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LOW ENERGY ACCELERATOR DEVELOPMENT FACILITY UPGRADES*

S. V. Shchelkunov[†,1], J. Alzamora[1], M. Babzien[1], M. Fedurin[1], T. Ilardi[1], V. Janucik[2], K. Kusche[1], A. Lueangaramwong[1], W. Li[1], R. Muskopf[3], M. Palmer[1], M. Peniera[1], K. Roy[1], Y. Sakai[1], A. Simmonds[1], G. Stenby III[1], L. Wallace[4]
[1]Brookhaven National Laboratory, Upton, USA
[2]St. John's University, Jamaica, New York, USA
[3]SUNY New Paltz, Paltz, USA
[4]Stony Brook University, Stony Brook, USA

Abstract

The Low Energy Accelerator Development (LEAD) Facility is a part of the Accelerators Facilities (AF) Division of the Brookhaven National Laboratory (BNL). The facility has three capabilities and runs a program specifically targeting new collaborations for user-driven research. The first and oldest of capabilities is the Ultrafast Electron Diffraction (UED) capability. The other two are radiation-shielded bunkers.

At the UED, the deployment of a new stable solid-state modulator and klystron is in progress. The beamline updates are now being introduced into place for a National Aeronautics and Space Administration Jet Propulsion Laboratory (NASA JPL) electron irradiator for Single Event Effects (SEE) testing; and the capability for UED testing is being expanded.

In both bunkers (153 and 77 sq. m) a range of cooling, air, electrical, fire protection, and RF (radio frequency) capabilities are presently being introduced. The first bunker will accommodate the Electron Cyclotron Resonance (eCRA) Demonstrator (a project together with Omega- P R&D). The deployment is expected to start in the last quarter of 2025.The second bunker will accommodate the superconducting radiofrequency (SRF) photo-gun (a project by Euclid Techlabs, LLC) to be the electron beam source for an envisioned Ultrafast Electron Microscopy (UEM) capability.

LEAD FACILITY

The LEAD Facility is in building 912 at BNL (Fig.1). It is a part of the Accelerators Facilities (AF) Division [1] together with the Accelerator Test Facility (ATF). Unlike the ATF, however, the LEAD is a non-dedicated user facility.

RADIATION-SHIELDED BUNKERS

The two shielded bunkers are available with shielding being two layers of concrete blocks to eliminate seams. The roof's total thickness is 1.35 m; the wall's total thickness is 1.83 m.

As of now, both bunkers (Fig. 2) have distributed piping for the compressed air serviced by a central compressor located outside the bunkers at about 100 psi. The cooling pipes are connected to the two Carrier Aqua Snap chillers located outside the building (Fig. 3, left). There are cable trays in a configuration that separate power, signal and magnet power cables.120 V, 208 V, and 480 V electric services are installed with house and experimental power separated.

A new storage cage was erected with work areas for the user technical support (Fig. 3, right).

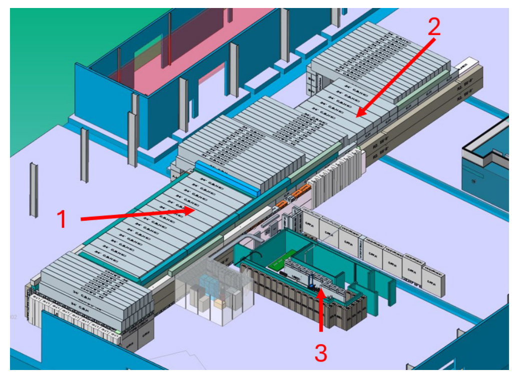

Figure 1: LEAD Facility capabilities – bunker #1 (1), bunker #2 (2), and the UED (3).

Figure 2: Bunker utilities – compressed air (left, 1), cooling (left, 2), cable trays (left, 3), and electrical (right).

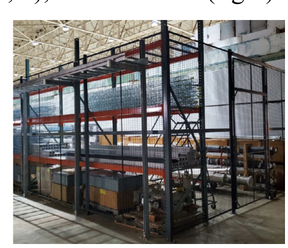

Figure 3: Carrier Aqua Chillers (left), and the storage cage with work areas outside the bunkers (right).

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† sshchelku@bnl.gov

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NEW RF SYSTEM FOR UED

A new RF system will be constructed for the UED. The RF-power source will be a Canon E 3772A klystron [2] installed into a Scandi Nova K-100 modulator [3]. The schematic of new system is shown in Fig. 4, right. After the ceramic break (RF window) #5, a waveguide will connect the new system to the portion of the old system starting with the E- bend #8 (see Fig.4, left). The old waveguide system starting from the H-bend #7 and down to the directional coupler mounted on the present klystron output port will be disassembled.

The major long-lead time components - the K-100 unit (with a solenoid and an RF-amplifier), the E 3772A klystron (with a radiation shielding kit), and the circulator (model 2320-25 with loads) - have been already acquired.

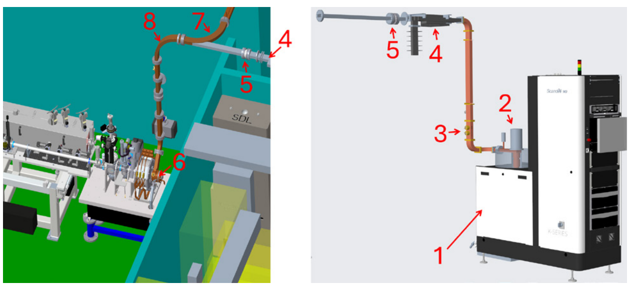

Figure 4: New waveguide system and RF-source for the UED. 1 – Scandi Nova K-100 solid-state modulator; 2 – Canon klystron E 3772A (7.5 MW peak at 2856 MHz); 3 – waveguides and a directional coupler; 4 – CML Engineering S-band SF6-filled circulator 2320-25 (rated 10 MW peak); 5 – RF window; 6 - UED photo-cathode electron gun; 7 – H-bend; 8 – E-bend.

NEW RF SYSTEM FOR BUNKER #1

The presently used klystron (Toshiba E 3730A) [4] will receive a new waveguide system. The system will go to the bunker #1 (see Fig. 5) and deliver RF-power to our first user there, the eCRA demonstrator [5].

Given the fact that the eCRA accelerating mechanism requires a rotating TE_{111} mode, the incident RF-power is split by a hybrid (Fig. 5, item #3) into two portions, with the first one being ahead of the second one by 90^{o} in phase. After reflections (if any) from the eCRA cavity the reflected waves recombine in the hybrid and given their relative phase shift will propagate to a matched load (Fig. 5, item #5), but not back to the klystron. Consequently, the waveguide system does not require an isolator or circulator.

The major waveguide components, and the hybrid are already available.

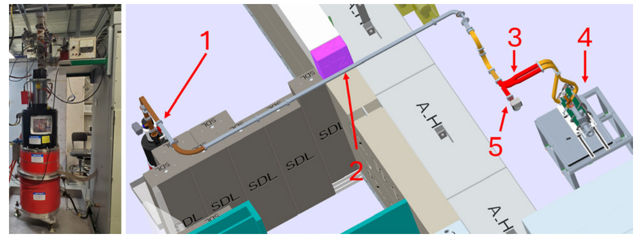

Figure 5: 1- klystron E 3730A (50 MW peak at 2856 MHz); 2- new waveguide system; 3 – hybrid; 4 - electron cyclotron resonance accelerator (eCRA) demonstrator; 5 - matched load.

NEW RF SYSTEM FOR BUNKER #2

A preliminary version of the RF system (2856 MHz) for the bunker #2 has been developed. The layout is shown in Fig. 6. The quotations for almost all waveguide components were obtained from multiple vendors.

The system uses a Scandi Nova K-300 solid state modulator [6], and a Canon E 3730 A klystron (50 MW peak at 2856 MHz) [4]. The system does not feature an isolator/circulator yet. Since 50 MW circulators are not available, it is envisioned that two SF6-filled 20-25 MW units can be used. The RF-power is to be split in two arms each leading to a circulator via an RF window. After each circulator the power to be recombined. The system will need 4 RF windows, two circulators, and two power splitters.

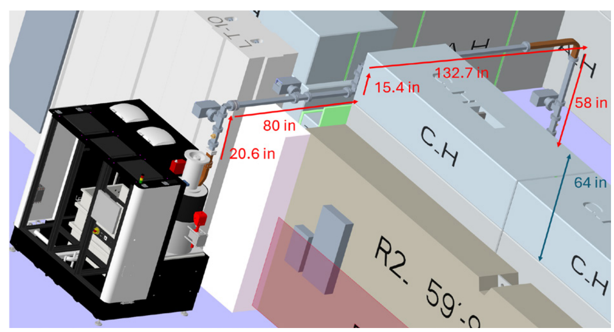

Figure 6: A preliminary version of the RF system for the bunker #2.

A preliminary version of an enclosure (Fig. 7) to house the klystron and ancillary equipment has been designed with associated costs estimates. The trapdoor (Fig.7, item #4) will allow removal of the klystron (by an overhead crane).

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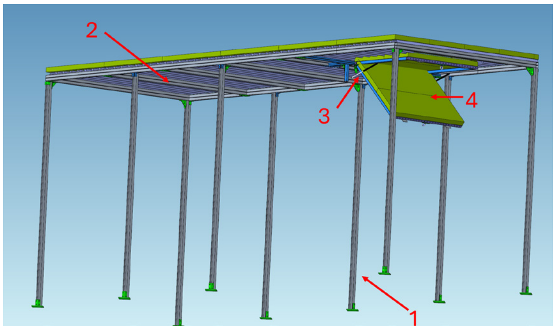

Figure 7: Klystron Enclosure. 1- galvanized steel supports; 2 – corrugated stainless steel B-deck; 3 – gas spring; 4 - trap door (using Rockwool comfort board 80).

NEW LOW LEVEL RF SYSTEM

Having presently one Titanium-sapphire laser and multiple klystrons that may possibly have a need to be phase-locked to the laser, a low-level RF system like that depicted in Fig. 8 is envisioned. The optical clock signal is to be delivered to each klystron location. It is to be converted by a photodiode to an electrical signal containing the phase-locked harmonic at 2856 MHz. After filtering, I/Q-modulation and amplification the 2856 MHz RF-signal is to be used to drive a klystron. A feedback loop will be perhaps needed to correct for possible phase drifts.

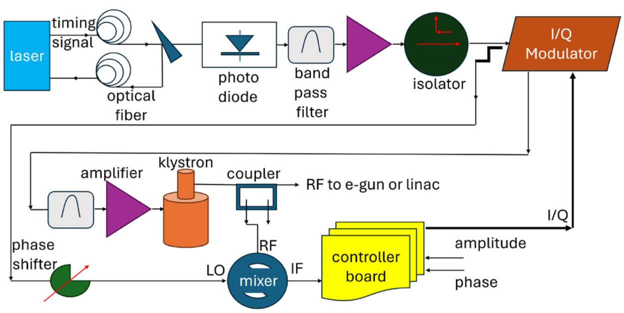

Figure 8: Possible low-level RF system(s) (starting from the photodiode each will be a replica at each klystron location).

JPL BEAM LINE EXTENSION

A new sample chamber is being introduced to the UED. With it, samples will be located about 6.5 meters away from the cathode as compared to the present 0.65. This substantial distance will allow for the differential vacuum pumping. Thus, the samples in the new chamber do not necessarily need to conform to ultra-high vacuum requirements, unlike any sample loaded into the present chamber. The layout of the beamline extension with the new chamber is shown in Fig. 9.

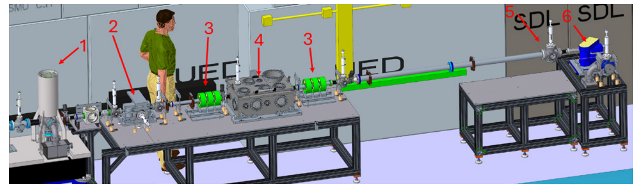

Figure 9: New beamline extension at UED, nicknamed the JPL extension because the first user will be NASA JPL. Here: 1 – present detector; 2 – chicane; 3 – triplet(s) of quadrupole magnets; 4 – new sample chamber; 5 - new detector; 6 - dipole magnet.

For the first experiment at the new extension, a small electron beam size is required, of an order of a few micrometers (μm). Preliminary numerical simulations using code OCELOT [7] indicate that a possibility to achieve that exists (see Fig. 10). In Fig. 10, the triplet of permanent magnetic quadrupoles (PMQs) is located inside the new sample chamber. The distance between the last PMQ and the sample is 5 cm. The PMQ strength is assumed to be 60 T/m, and the effective length is 5mm for the first and the third (last) PMQs. The second (middle) PMQ has its effective length equal to 10 mm. The final spot sizes are $\sigma_x = 1.7$ μm and $\sigma_y = 0.8$ μm. This, however, requires having a large beam size before the chicane chamber and a portion of the electron beam is being intercepted by the chamber's small aperture. An investigation is being conducted as to have the aperture sizes increased.

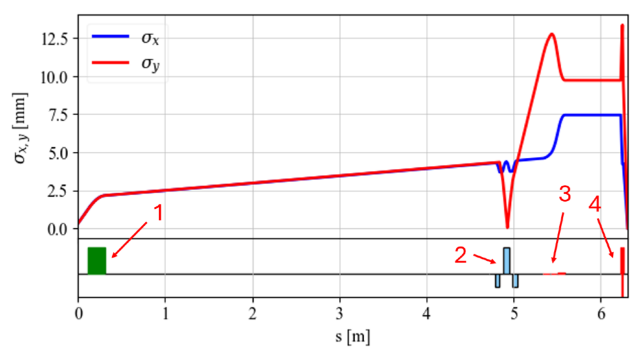

Figure 10: preliminary tracking simulations to achieve a micron spot size at the sample location. Here: 1 – solenoid; 2 – chicane; 3 - triplet of electrical quadrupole magnets; 4 – triplet of permanent magnetic quadrupoles. S is the distance from the electron gun cathode.

CONCLUSION

The described efforts will enhance the range of capabilities of the LEAD facility to better serve to industrial partners, big and small businesses, other laboratories and research institutions. It is a part of BeamNet US [8], and a training ground for the future workforce. This summer, for instance, students under Ernest Courant Traineeship, Science Undergraduate Laboratory Internship [9], and RENEW [10] programs have been already trained.

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