PRESENT STATUS OF COHERENT ELECTRON COOLING PROOF-OF-PRINCIPLE EXPERIMENT*

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Abstract

The status of FEL-based Coherent Electron Cooling Proof-of-principle Experiment at BNL is presented. The experimental set-up is comprised of a 2 MeV CW SRF electron gun and 20 MeV CW SRF linac and 8-m long helical FEL amplifier. The status of the accelerator commissioning, and progress in the construction of the helical undulator at Budker INP, is also reported.

PROJECT OVERVIEW

Figure 1 shows the overall layout of our experiment [1, 2]. A CsSb photocathode inside a 2 MeV 112 MHz SRF gun will generate the electron beam when illuminated with a 532 nm laser. Two 500 MHz copper cavities will provide energy chirp for the ballistic compression of the electron beam. The compressed bunches will be accelerated further to 22 MeV by a 704 MHz 5-cell superconducting RF linac.

After passing through a dogleg the electron beam will merge with 40 GeV/u gold ion beam. The ions will "imprint" their distribution on to the electron beam by modulating its density. This modulation will be amplified in a high-gain FEL comprising of three 2.5-m-long helical undulators.

The ions will co-propagate with electron beam through the FEL. Therein, the ion's average velocity is matched to that of the group velocity, e.g., to the propagation speed of the wave-packet of the electron beam's density modulation. A phase shifter, a system of four dipoles forming a chicane structure, follows each undulator. The phase shifters between the undulators will match the phase advance of the optical packet with electron density. The one at the exit of the FEL provides the means to tune the phase of the wave-packet such that the ions with the nominal energy experience zero longitudinal electric field.

The dependence of time-of-flight on the ion's energy will insure that the off-energy ions will be accelerated or decelerated, depending on the sign of their energy error. Such interaction will lessen the energy spread in the ion beam [1]. The used electron beam will be bent away from the ions' path and then dumped.

RF SYSTEM

112 MHz RF Gun

The 112 MHz SRF cavity [3, 4], modified by Niowave, was installed into the RHIC tunnel. Modifications included cavity incorporation into a new cryomodule, addition of the two manual tuners for coarse adjusting of the cavity's resonant frequency. After the installation the cathode launching mechanism manufactured by Transfer Engineering was attached and after several attempts was aligned with cavity (see Fig.2). This mechanism will allow in place exchange of the multialkaline photocathodes planned for usage. The 112 MHz gun was equipped with a water-cooled fundamental power coupler, as shown in Fig. 3. It will be used to fine-tuning of the cavity's frequency. The cathode stalk, situated inside the cavity, is maintained at room temperature by circulating water. Both parts can freeze and piping can be damage if water flow stops. To protect the cavity we developed an emergency blow out system which we expel water with gaseous helium if water block is sensed.

Although its design accelerating voltage is 2 MV, during the test we were limited the maximal voltage to 1 MV by the increasing radiation levels in the semi-open test environment. The SRF gun will be tested at its full accelerating voltage during September 2012. The 112 MHz 2 kW amplifier for the gun is already in place.

After the cavity conditioning and reaching the design voltage we will test photocathode operation in the SRF environment

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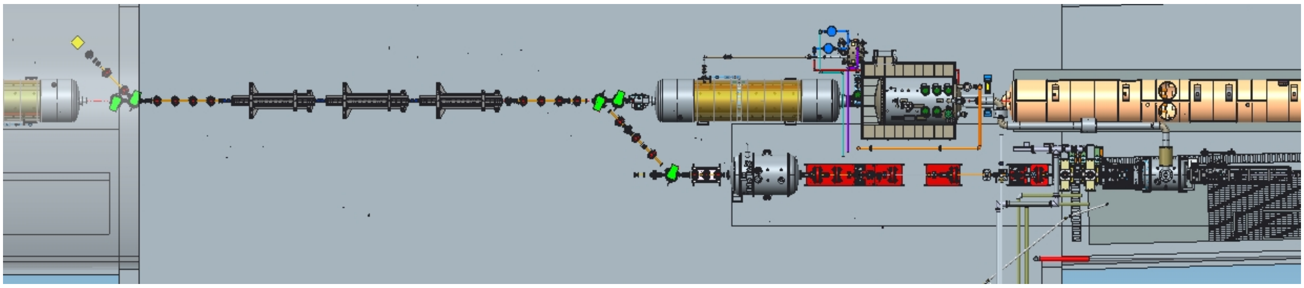

Figure 1: Layout of the coherent electron cooling proof-of-principle experiment in the RHIC tunnel.

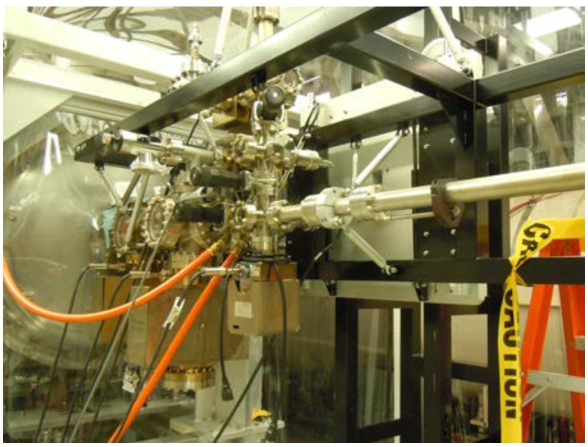

Figure 2: Cathode launch mechanism with 112 MHz gun inside the clean room.

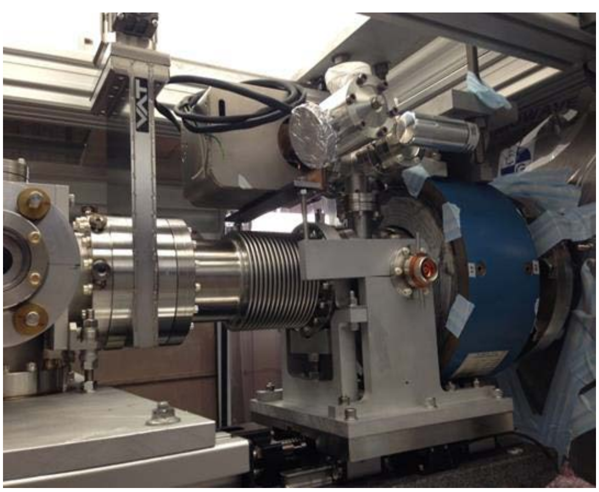

Figure 3: View of the 112 MHz power coupler mounted on the translation stage for tuning. On the left side viewport for the seed laser injection can be seen.

500 MHz System

The Daresbury Laboratory, UK provided two 500 MHz copper cavities on a long-term loan to BNL. Presently, the cavities are refurbished and are installed into the RHIC's tunnel (Fig. 4). The cavities are water cooled, and water flow switches as wells as four body temperature sensors are connected to the machine protection system. We are installing infrared temperature gauges of the ceramic RF windows, after this procedure the cavities will be ready for full power tests.

The cavities will be fed from an amplifier installed a the adjacent building. The output of the amplifier is connected to a circulator for protection. The power will be split using a special waveguide tee to avoid cavities crosstalk. A remotely controlled phase shifter is installed for the proper matching.

Figure 4: 500 MHz cavities with water manifold installed in the RHIC tunnel. The RF power is fed from the two waveguides on the top of the cavities.

704 MHz Accelerating Cavity

The BNL conducted the test of the two 20 MV 5-cell accelerating cavities (Fig. 5). One was fabricated by Advanced Energy Systems [4], and the other by Niowave.

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After the test we selected the AES one for placing in the cryomodule, which is now is being built by Niowave. The main remaining issue is design of a fine cavity tuner, the testing of which is scheduled in September.

Figure 5: 704 MHz cavity manufactured by AES at vertical test facility.

DIAGNOSTICS

The diagnostics for the CeC system [5, 6] include nine beam position monitors (BPMs), two integrating current transformers (for measuring the current and the beam's transmission), four flags to measure the beam sizes (as well as the emittances and energy spread at 22 MeV), and one pepper pot (for measuring the emittance of the low-energy beam in the 2 MeV section). The view on the flag installed into the low energy section is shown in Fig. 6. Another flag is preceded with pepper-pot target. The target has three positions: fully retracted for the normal operations and two for the measuring of emittance in each plane. We will employ beam-loss monitors to control the beam losses in the CeC beam-line and the irradiation of the helical undulator. The longitudinal profile of ion beam will be observed using the existing RHIC wall-current monitor with a 6 GHz bandwidth.

The transvers beam position will be monitored with 4-buttons pick-up electrodes connected to Libera Brilliance BPM receiver manufactured by Instrumentation Technologies. Position of the electron beam will be used for fast interlock by MPS.

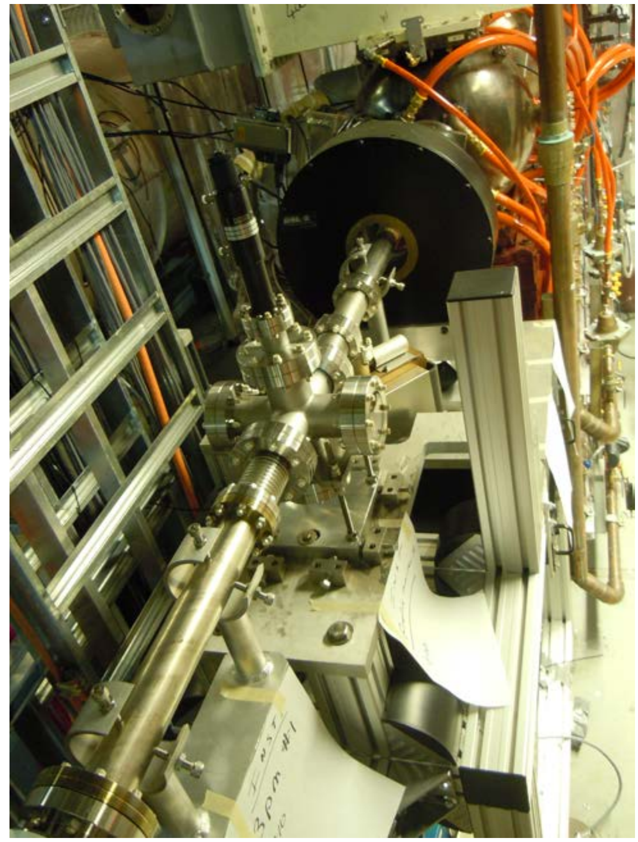

Figure 6: View of the vacuum cross with flag installed into the low energy beamline. The GigE camera will be added soon.

HELICAL UNDULATOR

Figure 7 shows the field integrals of the first out of three helical wigglers manufactured at BudkerINP. The wiggler was tuned to reach the requirements for CeC PoP project using 1D Hall probe. Fine tuning of the helical wiggler presently is being performed with a 3D Hall probe. The delivery of the first of the three helical undulators is scheduled for September.

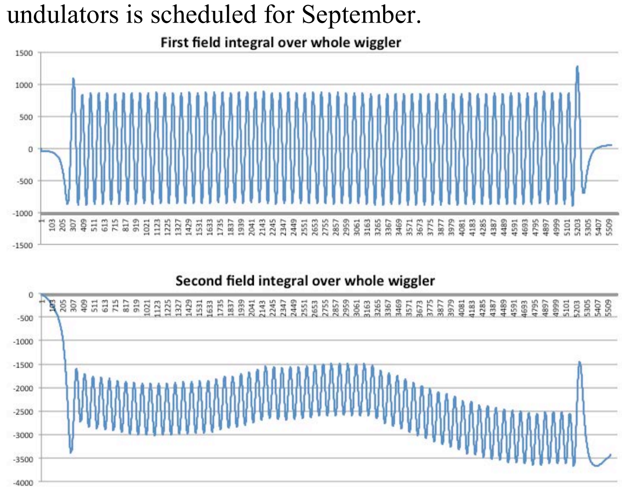

Figure 7: The first and second integral of the wiggler field after the initial tuning.

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OTHER SYSTEMS

We are steadily progressing with installation the cryogenic system and the driver laser. The laser is acquired and will generate flattop pulses of variable durations from 100- to 500-picoseconds, and with the leading- and the falling-edges below 50 picoseconds. The optical peak power should exceed 1 kW at 532 nm. The laser will be synchronized with the RHIC's timing system via a low-level RF system. The laser will be installed in the special shed outside RHIC tunnel and optical power will be transferred via optical fiber.

The solenoids are installed as well as most of the vacuum system for the low energy part as shown in Fig. 8. The RHIC personnel protection system was modified to include the components of the CeC PoP project and allow local run of the equipment without need to close the whole tunnel.

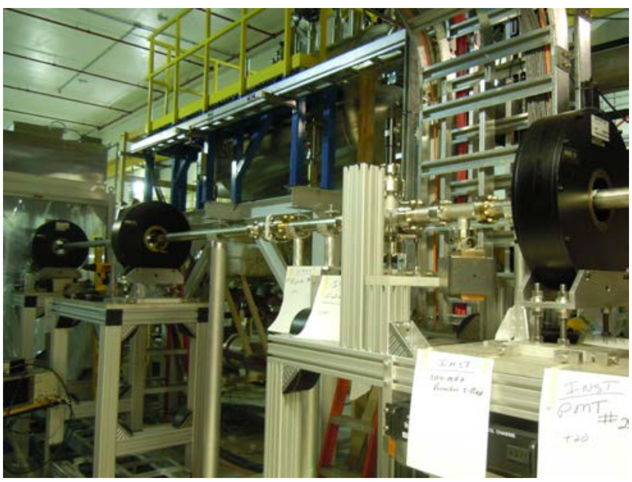

Figure 8: Solenoids and the vacuum chamber in the low-energy drift section. On the left side there is a portable clean room used for the particle free assembly. On the background the quiet helium source for the 112 MHz gun is placed on a platform

PLANS

We plan to commission the 500 MHz bunching cavities and 112 MHz gun in September this year. We plan to be install the linac, the helical undulators, the high power beam dump, and the balance of equipment during the RHIC shutdown in 2014 and commission the electron part of the equipment during Run 15.

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