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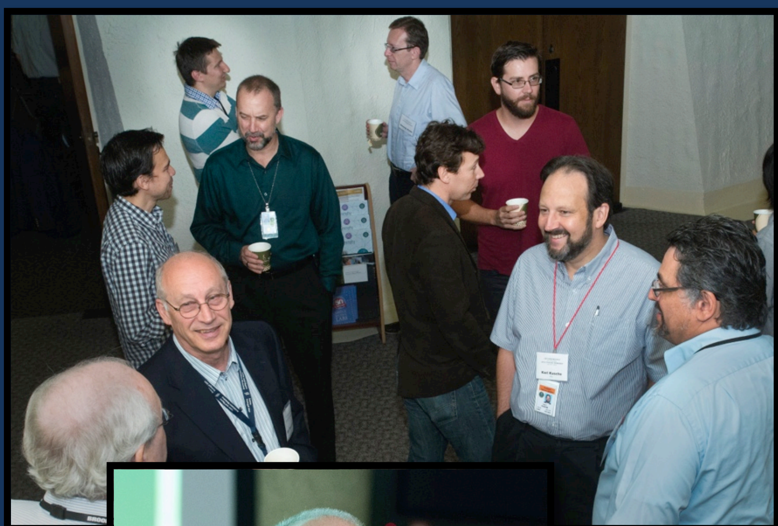
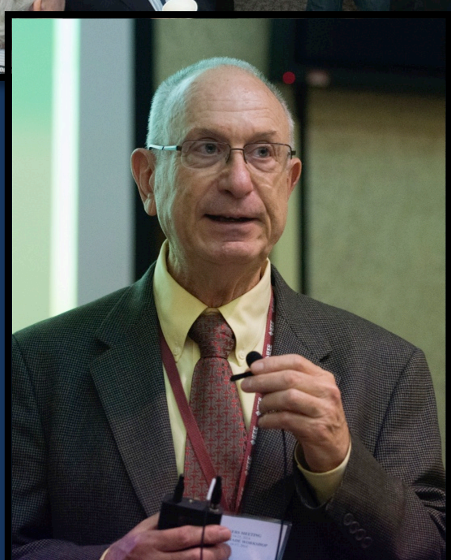
Brookhaven National Laboratory

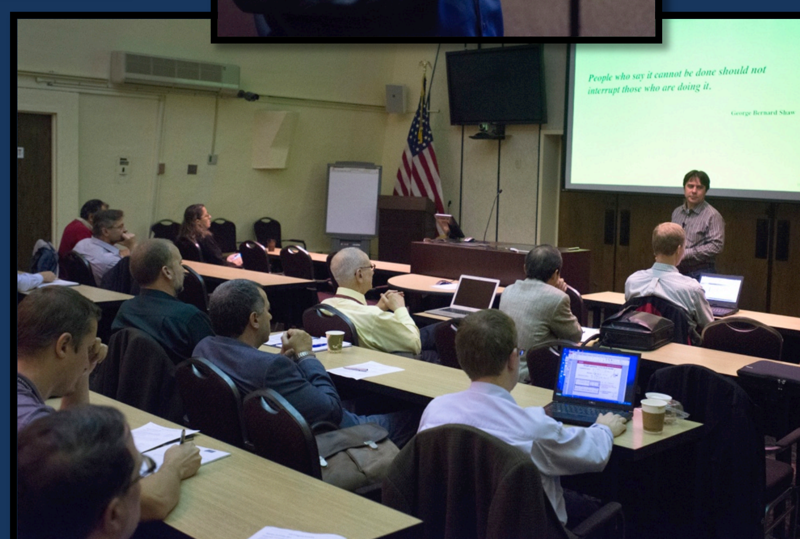
ATF Newsletter

Special Issue:

ATF Upgrade Workshop







Workshop Chairs: Ilan Ben-Zvi & Igor Pogorelsky
Workshop Coordinator: Kathleen Tuohy
Local Organizing Committee: Christina Swinson, Marcus Babzien, Karl Kusche & John Skaritka
Newsletter Editor: Christina Swinson

Talks: **http://go.usa.gov/sQzW**
Photos: **http://flic.kr/p/pPPjzL**

BROOKHAVEN NATIONAL LABORATORY

ATF ACCELERATOR TEST FACILITY

1. List of Workshop Talks and Presenters

ASSMANN, Ralph	- Advanced Accelerator R&D at DESY and Roadmap Towards Applications
BABZIEN, Marcus	- Laser Upgrade
BEN-ZVI, Ilan	- Welcome
COLBY, Eric	- Longer-term Evolution of the Accelerator Stewardship Program
FEDURIN, Mikhail	- Accelerator Lattice, Focused and "Masked" Beams - Experimental Study of Undulator Spontaneous Radiation Suppression by Current Noise Control in High Energy e-beams
GORDON, Daniel	- Controlled LWFA with External Injection
JING, Yichao	- Femtosecond Electron Bunches, "Flat" Beams
KIMURA, Wayne	- High-Rep-Rate, Terawatt-Class CO2 Lasers/1-m, Density-Tapered Capillary Discharges
LU, Wei	- Future Perspectives on Ultrafast CO2 Laser Driven LWFA and LPI
MUROKH, Alex	- ATF Experience from Small Business Angle
MUSUMECI, Pietro	- 1 GeV/m IFEL
NAJMUDIN, Zulfikar	- Shock Wave Ion Acceleration
POGORELSKY, Igor	- Review of ATF II Upgrade Plan and Spectrum of Science Trusts
ROSENZWEIG, James	- Laser Enabled Experiments: New Opportunities in Dielectric Laser Acceleration and Inverse Compton Scattering - E-beam Enabled Experiments: New Opportunities in DWA and PWFA
SCHACHTER, Levi	- Novel Paradigms and New Options for Experiments at ATF-II Employing Laser Radiation and Relativistic e-beam
SHVETS, Gennady	- Generation of Conditioned GeV-range Electron Beams in a Hybrid Laser Wakefield/Direct Laser Accelerator
SKARITKA, John	- ATF II Layout and Construction Schedule
TOCHITSKY, Sergei	- Experimental Opportunities for CO2 Laser-plasma Research at the ATF II
WILCOX, Russell	- Femtosecond Beam Synchronization
YAKIMENKO, Vitaly	- A Tale of Two User Facilities
ZGADZAJ, Rafal	- Advanced Plasma Diagnostics

All the presentations can be viewed at https://indico.bnl.gov/conferenceDisplay.py?confId=913

2. List of Workshop Participants

Gerard Andonian	UCLA
Sergey Antipov	Argonne National Laboratory
Ralph Assmann	DESY, Germany
Marcus Babzien	Brookhaven National Laboratory
Samuel Barber	UCLA
Ilan Ben-Zvi	Brookhaven National Laboratory
Massimo Carpinelli	University of Sassari and INFN, Italy
Yu-hsin Chen	Naval Research Laboratory
Allen Egon Cholakian	Harvard University
Eric Colby	DOE's Office of Science
Nathan Cook	Stony Brook University
Xiaoping Ding	UCLA
Joseph Duris	UCLA
Mikhail Fedurin	Brookhaven National Laboratory
Daniel Gordon	Naval Research Laboratory
Yulia Grebenyuk	DESY, Germany
Lee Hammons	Brookhaven National Laboratory
Victor Hasson	University of Arizona
Yichao Jing	Brookhaven National Laboratory
Yoshio Kamiya	The University of Tokyo, Japan
Wayne Kimura	STI Optronics
Karl Kusche	Brookhaven National Laboratory
Wei Lu	Tsinghua University of Beijing, China
Robert Malone	Brookhaven National Laboratory
Alex Murokh	RadiaBeam Technologies
Pietro Musumeci	UCLA
Zulfikar Najmudin	Imperial College, London, UK
Ariel Nause	UCLA
Igor Pogorelsky	Brookhaven National Laboratory
Mikhail Polyanskiy	Brookhaven National Laboratory
James Rosenzweig	UCLA
Marcos Ruelas	RadiaBeam Technologies
Yusuke Sakai	UCLA
Levi Schachter	Technion, Tel-Aviv, Israel
Sergey Shchelkunov	Omega-P R&D Inc
Gennady Shvets	University of Texas at Austin
John Skaritka	Brookhaven National Laboratory
David Sutter	University of Maryland
Christina Swinson	Brookhaven National Laboratory
Antonio Ting	Naval Research Laboratory
Sergei Tochitsky	UCLA
Russell Wilcox	Lawrence Berkeley National Laboratory
Rafal Zgadzaj	University of Texas at Austin
Vitaly Yakimenko	SLAC

3. Introduction

Over a quarter of a century ago, the Brookhaven Accelerator Test Facility (ATF) pioneered the concept of a user facility for advanced accelerator research. In bringing advanced accelerator science and technology to individual users, small groups of researchers, and large collaborations, the ATF offers a unique combination of a high-brightness 80-MeV electron beam synchronized to a 2-TW picosecond CO_2 laser.

The DOE's Office of Science recently identified the ATF as a flagship facility for their newly established Accelerator Stewardship program. The essence of this program lays in applying the expertise on particle accelerators of the Office of High Energy Physics (OHEP) and its accelerator R&D community to exploration of revolutionary new methods of acceleration for discovery science, as well as for economical solutions for realizing compact particle accelerators that are essential for many applications in industry, medicine, and other civil ventures.

At this juncture, the ATF has embarked upon a transformational upgrade of its capabilities. We plan to greatly expand the ATF's floor space, and the number of independent experiment halls, while upgrading the electron beam's energy, in stages, to 500-MeV, and the CO_2 laser's peak power to 100 TW. This upgrade will offer a new, vast space for both the laser and electron beam for conducting research in accelerator science and technology at the forefront of advanced accelerators and radiation sources, and to support the most innovative ideas in these fields.

These emerging opportunities were discussed at the two-day ATF Upgrade Workshop held at Brookhaven National Lab. (BNL) on October 16-17, 2014. Researchers from around the world, representing universities, national facilities, and small businesses assembled to learn and discuss the new opportunities to be offered at the ATF-II, and to provide their feedback and recommendations aimed at strengthening the ATF's capability in supporting the forefront of research in advance accelerator and radiation sources and their multi-disciplinary applications, as mandated by the DOE's Accelerator Stewardship program.

4. Workshop Presentations

The workshop was held in conjunction with the 17^{th} ATF Program Advisory Committee and Users' Meeting, October 14-15, http://www.bnl.gov/atfusersmeeting/, where ATF users met to present their recent achievements and detail their near-term plans. This event showcased the traditionally strong area of ATF's user research program that will be elevated even further with the new ATF-II's upgraded capabilities. This includes: Dielectric- and Plasma- Wake Field research, laser-driven ion acceleration, Compton scattering, IFEL, beam conditioning, and instrumentation development.

In addition, the ATF upgrade opens up new research opportunities that could not be addressed within the previous facility's capabilities. They include studies of new regimes in Laser Wake Field Acceleration (LWFA) wherein the longer laser wavelengths will engender a proportional increase in the beam's charge, while the ATF II linac will assure, for the first-time, the opportunity for undertaking detailed studies of seeding and staging of the LWFA, as was vigorously discussed at the Workshop.

The ATF's future role in Accelerator Stewardship program and in supporting small-business initiatives in particular was in the focus of several presentations at the Workshop.

BNL personnel gave an account of the upgrade plan and technical details of the future facility's parameters and configuration.
The workshop concluded with a lively discussion on the desired beam line design, the experimental setups, and the upgrade schedule to assure a better fit to the needs of the user community.

We review here the workshop presentations grouped to subjects.

4.1 Introductory talks

Following the welcoming remarks from Ilan Ben-Zvi (BNL), the ATF Scientific Program Director, we heard a talk from Vitaly Yakimenko (SLAC) entitled "Examples in Advanced Accelerator R&D: Path from not believable to routine" about his professional experience in pioneering projects at the ATF and FACET. His approach has been summoned well by George Bernard Shaw who stated: "People who say it cannot be done should not interrupt those who are doing it", thus setting the appropriate optimistic mood for the workshop.

Eric Colby's (DOE) talk "Longer-Term Evolution of the Accelerator Stewardship Program" was instructive in encompassing the role of the BNL-ATF in this newly established DOE program. ATF naturally fits in the scope of Stewardship, as has been well demonstrated by its serving a broad population of users from laboratories, universities and industry throughout its 25-year history; this is strengthened by its present-day program that meets interests of HEP, BES, NP, DARPA, DNDO, among others. The ATF's inclusion as a flagship facility in Stewardship signifies the following: An upgrade to a larger facility; Its designation as an Office of Science User Facility (yet to be formalized); Increased priority for technology demonstrations; and, a broadening list of stakeholders, with HEP being one of them. The ATF upgrade will be aimed not only on better accommodating current users, but on attracting a new category of "non-beam" users interested in utilizing RF power or lasers, as well as "accelerator application" users, who generally are more interested in process control and monitoring, and in access to special equipment than in our cutting-edge capabilities. For better complying with Stewardship, the facility outreach program will be modified accordingly to address this expanding category of users.

Igor Pogorelsky (BNL) presented a "Review of ATF-II's upgrade plan and spectrum of science thrusts". The ATF will fulfill its vision of providing users with research opportunities not available elsewhere, at the cutting edge of strong-field physics and advanced accelerator science, with the required diverse coverage of the Office of Science's missions in Accelerator Stewardship and Accelerator R&D through improving the facility's capabilities and ensuring higher productivity. The latter will be attained by quadrupling the number of experimental halls, tripling the total floor area, and increasing the radiation shielded area by a factor of seven. The machines' capabilities will be elevated via an increase in the e-beam's energy from 80- to 500-MeV (during Stage 2 upgrade), by reducing the bunch size to 10 fs, and focusing to 2 μm. Towards the end of this 3-year upgrade project, the CO_2 laser peak power will be increased from 1 TW to 100 TW in 100-fs, 3-cycle pulses. This unique combination of a strong-field mid-IR laser with a well-controlled electron beam will benefit many areas of research including the following:

- Enhancement of traditionally strong areas of ATF research based on combination of the laser with the e-beams (e.g., IFEL, Compton scattering).
- Expansion of the physical processes previously demonstrated with solid-state lasers (e.g., THz radiation, neutron sources).
- Studies practically affordable only with long wavelength lasers (e.g., shock-wave ion acceleration, HHG).
- New opportunities for LWFA research due to bigger, higher-charge bubbles and their probing and injection with femtosecond e-beams.

4.2 Heightening traditionally strong ATF research areas (IFEL, Ion Acceleration, ICS, DWFA, PWFA, and beam conditioning)

Pietro Musumeci's (UCLA) talk addressed the scaling of the already record-breaking IFEL RUBICON experiment towards demonstrating an order- of-magnitude higher, GeV-class energy gain. He pointed out that the availability of a high brightness e-beam combined with the high-power CO_2 laser, leveraged on the experience gained during the ongoing collaboration, makes the ATF-II the ideal place for the next-generation IFEL experiment. It is anticipated that a 25-TW CO_2 laser power, coupled inside a strongly tapered 75-cm long undulator on to a micro-bunched 90-MeV e-beam, should result in its acceleration to 500 MeV with a 2% energy spread. Importantly, the length of the laser pulse needs to be >0.5 ps so as to avoid phase slippage. The proposed research is highly relevant to gaining further insights into such IFEL physics problems as controlling the beams' quality (emittance and energy spread), injecting a pre-bunched beam with up to a 25 % energy gain in single period at extreme tapering and beam loading. Applications enabled by the laser-driven compact IFEL accelerator will include the following: Inverse Compton Scattering-based compact gamma-ray source (of DNDO – DTRA interest); Compact mode-locked soft-X-ray FEL; and, Recirculating drive laser for IFEL to increase the repetition rate and average flux of photons.

Two talks addressed opportunities for CO_2 laser-driven ion-acceleration. Zulfikar Najmudin (Imperial College) reviewed in his talk, titled "Laser driven ion acceleration with near-critical targets", the potential advantages of laser-driven ion sources compared to conventional accelerators. This includes lower cost, compactness due to ultra-high acceleration gradients; and, high-flux, low-emittance, short bunches. CO_2 lasers add to the possibility of using gas targets, resulting in less bremsstrahlung radiation, easy scalability to a high repetition rate, and flexibility in producing different ion species.

Sergei Tochitsky (UCLA) continued the same subject in his talk "Experimental Opportunities for CO_2 Laser-plasma Research at ATF-II". He reviewed the present results from the Neptune laboratory in shock-wave proton acceleration, and pointed out that the ATF-II will be especially attractive for continuing this research, due to the unique availability of single picosecond CO_2 pulses with a_0=5-10. Simulations for $I_L \geq 10^{17}$ W/cm^2 show >50 MeV protons with a 2-10% (FWHM) energy spread. He recommends using 100-fs, 400-nm probe pulses (2nd harmonic Ti:sapph.) for visualizing and optimizing the process. With access to unprecedented-high intensities in the mid-IR spectral domain, a variety of new studies in nonlinear physics could be possible, for example, the laser beam's filamentation in air over hundreds of meters that is important for many applications, such as lidars.

James Rosenzweig (UCLA) talked about other opportunities offered by combination of the ATF CO_2 laser with electron beams, including Dielectric Laser Acceleration (DLA) and Inverse Compton Scattering (ICS). A long laser wavelength allows proportional scaling of the dielectric structures that engenders improved efficiency in using electron beams of a realistic emittance. He predicts x150 increase in the geometric emittance tolerances compared with the case of a Ti:sapph laser. This allows DLA investigations with the 100-500 MeV-class beams available at the ATF-II, so avoiding problems with structural activation and damage typical for multi-GeV-class DLA experiments at SLAC. In the long run, this study may lead to the development of 5th generation compact light-sources configured as a 40-keV SASE FEL driven by a 2-meter long 800 MeV multi-stage DLA, or to future colliders.

Traditionally successful ICS studies at the ATF capitalize, in part, on a CO_2 laser's capability to deliver a copious number of photons per Joule of the laser energy, and its established good coupling with high-brightness e-beams. The ATF-II ICS studies will progress in several promising directions including the following: Photo-fission- or nuclear-resonance- based active detection of nuclear materials important for DNDO; Study of nonlinear effects in ICS; and, High-average-flux x-ray sources obtained from recirculating the laser pulse through the Compton interaction point.

Simultaneously, the improved ATF-II linac features and parameters (higher energy, lower emittance, tighter focus, flat beams, 10-fs compression), added to the already available high-brightness and mask technique, offer better opportunities for electron-beam-only enabled experiments, such as dielectric- and plasma- wakefield acceleration. This will better our control over quasi-nonlinear PWFA that, via a mask technique, should provide 3 GV/m with a ramped bunch train. The ATF-II will become a test bed for experimenting with the "Trojan Horse" concept of producing 10 nm emittance beams by precise ionization inside a bubble. With an updated solid-state laser, a precision plasma photoinjector can be achieved. The desired parameters of the electron beam for this experiment, Q=1 nC, σ_z=60 µm, ε_n=2 mm-mrad, are achievable at ATF-II. Stewardship may permit development of the following applications: Plasma injectors; THz sources, HHG, Space radiation simulator.

Mikhail Fedurin (BNL) presented on behalf of Adrian Nause (UCLA) "Experimental Study of Undulator Spontaneous Radiation Suppression by Current-Noise Control in High Energy e-beams". After the recent completion of a first successful experiment on the beam homogenization and noise suppression in the IR spectral-domain, experimenters are planning to progress into the UV spectral range with the main goal of demonstrating the suppression of radiation noise and the enhancement of coherence in seeded FELs. This experiment requires a flexible beam-line configuration with two chicane magnets and an undulator. The effect will be measured by observing the suppression of undulator radiation at the proper chicane setting.

4.3 New opportunities in Laser Wake Field Acceleration (LWFA) and other novel research

Wei Lu (Tsinghua Univ.) in his talk "Future Perspectives on Ultrafast CO_2 Laser Driven LWFA and LPI" suggested adding a programmable plasma structure available as a third component in the unique combination of ultrafast high power CO_2 laser and high brightness linear accelerator at ATF-II. This will allow longitudinal tailoring of a plasma structure, so providing the coherent phase-space matching necessary for staging LWFA in combination with traditional RF accelerators. Wei presented simulations for different scenarios leading to demonstration LWFA with low energy spread, a few nC beams of up to 2.5 GeV energy per a single accelerator stage (60 cm long). He concluded his talk by saying: "By combining the 100-TW CO_2 laser, the 100-500 MeV electron beam and the tunable plasma structure, many new frontiers of LPI at relativistic intensity can be explored with certainty and elegance! Plenty of new ideas on super-high brightness electron beam generation can be explored at ATF-II, opening up the possibility of coherent Compton scattering in the future. Practical high quality accelerator technology with CO_2 lasers seems real!"

Gennady Shvets (Un. of Texas at Austin) continued the subject of laser-driven electron acceleration in his talk "Conditioned Electron Beams in a Hybrid Laser Wakefield/Direct Laser Accelerator" wherein he explored a new opportunity of combining far-field and laser-wakefield acceleration mechanisms to mitigate de-phasing. Direct laser acceleration occurs when the Doppler-shifted laser frequency comes into resonance with the betatron frequency of the electron beam in plasma. The role for a CO_2 laser in this LW/DLA hybrid scheme is to produce a large plasma bubble convenient for injecting external electrons. The CO_2 laser should be used in conjunction with ultra-short solid-state laser pulse that injects electrons, excites betatron oscillations, and directly accelerates electrons.

Don Gordon (NRL) explored the possibility of injecting electron bunches from the ATF linac into the near-linear LWFA produced with a 20-TW CO_2 laser. For efficient self-bunching and trapping, the electrons should be at a low energy of 2 MeV. Injecting 70-Mev bunches requires short bunches (a small portion of the wake period). Simulations predict a tripling of electron energy without external guiding, and with good control of the beam's energy spread and emittance.

The external injection requires 10-fs synchronization between the laser and linac. This subject has been addressed by Russell Wilcox (LBNL). He described practical steps and setups in fulfilling this goal. Short-term studies include defining the magnitudes and sources of sub-system jitter. Further solutions will be derived from these measurements. Such measurements are possible with a simple cavity device that comprises an RF or an optical cavity "pinged" by an e-bunch- or an optical-pulse. Electrical output provides phase information to a referenced phase detector. A phase-locked technique uses two frequencies: First lock to fundamental, then to a higher harmonic. At the low repetition rates typical for ATF operation, correction is complicated. An additional quasi-CW pilot laser may be needed for a fast feedback.

An important advantage of a low-density LWFA affordable with a long-wavelength CO_2 laser is the relative ease of resolving the structure of the plasma wakefield. Rafal Zgadzaj (Un. of Texas at Austin) described different methods of diagnosing the plasma wakefield including: Frequency Domain Holography with chirped reference and probe pulses for wakefield imaging; Frequency Domain Streak Camera (FDSC) for recording the evolution of a bubble; Frequency Domain Tomography (FDT) for recording multiple-phase streaks, and, transverse optical probe Faraday rotation measurement of the electron bunch's magnetic field. In addition, Wei Lu proposed using a transverse electron-probe for imaging the plasma wakefield. We will evaluate implementing all these diagnostics in the ATF's LWFA experiment.

Wayne Kimura (STI Optronics) described a proposal for creating one-meter-long capillary discharges for LWFA applications. Conventional capillary discharges cannot satisfy the combination of requirements that include low on-axis plasma density while maintaining a matched spot size during the density tapering necessary for mitigating phase slippage. The STI's Dynamic Capillary Discharge based on deepening of the plasma's profile due to its oscillatory behavior at the pulsed discharge regime, combined with special current-profiling and capillary-tapering, supports the maintenance of a matched 60 μm laser waist along the entire 1 m of the capillary's length. Previous studies have aimed to producing an on-axis density ~10^{17} cm^{-3}. Lower densities need to be studied for an LWFA driven by a CO_2 laser.

Levi Schächter (Technion, Tel-Aviv) addressed novel paradigms available for exploration at ATF-II with its unique combination of laser and the e-beam. Among the proposed ideas were the following:

- An active medium two-beam accelerator wherein a driver beam produces a Cherenkov wake that is amplified by an active medium close to saturation, provides Rabi-trapping of a probe bunch and accelerates it.
- An optical injector producing a train of micro-bunches of a fraction of the laser's wavelength ($<\lambda/4$) in a dielectric structure with a gap chosen such that its transit time is an integer number of laser periods.
- Channeling radiation resulting from interaction of e-beam with a Bessel CO_2 laser beam. Contrary to the Inverse Compton scheme, the emitted wavelength here is determined by the laser's intensity, so opening a broad spectral access from THz to soft X-rays.

4.4 Small business and international users speaking on the ATF-II perspectives

Alex Murokh (RadiaBeam Technology) in his talk "ATF experience from a small business angle" discussed the importance of ATF in helping his company to realize a competitive edge. He outlined the similarity and differences between small businesses (SBs) and research institutions (RIs), which are parts of the same community. RIs pursue scientific outcomes while SBs are interested in developing products, marketing and selling them. Importantly, the DOE's SBIR and Stewardship programs facilitate close programmatic ties between the SBs and RIs in the field of Accelerator Science and Technology. This includes R&D funding, access to infrastructure (test facilities, specialized capabilities); access to expertise and tech-transfer (academic institutions and National Laboratories are encouraged to work with businesses). The ATF is a part of a publicly funded infrastructure, which makes US businesses more competitive internationally, thereby playing a crucial role in helping small American businesses to invent, develop and test new products. Among concrete examples of innovative solutions that benefited the field, and simultaneously helped the RadiaBeam company in developing new capabilities and product lines are several projects conducted by the company at the ATF. They include the following:

- X-band deflector with 10 fs resolution.
- Attoscope: Enhancement to RF deflector based on laser/e-beam interaction and supporting sub-fs resolution.
- New e-beam diagnostics.
- High efficiency ICS with laser recirculation.

Future work will progress towards developing stand-alone systems based on recirculated ICS, a high-gradient IFEL, and a combined IFEL+ICS scheme.

Overall, ATF has proved to be an ideal host facility for long-term multi-institutional programs that eventually can bring notable innovations to the market. The speaker concluded with his wish list for ATF-II that includes streamlining a procedure for approving rapid experiments within the time constraints imposed by the SB's funding agencies, and providing more floor/ bench top /shielded /office space for users.

Another long-time ATF's SB user, Wayne Kimura (STI Optronics) echoed these recommendations. He pointed out that a new DOE program focused on Accelerator Stewardship provides foundation necessary for the U. S. industry's sustained innovation. This expands the metric of merits for a user facility, including a new focus on developing accelerator applications towards testable prototypes with the ultimate goal of enhancing the accelerator-technology capabilities of U. S. industry. One particular recommendation was to expedite approval of experimental testing at ATF for the SBIR and other similarly close-scheduled projects typical in the SB's practice. Notably, the SB/ATF collaboration is a two-way road that equally benefits the ATF by expanding its capabilities.

Ralph Assmann's (DESY) talk was instructive in clarifying how the ATF compares to European efforts in sharing resources, and where is a scientific synergy. The idea of avoiding expensive duplication of facilities, profiting from networking and scientific exchange, creating synergy and thereby moving faster is widely supported in Europe, and globally. This points towards using existing/proposed facilities like ATF/ATF-II as much as possible. The ground for such integration and resource sharing lies in the similarity of scientific goals for different institutions. In particular, several activities at DESY are relevant to the ATF's research environment:

- Accurate fs timing and synchronization, important to many applications.
- Bunch compressors for ultra-fast science.
- Helical undulators to better FEL's efficiency.
- Dielectric structures and ICS in relation to atto-second bunches and ultra-fast science.
- Laser-driven plasma acceleration for a compact FEL and a compact injector.
- Plasma acceleration with external injection and staging for HEP.

The speaker acknowledged ATF's pioneering results that influenced many of the aforementioned future activities at DESY. This mutually beneficial exchange might continue. DESY is interested to learn from, and possibly can participate in, the planned experiments for several ATF-II topics:

- CO_2 LWFA with both internal and external injection and bunch compression
- Elliptical undulator
- ICS
- Damage tests of dielectric structures related to a compact atto-second light source based on dielectric acceleration

The speaker emphasized a unique ATF-II opportunity for an alternative LWFA route with a CO_2 laser, which allows lower plasma density compared to Ti:sapph. The community must assess possible advantages with LWFA at a lower plasma density. This regime is being simulated already at DESY. Early results point towards potentially crucial advantages in beam dynamics at the lower plasma densities accessible with the CO_2 laser. This needs to be counter-balanced against its disadvantages (such as reduced acceleration gradients) and investigated experimentally. The conclusions will be important for proposing a best solution for a European project of ultra-compact FEL aimed for 2020.

4.5 Facility presentations and technical discussions

In several presentations, BNL participants described the content of the ATF upgrade with the dual purpose of informing the community about upcoming facility capabilities and seeking feedback for possible accommodations.

The ATF-II Principal Engineer John Skaritka presented "ATF-II Layout and Construction Schedule". From his talk, one can learn that the ATF's productivity will double while the floor space tripled. The upgrade to the ATF is on track to serve more users, better than ever before.

The ATF-II beam lines will feature several innovations:

- The linac sections and beam line components will use structural supports with a net zero thermal-expansion and an auto-alignment capability to assure extreme stability.
- Laser tracker reference monuments will allow for precisely aligning the beam. This will permit the positioning of the beam line's component to a tolerance of a few microns.
- User experiments will be installed on kinematic platforms to facilitate off-line installation and then rapid integration of to improve scientific throughput.
- Beam lines will be rapidly expandable to efficiently accommodate ever-changing user requirements.

The project management team located significant technical resources that mitigate the limited funding. This includes assets from a general BNL stock, and decommissioned facilities such as SDL and NSLS-I, as well as external surplus from MIT, SLAC and others. The ATF-II project is underway, vigorously pursuing its completion in less than 3 years. With its unique attributes, innovations and community support, ATF-II will fully demonstrate the promise of laser-driven accelerators and support other significant accomplishments relevant to the HEP's strategic research directions and the Stewardship mission.

Mikhail Fedurin and Yichao Jing (both BNL) presented details of the ATF-II e-beam lattice that will support the tight compression of the beam, and special profiling (flat beams) to benefit many categories of user experiments. The ATF-II design will capitalize on existing ATF capabilities and expertise, such as high-brightness, tunability, mask technique and more, elevating these advantages to a new level of performance. For example, a new 20-meter-long bunch compressor will reduce the minimum bunch length from the present 100 fs to 10 fs. This design will use two chicanes, with opposite bending directions to compensate for emittance growth by cancelling the transverse effects induced by CSR wakes. A staged e-beam energy upgrade, starting from 150 MeV and available in two experimental halls at Stage 1, will progress to 500 MeV at Stage 2 that will feature two additional experimental halls.

Babzien (BNL) described the extensive laser part of the ATF upgrade project that, in addition to a 100-TW CO_2 gas laser, which is envisioned as the main tool for strong-field experiments, will include several solid-state lasers serving as a single-bunch RF photocathode gun drive, bunch-train photocathode laser, and a several-terawatt NIR laser for strong-field applications. Examples of such applications are electron injection via photoionization for plasma-wakefield accelerators, or a two-color Compton scattering scheme. The modular design of a 170-fs Ti-sapph. laser serves generating both the gun drive and CO_2 seed pulse. The difference lays in the nonlinear devices, that is, the 3rd harmonic generator for the first application, and an optical parametric generator (OPA) for the second application. The advantages of such approach include the following:

- Duplication of systems allows for fewer requirements for spare parts
- One system can be used as donor to get another system through major component failures
- Operational experience benefits both systems

He addressed challenges in achieving timing stabilization between these two laser systems, including up to 50 m length of transport to user experiments, to an accuracy of 10 fs.

The laser development will be offered in concert with other facility upgrades. A 100-TW CO_2 laser will be available at the ATF-II to the end of the 3-year Stage 1 upgrade while incremental improvements in peak power are already underway.

In addition to the described main objectives of the laser upgrades scheduled for ATF-II, other developments are under investigation. Wayne Kimura (STI Optronics) talked about prospects of upgrading a picosecond CO_2 laser not just in peak power, but also to a high repetition rate. This proposed improvement, still subject to approval by funding agencies, meets the recommendations of the 2013 Workshop on Laser Technology for Accelerators where development of robust, turn-key, large aperture, high-repetition-rate gas-based laser amplifiers is identified among the needs with high impact. The STI proposal aims to multiply the present 0.2-pps repetition rate of the ATF CO_2 laser by a factor of 50-500 by implementing solid-state switched PFN in place of a present Marx generator based on air- spark gaps. Using thyristor switches combined with magnetic pulse compression appears to be the best approach. High-repetition-rate, multi-TW CO_2 lasers based on this principle will open a door for new scientific-, industrial-, and medical applications.

The workshop culminated in discussions that provided a community feedback on the facility's architecture, beam line's configuration, and procedures that might serve better the user needs. These included:

- Adding 2-feet distance between a gun and a linac for installing an optional prebuncher.
- Adding 2-meter distance between the linac and a chicane for an optional x-band linearizer.
- Extending the space at the end of beamlines for an x-band deflector cavity.
- Anticipating a shielded space with RF power outside the beam line's experimental halls for industrial tests of RF components, new electron injector guns, and low-energy (5 MeV) experiments.

- Providing several locations for user setups within each beam line.
- Providing users with dimensions of kinematic mounts for installing experiments.
- Giving users the option of low (<30 MeV) bunch energy.
- Considering running ATF and ATF-II in parallel until the ATF-II is sufficient for all user projects.
- Developing a procedure for quickly approving of short time-line experiments (e.g., funded by SBIR).
- Anticipating space for a second gun for redundancy or injecting a witness bunch.
- Anticipating expansion space for applied experiments, e.g., using Compton x-rays or laser-generated ions for biological tests.

The users' suggestions currently are being implemented into the facility blueprint.

5. Conclusions

The ATF Upgrade Workshop became a venue for informing the user community about new research opportunities opened by the facility's improved technical capabilities while simultaneously expanding in the scope of its multi-disciplinary activities according to the new DOE program on Accelerator Stewardship.

These new capabilities have been highly acknowledged by the workshop participants who outlined a number of research directions that meet the strategic interests of several DOE offices, as well as demands of small businesses that rely on access to the first class laser- and accelerator-equipment.

The workshop became a forum for presenting new ideas for research, and forming collaborations that will ensure a strong and fruitful agenda for the ATF-II activities.

The received feedback from user community helps in shaping the ATF-II upgrade plans to best accommodate new experiments and future trends. This active exchange will continue throughout the ATF-II construction stages via the multiple channels that the ATF uses to communicate with its users and the advanced accelerator community.