2019 ATF Scientific Needs Workshop (SNW) Statement of Purpose

ATF is convening a meeting of experts to identify priority research directions consistent with the ongoing operations and upgrade plans at building 820. The previous workshop held in 2017 was centered around the "assessment of the scientific needs associated with the mid-IR laser capabilities" as were expected to be implemented at the ATF II facility (Building 912)[1]. Significant developments have since occurred in the direction of the DoE Office of Science as well as the developments in the capabilities of the ATF Facility. There is therefore a need to reassess the scientific needs of the community in a broader scope that includes all the unique capabilities available at Building 820. This will ensure that the ongoing operations and upgrade plans of ATF facility are consistent with the priority research directions of the community.

Background

ATF provides the community with access to four classes of experimental facilities:

- Long-wave IR (LWIR) High Power Laser at $\sim 9.2\ \mu m$
- Electron Beam
- Near-IR

The capabilities of these facilities and the expected R&D path in the mid-term (∼3 years) are as follows:

1. LWIR High Power Laser Facility: The ATF is pursuing an R&D plan with the goal of delivering 10-20 TW of CO_2 laser power with sub-ps pulse length to the users in the mid-term. Currently, the facility is capable of producing a 5 TW CO_2 pulse with a 2 ps pulse length. However, with the current air transport line, the delivered energy to the users is kept below ∼2.5 TW to avoid nonlinear distortions in the pulse. The vacuum transport upgrade is planned to be completed within a year, which will enable the full 5 TW delivery to users. ATF's R&D effort encompasses the realization of two more capabilities in the mid-term: First, modification of the gain profile is a potential route to enable the delivery of 10 TW, 1 ps pulses. Second, a recent proof-of-principle demonstration of the nonlinear pulse compression (NLPC) technique has delivered a sub-picosecond pulse. These preliminary results show that ~0.5 ps pulse lengths may become possible with this technique in the near future. To achieve this path, additional R&D and upgrade funding will be required over the course of next 3 years.
2. Electron Beam Facility: Currently the facility is capable of delivering an electron beam with and energy of 50-65 MeV, 0.1-2 nC in charge, a pulse-length down to 100 fs, and a normalized emittance of 1 μm at a 1.5 Hz repetition. ATF is considering several upgrade thrusts in the e-beam energy and pulse duration and is looking for feedback on the impact of these upgrades.
    a. With respect to the electron energy, a second klystron powering the existing two linac sections would result in an increase in the beam energy up to 125 MeV. The increased $\gamma \sim 250$ will be very advantageous for the many physical processes that scale nonlinearly with γ. Additionally, the increased energy will result in

[1] The full report can be accessed at https://www.bnl.gov/atf/docs/atf_snw_report_final.pdf

significant gain in the pump depletion length for experiments that use the electron beam as a driver (e.g. of plasma waves). Therefore, the increased energy is expected to be an enabling factor for some beam-driven experiments.

b. Several schemes exist for improving the bunch compression. Two of these schemes, which were discussed at the previous user meeting (Link) involve the use of a double chicane or a chicane-dechirper combination. The choice between these two methods involves the tradeoff between the energy spread and the compression. Another novel bunch compression technique has also been shown in simulations to be able to reduce the bunch length to 30 fs. This latter technique is expected to be implemented once tested and demonstrated experimentally.

c. The diagnosis of the electron beam's longitudinal phase space can be enabled by installing and commissioning an additional transverse deflector cavity at end of both beamlines where the electron beam can be delivered (currently existing only on one of them).

The high-power CO_2 laser and electron beam capabilities can be combined at the interaction point (IP), but the pursuit of applications driven by the electron beam – independent of the LWIR laser – is also highly desired.

3. Near IR Facilities: The ATF is in the process of significantly expanding its near IR capabilities. Currently, a Nd:YAG laser with 1-15 ps and 1-5 mJ in energy can be delivered to the IP. The expansion of the near IR capabilities encompasses the integration and the delivery of a short-pulse ($\leq$ 100 fs), terawatt-class Ti:Sapphire laser pulse to the IP. This expanded capability is consistent with the interest expressed by the community at the SNW 2017 meeting. Further upgrades to the laser power are possible, but will depend on the interest of the scientific community and availability of funding.

<u>Goals</u>

ATF is seeking the guidance of the user community in the following areas in order to prioritize the upgrades planned for the facilities described above:

- Determine or reaffirm the set of variables that will enable the exploration of new physics
- Determine the priority research directions that can be leveraged to establish a priority-based upgrade path.

The priority research directions identified in the SNW 2017 meeting resulted in a table of required parameters compiled in the report (https://www.bnl.gov/atf/docs/atf_snw_report_final.pdf, Table 5.1), which has been reproduced in Table 1 below. From this table, a laser power of >25 TW is needed to enable several key research areas, such as the laser plasma acceleration (LPA) in the bubble regime, ion acceleration, and IFEL. The LPA in the bubble regime is particularly of interest as the combination of the upgraded near-IR capability with the CO_2 laser pulse creates a path for an all-optical electron beam injector via ionization injection. A primary goal of the present workshop is to revise or reaffirm these parameters.

Since the focus of the SNW 2017 was on LWIR laser systems, the novel physics driven by the linac-produced electron-beam was not discussed as part of the 2017 workshop. In the present workshop however, the intent is to focus also on novel physics enabled by all ATF facilities, including those driven by the electron-beam facility *in addition* to those enabled by the integration of the electron beam and CO_2 facilities.

The second goal of the present workshop is to identify particular techniques and directions that can be used to reach the parameters that enable the novel physics. For the CO_2 facility in particular, ATF is interested in a discussion of relative merits of various technologies for reaching above 25 TW of delivered energy, including the commonly used electrical discharge pumping, as well as new approaches such as optical pumping or diode pumping.

Deliverables of the Workshop
Through a combination of technical and scientific presentations, at the end of the workshop, the ATF expects to have

- A summary of scientific needs for the parameters to pursue for exploration of new physics
- A summary of capability upgrades required for enabling key research thrusts in the near term
- A prioritized list of upgrades that will enable a long-term path for the facility.

Experiment	Requirement
Nonlinear Kerr effect	1-10 TW
Non-linear LPA	~2 TW
Blow-out LPA	5-10 TW, 0.5 psec
Bubble LPA	25-30 TW, 0.5 psec
Ion acceleration	25-100 TW; long-term circ. polar.
IFEL	25-100 TW
DLA	10-100 GW, lin. polar.
ICS	2-10 TW
ICS OAM	Circ. polar.
Phase space manipulation	~ TW

** Circularly polarized laser light is not currently part of the proposed project plan*

Table 1. Summary of laser parameters required to enable experiments as discussed in the SNW 2017