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# ATF FACILITIES UPGRADES AND DEFLECTOR CAVITY COMMISSIONING*

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*Abstract*

The Accelerator Test Facility (ATF) at Brookhaven National Lab is an Office of Science user facility focusing on advanced acceleration techniques. It houses several electron beamlines synchronized to high power lasers, including a TW-class carbon dioxide (10 µm) laser. Here we outline ongoing upgrades to both the accelerator and laser systems, give a brief overview of the experimental landscape, and report on the recent commissioning of a newly installed X-band deflector cavity [1]. The deflector cavity is implemented as a longitudinal electron beam diagnostic, which will allow us to measure the structure of ultra-short bunches.


## INTRODUCTION

The mission of the ATF is to provide the advanced accelerator community with state-of-the-art facilities and scientific support. We also host beam instrumentation and transport R&D, laser research, and materials/condensed matter physics programs. Figure 1 highlights the major components of the ATF complex.

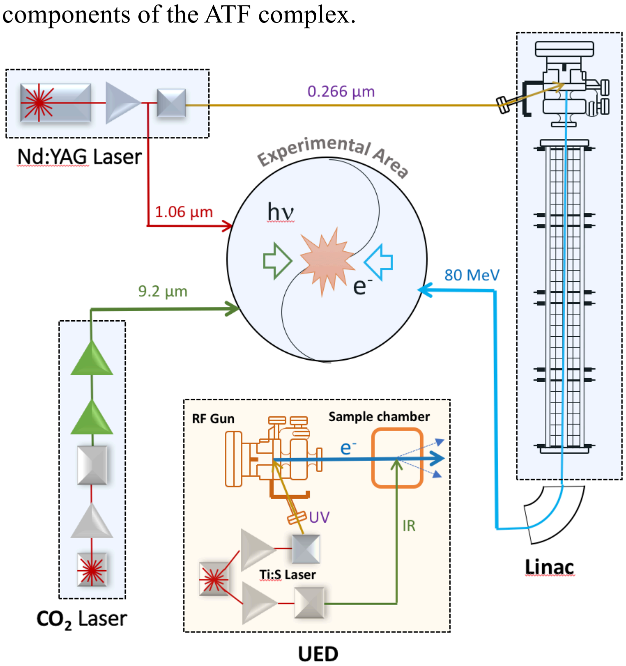


Figure 1: Schematic of the ATF, featuring the four ma-jor components. We plan to add a strong field laser to the ATF portfolio, in the near future.

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## PRESENT STATUS

The ATF is presently hosting a full user program. Table 1 shows the presently available electron beam parameters at the ATF. A maintenance program, currently underway and continuing over the next few months, will allow us to routinely reach the highest achievable beam parameters. This paper outlines upcoming R&D, designed to expand the $CO_2$ laser parameter space, shown in Table 2.

Table 1: Presently Electron Beam Parameters at ATF

| Beam Property | Nominal | Best Achievable |
|---|---|---|
| Energy (MeV) | 57 | 80 |
| Rep. Rate (Hz) | 1.5 | 3 |
| IP Beam Size (µm) | 50 | 5 |
| Bunch Charge (nC) | 0.01-1.5 | 3 |

Table 2: Present $CO_2$ Laser Parameters

| Laser Property | Value |
|---|---|
| Energy (J) | 7 |
| Pulse length (ps) | 3.5 |
| Power (TW) | 1.5 |
| Power delivered IP (TW) | 0.5 |
| Rep. Rate (Hz) | 1/20 |

### *Accelerator Improvements*

The ATF is presently undergoing a program of accelerator improvements aimed at improving RF stability and beam reproducibility. Alongside such improvements, we report the recent commissioning of an X-band deflector cavity as a longitudinal bunch diagnostic, and a focus on providing <100 fs long electron bunches through magnetic bunch compression.

### *X-band Deflector Commissioning*

An X-band (11.4 GHz), Traveling Wave, Deflection Mode Cavity [2] for Ultra-Fast Beam Manipulation and Diagnostics (fig. 2), developed and manufactured by Radiabeam Technologies, was recently installed in one of the ATF experimental beam lines. The system has been commissioned and has already been utilized by two user groups.

An initial estimate of time resolution showed better than 10 fs. This was done by using a microbunched beam of known spacing, produced using a mask technique [3]. The microbunched beam was used to calibrate a yag crystal screen downstream of the deflecting cavitiy. The measurement was limited by the resolution of the beam profile monitor camera.

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The X-band system was recently used in measuring the length of a compressed electron bunch to be used as a drive bunch for beam-driven plasma wakefield research. The aim, to observe the effect of the plasma on the energy spread of the bunch. During the user experiment, data was taken to calibrate the deflection. The streak was calculat-ed to be 1.04 µm/fs yielding a resolution measurement of 105 fs, for this optic [4].

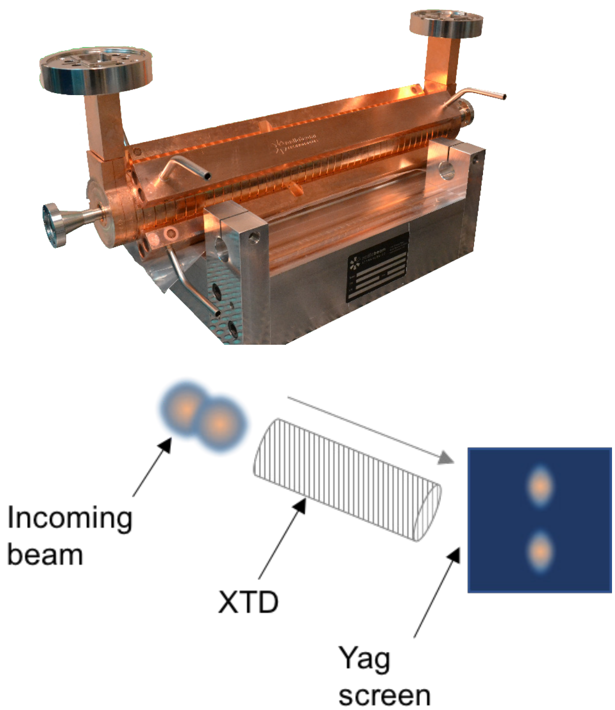


Figure 2: X-band deflector cavity (XTD), before instal-lation in the ATF beamline (top). Layout of initial meas-urement using micro-bunched beam (bottom).

The next step for this plasma experiment is to optimize the beam optic for small transverse beam size at the downstream profile screen, to improve the time resolu-tion, as in equation (1) [5]. This, while preserving the beam size at the plasma interaction point.

$$\Delta t = \sigma_y \frac{2mc^2\gamma}{L\omega eV_t} \qquad (1)$$

where Δt is the time resolution, σ is the transverse beam size, ω is the cavity resonant frequency, and $V_t$ is the transverse voltage.

Figure 3 shows a plot of measured deflection for various deflector phase settings, as recorded for the plasma exper-iment.

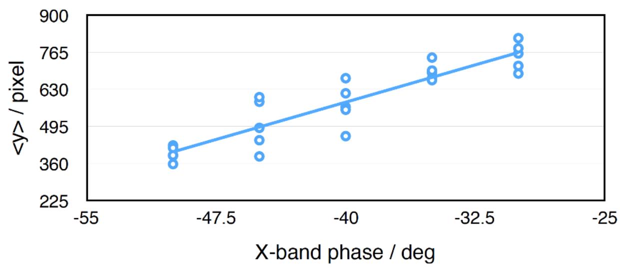


Figure 3: Plot of transverse beam size vs X-band RF phase.

### *Near-Term $CO_2$ Laser Upgrade*

A staged upgrade in laser power is ongoing and in-place at the current ATF location, with a view to move to the new complex in the next few years. Figure 4 shows the layout of the near-term upgrade plan for the $CO_2$ laser system.

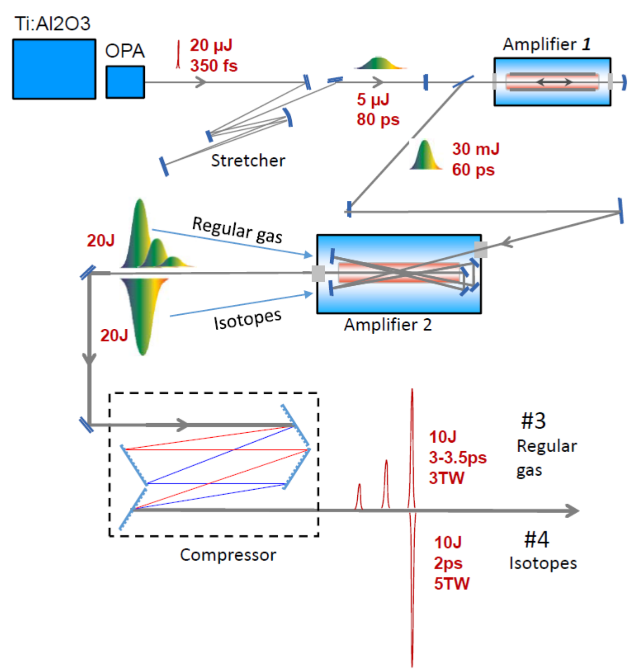


Figure 4: Layout of the near-term upgrade for the $CO_2$ laser system. The goal is to provide 3-5 TW peak power over the next few years.

The laser system currently has a full program of re-search in Compton scattering, inverse free electron lasers (IFEL), laser-plasma interactions (such as ion acceleration by shock wave and laser-wakefield acceleration), investi-gation of lasers in air, interaction with materials, etc.

### *Addition of UED to the ATF Complex*

As a part of the ATF-II complex, an Ultrafast Electron Diffraction (UED) facility has been assembled and com-missioned [6]. This resource will serve materials science and condensed matter physics users, and as a test bed for UED machine R&D.

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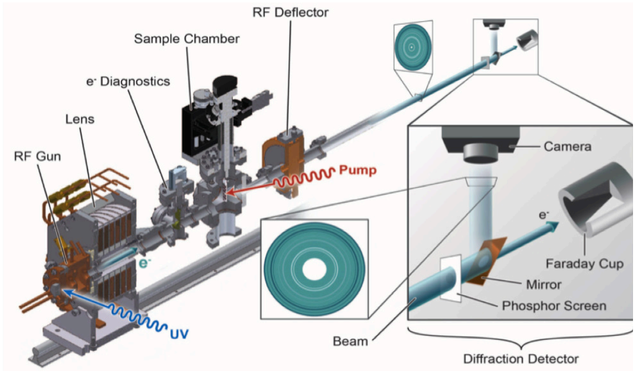

Figure 5: UED beamline layout. Allows observation of ultrafast processes, for example, as a material goes from an excited state (pumped by an IR laser) to the ground state.

Figure 5 shows the facility layout where there is presently one active R&D experiment, three active materials exper-iments and two more upcoming experiments. For this new facility, all users are presently internal BNL groups and we will begin considering outside proposals in 2018.

## FUTURE UPGRADES

An upgrade to ATF-II is planned, including relocation of the facility to provide more experimental space and further upgrade of the $CO_2$ laser to > 5 TW [7]. The new ATF complex will also include a strong field laser (SFL) and an Ultrafast Electron Diffraction (UED) facility. The UED is already commissioned and serving, materials science and accelerator R&D, users at the ATF-II loca-tion. We plan to begin work on the strong field laser in the next year.

### *Longer-Term $CO_2$ Laser Upgrade*

In the longer-term, laser operations will be transferred to the new site where further upgrades will take place. The first part of the plan is to increase peak power, be-yond 5 TW, by introducing additional amplification via the gas medium. Figure 6 shows the new amplifier discharge vessels along-side the present ATF setup.

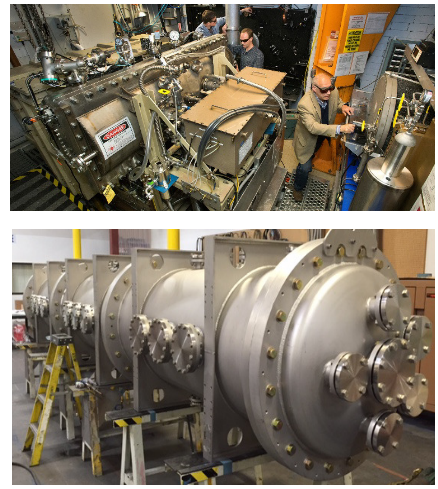
Figure 6: Gas amplifier vessel, working at the ATF (top) and newly acquired vessels ready for construction of the new amplification system, to be implemented at the ATF-II.

## SUMMARY

A large upgrade program is underway at the ATF, with multiple thrusts and the goal of providing users with high-quality, high-brightness electron beams and high-quality, high-power lasers. We hope to open up the landscape for electron-laser interaction research, focussing on utilizing the unique 10 µm laser system.

## ACKNOWLEDGMENT

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