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BNL ATF II beamlines design

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BNL ATF II BEAMLINES DESIGN *

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Abstract

The Brookhaven National Laboratory, Accelerator Test Facility (BNL ATF) is currently undergoing a major upgrade (ATF-II). Together with a new location and much improved facilities, the ATF will see an upgrade in its major capabilities: electron beam energy and quality and CO_2 laser power. The electron beam energy will be increased in stages, first to 100-150 MeV followed by a further increase to 500 MeV. Combined with the planned increase in CO_2 laser power (from 1-100 TW), the ATF-II will be a powerful tool for Advanced Accelerator research. A high-brightness electron beam, produced by a photocathode gun, will be accelerated and optionally delivered to multiple beamlines. Besides the energy range (up to a possible 500 MeV in the final stage) the electron beam can be tailored to each experiment with options such as: small transverse beam size (< 10 um), short bunch length (<100 fsec) and, combined short and small bunch options. This report gives a detailed overview of the ATF-II capabilities and beamlines configuration.

UPGRADE TO ATF II

The Accelerator Test Facility was established over a quarter of a century ago [1]. For more than two decades it has served national and international accelerator scientists, through a proposal-driven, program committee reviewed process that makes beams available to a broad community of users from Academia, U.S. National Laboratories, Accelerator Facilities and Small Businesses. The ATF offers the state-of-the-art tools that are required by its user community, including sources of high brightness electron beams and synchronized high-power laser beams [2]. While making these available for accelerator science R&D, the ATF continuously upgrades, reinvents and revamps these tools.

The current experiment program has e-beam only (Wake Field Acceleration in Quasi Non-linear Plasma and Dielectrics [3,4], THz radiation in dielectrics [5]), combined laser and e-beam (Inverse FEL acceleration and X-ray generation from non-linear Inverse Compton Source [6,7]) and laser only experiments (Ion Acceleration [8]).

Table 1: Projected beam parameters

Parameter	Expected Value
Energy	0-150 MeV
Maximum charge	3 nC
Normaliazed emittance	1 mm-mrad
Bunch current	100 A
Compressed bunch	1700 A
Compressed bunch length	10 fsec

The ATF upgrade is focused on three principal components: electron accelerator, CO_2 laser, and experiment area. The plan for the CO_2 laser is to increase power from the present 1 TW to 100 TW and the experiment hall area will increase to seven times it's the size of that available at the current ATF. A detailed description of the electron accelerator upgrade will be discussed here, with specific focus on beamline configuration.

GENERAL BEAMLINE DESIGN

The ATF II electron accelerator will succeed the present ATF electron beam generation technology. The electron source will continue to be a photocathode electron gun (pioneered at the ATF). The fourth harmonic of an Nd:YAG laser, incident on a copper cathode, yields 5E-3 e/γ at the present ATF. This gives a high-brightness electron beam with peak current of 100 A and 1 μm normalized transverse emittance. The beam peak current

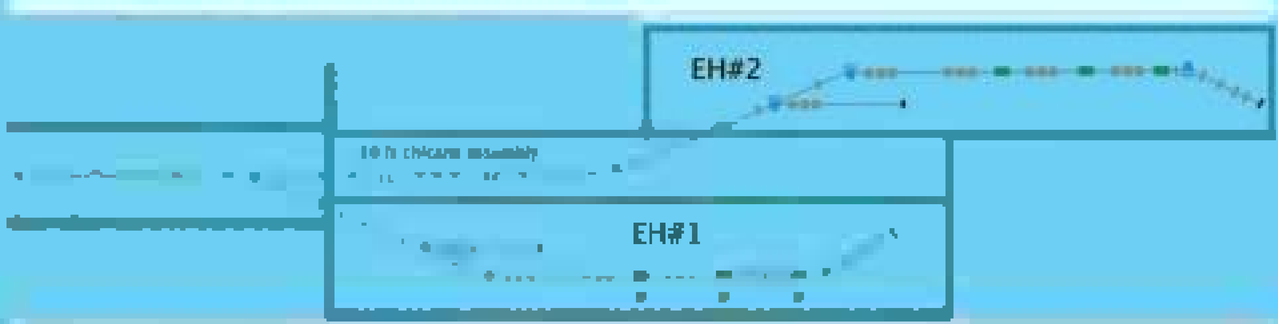

Figure 1: Schematic view of ATF II beamline configurations

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will increase to 1700 A as a result of the upgrade, while keep transverse size small.

General beamline layout is shown in Fig. 1. The photocathode gun will be followed by two 75 MeV accelerator sections with bunch compressor assembly between them. This means that the electron bunch can be accelerated to 150 MeV together with the ability to raise peak current. The second accelerator section may be used to minimize the energy spread of an initially chirped bunch for compression purposes. The bunch compressor will be surrounded by triplets for beam manipulation to correct for beam disturbance generated by it.

Quadrupole triplets following the linac allow beam tuning for delivery of a tailored beam to beamlines in one of two experiment halls. Beam is transported to these individual experiment halls via "dog-leg" dispersion sections, which allows for beam manipulation in longitudinal space. While the beamline to Experiment Hall #1 has a convenient dogleg section, the beamline to Experiment Hall #2 is designed to accommodate an advanced bunch compressor assembly. This compressor arrangement will achieve bunch lengths of down to 10 fs.

Dispersion section

The diagonal beamline sections that transport the beam from the linac to individual experiment halls have non-zero dispersion, generated by a dipole magnet. This section contains 5 distributed quadrupoles that are arranged symmetrically around the middle one, making it possible to tune the beam in the experiment hall beamlines while 1) having energy collimator slits at a high dispersion location, 2) having use of a second high dispersion location for beam manipulation by mask technique [9] 3) using the central quad to manipulate the beta function in the experiment hall beamline, with minimum disturbance of dispersion (dispersion is close to zero at this location).

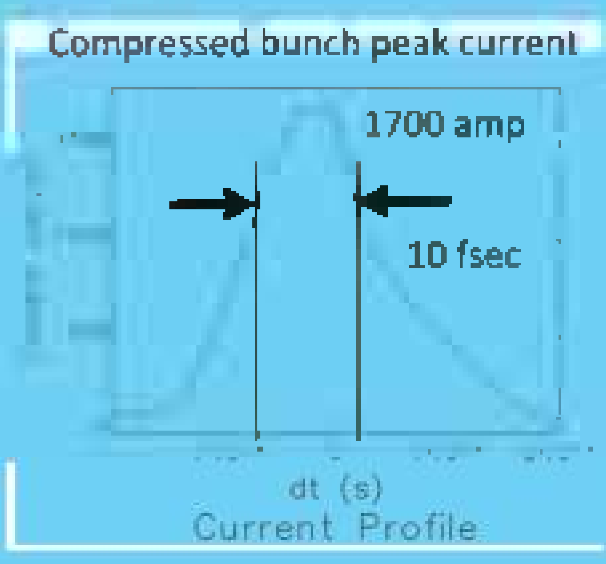

Figure 2: Compressed bunch profile (modelled using ELEGANT [11]).

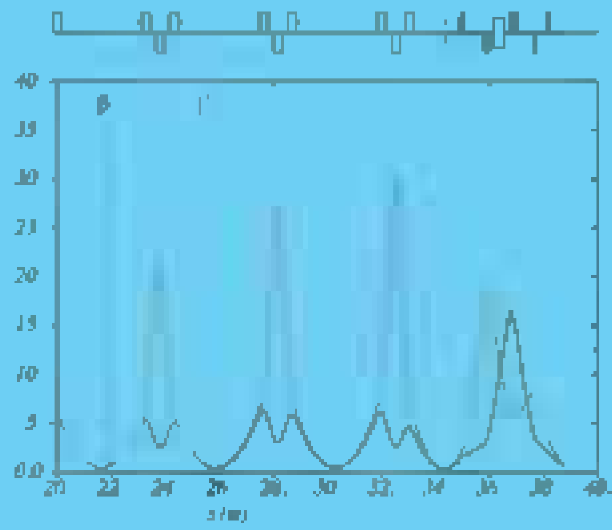

Figure 3: Beam optic functions in experiment hall long beamline with multiple interaction points, optic functions at the end optimized to use deflector cavity with image on spectrometer screen.

Experiment hall beamlines

Each experiment hall will contain two beamlines. One will be short and used for instrumentation testing, insertion devices etc. whereas the other will occupy the full length of the experiment hall and will host multiple experiment stations, and sophisticated equipment, such as a beamline spectrometer and deflector cavity. Strong quadrupole triplets with long beamline arm will allow to focus beam transverse size down to 10 micron at last chamber Interaction Point.

10 FEMTOSECOND BUNCH LENTH

While the initial bunch compressor, that is located between the linac sections, can provide compressed beam of up to 1 kA peak current to both experiment halls, another advanced bunch compressor , currently in the design phase, will make very short 10 fsec bunches available for use in EH#2. This will be ideal for e-beam/laser/plasma interaction experiments. This advanced compressor system will consist of two chicane compressors, situated in the forward direction, down stream of the linac (see Figure 1).

The arrangement is as follows: The first chicane houses magnets of 0.5 m in length with deviation angle 0.133 rad and distance between them 1 m, while the second set is 0.25 m in length with angle 0.089 rad and distance 1.25 m. Design of such a chicane assembly configuration is to compensate CSR effects produced by chicane magnets. The bunch compressor is optimized for compression of a 1 ps, 10 A peak current bunch to a bunch of 10 fs, 1700 A peak current [Fig 2]. A more detailed description of this advanced chicane cascade is available at this conference [10].

BEAMLINE WITH MULTIPLE EXPERIMENT STATIONS

The longer beamline in each Experiment Hall has four quadrupole triplet assemblies, accompanied by sufficient space so as to allow multiple experiment chambers with Interaction Points (Fig. 3), together with the concept of independent halls, it gives rise to the possibility of carrying out several experiment setups simultaneously, when access to the experiment area is granted.

DIAGNOSTICS AND BEAM MANIPULATION

The highly tunable nature of the electron beam at the ATF II favours screens for use as both profile and position monitors. Plans are to use YAG crystals along the full length of the electron accelerator with, OTR screens at experiment chamber waist locations. Each experiment chamber will be equipped with four beam position/profile monitors (BPMs) to measure transverse size and emittance, and tune the beam waist at the desired location.

In between the experiment station and the spectrometer dipole, at the end of each beamline, a deflector cavity, which is available at ATF at present time, will be installed. The electron beam will be deflected in the vertical direction, followed by a horizontal bend from the spectrometer magnet. For effective deflector cavity operation the beam optic, shown in (Fig 3), has a large vertical beta-function and is at $\pi/2$ phase advance from cavity to spectrometer to ensure the highest possible resolution.

Bunch charge measurements will be made primarily using Faraday cups that will be integrated with key BPMs. Such BPMs will be located: at the output of the photo-injector gun, after the energy slits and spectrometer screens at the end of each beamline.

Energy collimator slits will be placed at the first and second doglegs at the point of minimum horizontal beta-function and non zero dispersion. Purpose of energy slits is to filter of some beam energy oscillations and to collimate good longitudinal portion of the bunch for smooth operation. Small horizontal size of the beam allows producing the beam with chirp and rectangular shape in longitudinal direction.

Non-destructive charge measurements by DCCT will be located after second linac section and before of auxiliary beamline dipoles in dogleg section.

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