purple trace is injected into the recirculating cavity. After a certain build up time period, stable cavity mode is established and the pulse train reaches saturation (yellow trace).

With a gas mixture optimized for the maximum energy gain, pulse trains reach up to 30 J contained within 60-80 pulses. This averages to about 300-500 mJ per individual pulse, which is an ideal operating regime for pulsed ICS. Also it was observed that the total pulse train energy is not very sensitive to the input pulse, and is relatively stable.

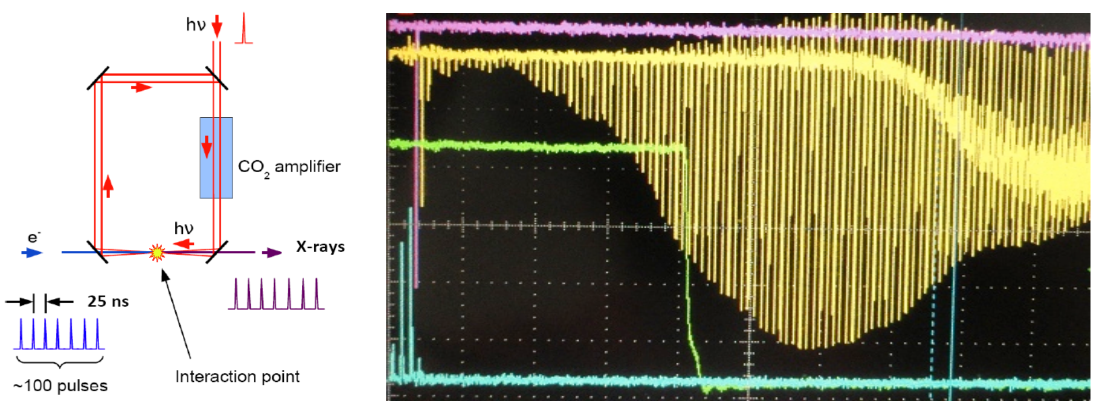

Figure 1: LEFT: Schematics of the recirculated bunch train ICS; RIGHT: Experimental test of the recirculated active cavity: regen pulse (blue), output from the resonator window (yellow); horizontal scale is 200ns/div.

The reported testing was performed in the ATF CO_2 room. The next step will be to reproduce the active cavity set up inside the experimental hall, and to conduct the recirculated ICS experiment. At the present time the ICS interaction chamber is under construction at RadiaBeam, and installation of the complete recirculated ICS system is scheduled for August 2014.

This work is supported by RadiaBeam DOE SBIR Award # **DE-SC0007703**.

FOR MORE INFORMATION

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Visit the ATF website
www.bnl/atf
to explore current
research opportunities

Send proposals for experiments
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James Rosenzweig, UCLA
Vitaly Yakimenko, SLAC

FIRST ANNOUNCEMENT

Active program of user experiments and new
proposals will be reviewed at the next
ATF User Meeting
at Brookhaven National Laboratory
Upton, New York, USA

17th ATF User Meeting

October 14-15, 2014

BACK TO BACK EVENTS

October 16-17, 2014

ATF II Upgrade Workshop

Explore new opportunities for research
in advanced accelerators and radiation sources
offered by future ATF upgrade
to 500 MeV electron beam energy and
100 TW peak power from a femtosecond CO_2 laser

See ATF Upgrade Proposal at
www.bnl.gov/atf/docs/
ATFupgrade.pdf

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