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

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Abstract

The Coherent Electron Cooling Proof of Principle (CeC PoP) system is being installed in the Relativistic Heavy Ion Collider (RHIC) at Brookhaven National Laboratory. It will demonstrate the ability of relativistic electrons to cool a single bunch of heavy ions in RHIC. This technique may increase the beam luminosity by as much as tenfold. Within the scope of this experiment, a 112 MHz 2 MeV Superconducting Radio Frequency (SRF) electron gun coupled with a cathode stalk mechanism, two normal conducting 500 MHz single-cell bunching cavities, a 704 MHz 20 MeV 5-cell SRF cavity and a helical undulator will be used. In this paper, we provide an overview of the engineering design for this project, test results and discuss project status and plans.

PROJECT OVERVIEW

Figure 1 shows the overall layout of our experiment [2]. We will generate the electron beam by a CsSb photocathode inside the 2 MeV 112 MHz SRF gun. 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 the 704 MHz 5-cell superconducting RF linac.

The electron beam will merge with 40 GeV/u gold ion beam after passing through a dogleg. The ions will "imprint" their distribution on to the electron beam by modulating its density in their locations. 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 e-beam's density modulation. We will use a three-pole wiggler at the exit of the FEL 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, modified by Niowave, was installed into the RHIC tunnel. Modifications included incorporation into a new cryomodule, addition of the two manual tuners for coarse adjusting of the cavity's resonant frequency. After the cavity 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 photicatodes planed for usage.

After the installation the 112 MHz gun [3] 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. 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. We plan to test the SRF gun at its full accelerating voltage during this summer. The 112 MHz 2 kW amplifier for the gun is already in place.

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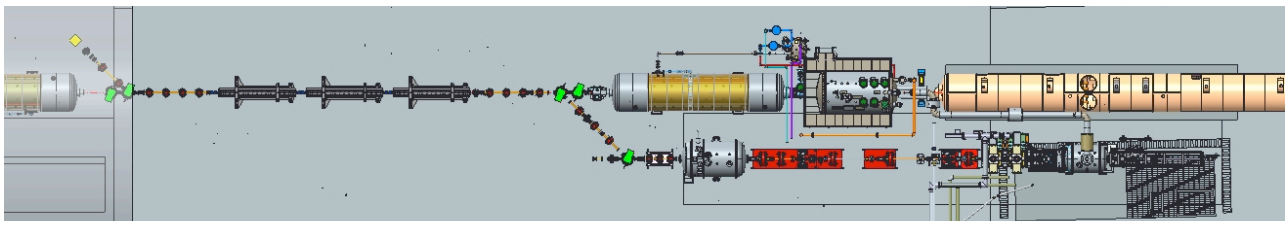

Figure 1: Layout of the coherent electron cooling proof-of-principle experiment in the RHIC tunnel.

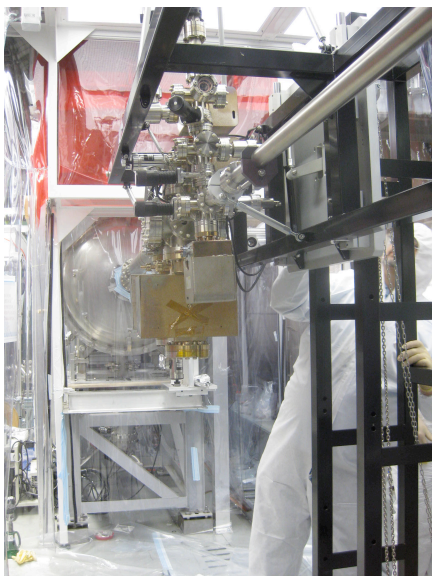

Figure 2: Cathode launch mechanism with 112 MHz gun inside the clean room.

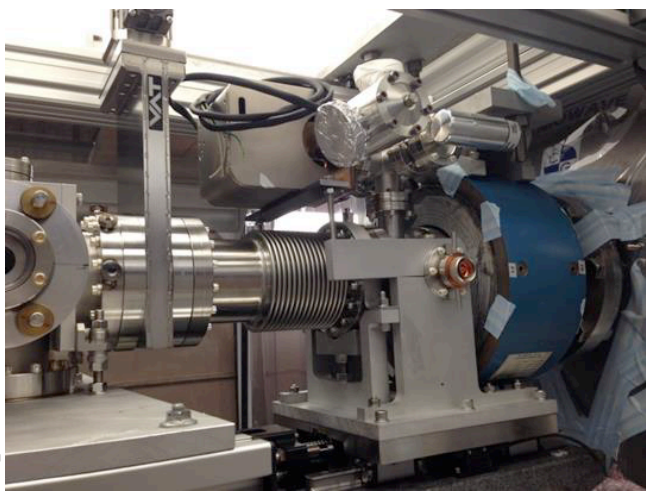

Figure 3: View of the 112 MHz power coupler mounted on the translation stage for tuning. On the left side viewport for the seed laser injection can be seen.

500 MHz System

We refurbished two 500 MHz copper cavities, on a long-term loan to BNL from the Daresbury Laboratory, UK. Presently, the cavities are conditioned and are installed into the RHIC's tunnel (Fig. 4).

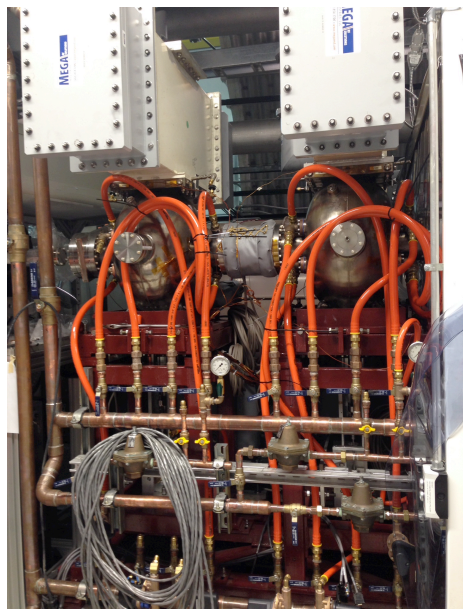

Figure 4: 500 MHz cavities installed in the RHIC tunnel.

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. After the test we selected the AES one for placing in the cryomodule, which is now is being built by Niowave.

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

DIAGNOSTICS

The diagnostics for the CeC system [5] 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 target of the pepper-pot is shown in Fig. 6. 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.

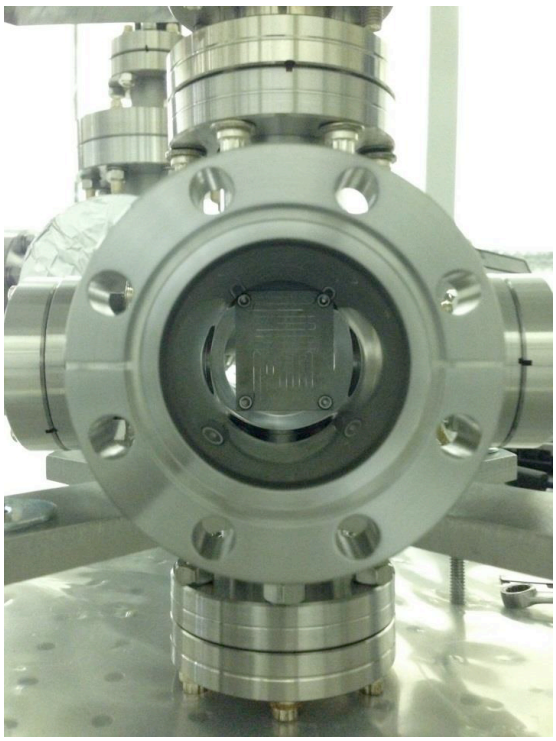

Figure 6: View of the pepper-pot target to be installed into the low energy beamline.

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 will be performed with a 3D Hall probe. The delivery of the three helical undulators is scheduled for summer/fall of 2014.

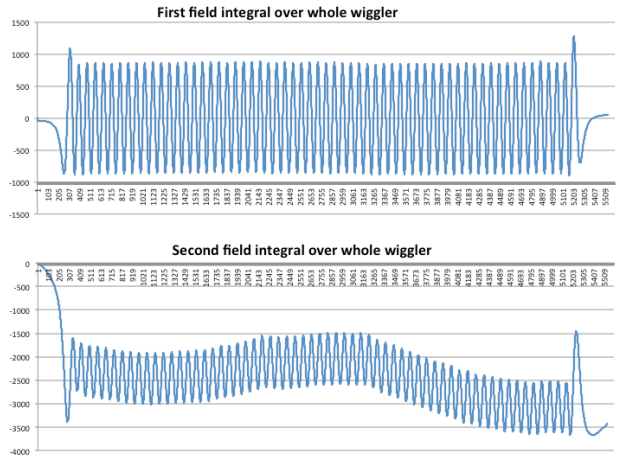

Figure 7: The first and second integral of the wiggler field after the initial tuning.

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 150 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.

Figure 8: Assembling of the in the low-energy beam-line. Black round magnets are two of five solenoids in this section.

PLANS

We plan to commission the 500 MHz bunching cavities in July and 112 MHz gun in August-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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