PRESENT STATUS OF COHERENT ELECTRON COOLING PROOF OF PRINCIPLE EXPERIMENT*

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Abstract

We conduct a proof-of-the-principle experiment of coherent electron cooling (CEC), that potentially wil significantly boost the luminosity of high-energy, high-intensity hadron colliders [1]. Herein, we discuss the current status of the experimental equipment, detailing our first tests of the electron gun and the results of magnetic measurements of the wiggler prototype. We describe the current status of the design, and our near-future 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.

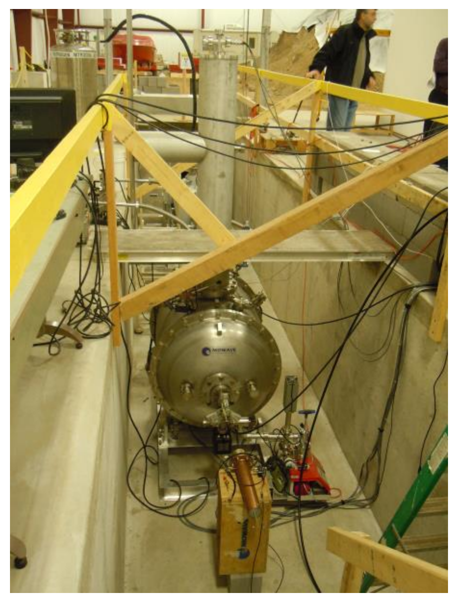

Figure 2: The 112 MHz cavity in the trench during the test at Niowave.

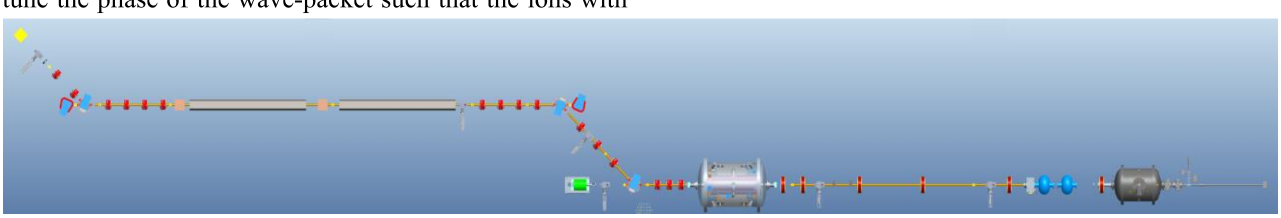

Figure 1: The layout of the CeC Proof-of-Principle experiment. On the right there is a electron gun with a cathode launcher. Between the gun and an accelerating cavity (gray) the electron beam is focused by solenoids (red). 500 MHz cavities (blue) modulate beam energy for ballistic bunching. After the accelerator the electron beam is transported with dipoles (red-blue) and quadrupoles (red). Two dumps are used: low power (green) and high-power (yellow).

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RF SYSTEM

112 MHz RF Gun

Niowave has modified the 112 MHz SRF cavity into a gun within a new cryomodule. Two manual tuners were added for coarse adjusting of the cavity's resonant frequency so that it can be tuned close to a harmonic of the RHIC's revolution frequency.

The cavity (Fig. 2) was tested at Niowave in February 2013 utilizing two small antennas and delivered to BNL in April. In the final configuration the 112 MHz gun [3] will be 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 after its installation into the RHIC tunnel during RHIC's shutdown. The 112 MHz 2 kW amplifier for the gun is in place. The cathode launcher is build by Transfer Engineering and is to be delivered to BNL in June.

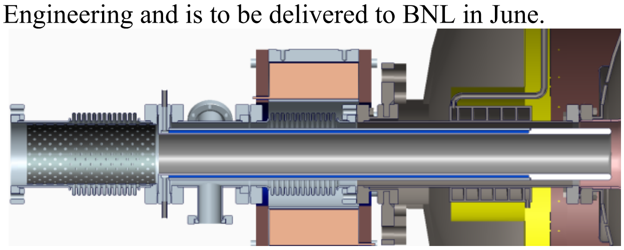

Figure 3: Design of a water-cooled fundamental power coupler for the 112 MHz RF gun. Two bellows allow the coupler to be used to fine tune the cavity's frequency. A focusing solenoid is placed over the bellow connected to the cavity vessel.

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 we will install them into the RHIC's tunnel during summer/fall of 2013 along with the gun.

704 MHz Accelerating Cavity

There are two 20 MV 5-cell accelerating cavities. One was fabricated by Advanced Energy Systems [4], and the other by Niowave. BNL will conduct the test of the both of them in the vertical test facility this summer. After the test we will select the best performing one for placing in the cryomodule, which is now is being designed by Niowave and BNL.

LOW ENERGY SECTION

We plan to install the low energy section of CeC accelerator (up to the 20 MeV linac) during 2013 shutdown of RHIC. We will employ a low-power beam dump with a Faraday cup at the end of the beamline will be used for low-current commissioning of the gin and the bunching cavities.

Figure 4: Two 500 MHz cavities mounted on a common support before their installation into the IP2 region.

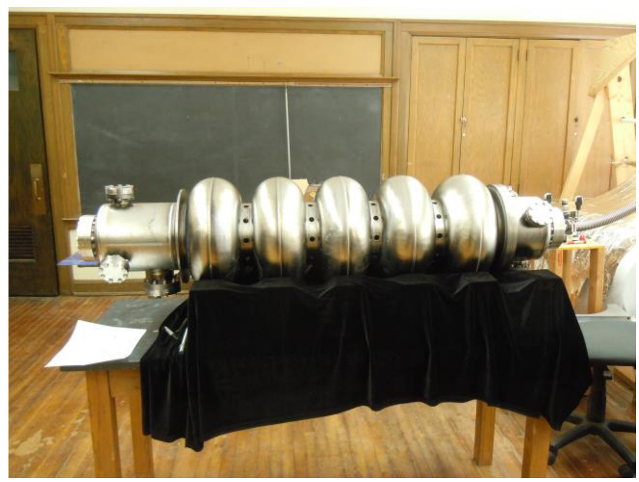

Figure 5: 704 MHz SRF accelerator cavity at Niowave after vacuum leak check.

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). 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.

HELICAL UNDULATOR

Figure 6 shows the 50-cm undulator prototype undergoing the magnetic measurements at BudkerINP.

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The undulator was tuned to reach the requirements for CeC PoP project. Figure 7 shows the residual phase error. The contract for building of the three helical undulators has been signed and the delivery is scheduled for fall 2014.

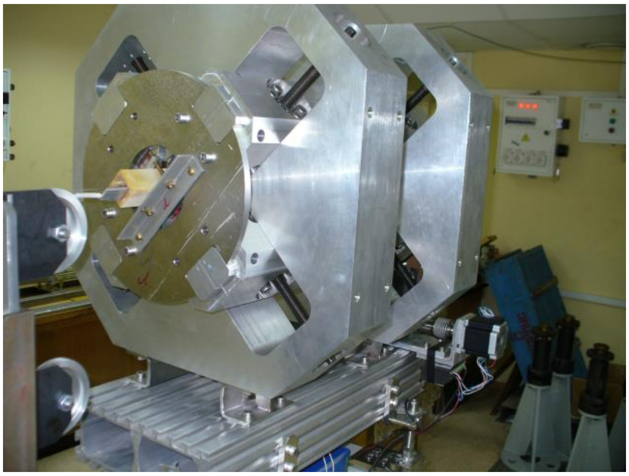

Figure 6: The prototype helical undulator undergoing magnetic measurements.

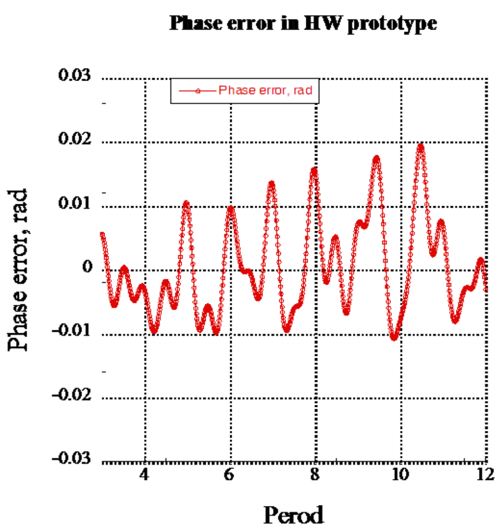

Figure 7: After the tuning, the measured phase error in the prototype helical undulator satisfied our requirements.

OTHER SYSTEMS

We are steadily progressing toward procuring the cryogenic system and the driver laser. The laser 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. The initial commissioning will utilize a UV laser (4^{th} harmonic of 1.04 microns), which is ready.

A significant part of other CeC equipment and manifolds have been installed in the buildings adjacent to the IP2 (see Figs. 8 and 9).

PLANS

We plan to commission the installed equipment, including the SRF gun, an generate the first e-beam during RHIC's Run 14. 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.

Figure 8: 2K cryogenic equipment for CeC PoP.

Figure 9: 500 MHz power amplifier for CeC PoP.

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