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DISCLAIMER

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

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Abstract

Coherent electron cooling (CEC) has a potential to significantly boost luminosity of high-energy, high-intensity hadron colliders. To verify the concept we conduct proof-of-the-principle experiment at RHIC [1]. In this paper, we describe the current experimental setup to be installed into 2 o'clock RHIC interaction regions. We present current design, status of equipment acquisition and estimates for the expected beam parameters.

PROJECT OVERVIEW

The overall system layout is shown in Fig. 1. The electron beam will be generated by a CsSb photocathode inside the 112 MHz SRF gun. Two 500 MHz copper cavities will be used to ballistically compress electron beam, which will be further accelerated to 22 MeV in the 704 MHz 5-cell SRF linac.

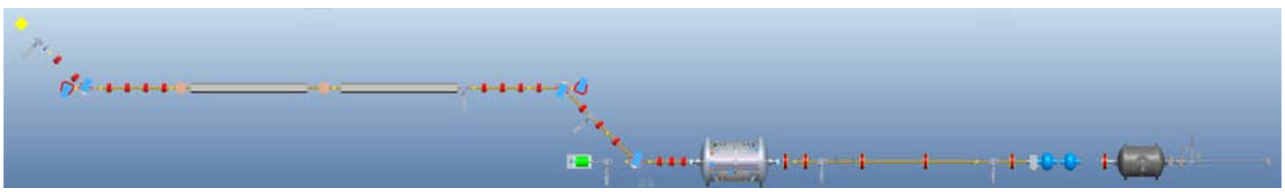

Fig. 1. The layout of the CeC PoP experiment.

We use a dogleg to merge the electron and ion beams. The ions "imprint" their distribution into the electron beam via a space charge density modulation. The modulation is amplified in an FEL comprised of a 7-m long helical wiggler.

The ions are co-propagating with electron beam through the FEL. The ion's average velocity is matched to the group velocity of the wave-packet of e-beam density modulation in the FEL. A three-pole wiggler at the exit of the FEL tune the phase of the wave-packet so the ion with the central energy experience the maximum of the e-beam density modulation, where electric field is zero. The time-of-flight dependence on ion's provides for the electrical field caused by the density modulation to reduce energy spread of the ion beam [2].

The used electron beam is bent off the ion path and damped.

RF SYSTEM

112 MHz RF Gun

The modification of the 112 MHz cavity and building of a new cryomodule was awarded to Niowave. The design modifications include addition of two manual tuners to adjust the cavity frequency to a nearest harmonic of the RHIC revolution frequency. A successful design review of the system was held in February 2012. The gun is expected to be ready in January of 2013.

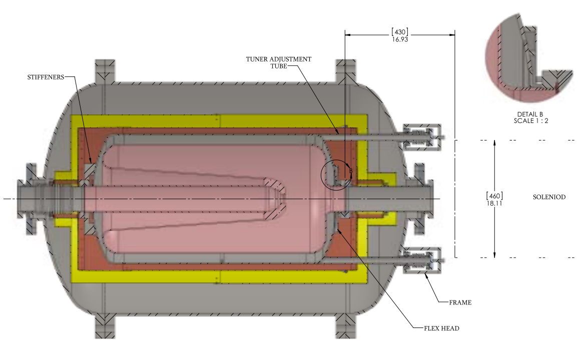

Fig. 2. Cross-section of the proposed design of the 112 MHz SRF gun. Two tuners will be added for precise setting of the resonant frequency.

500 MHz System

Two 500 MHz copper cavities are provided as a long-term loan from Daresbury Lab, UK. Presently, cavities are under conditioning and will be installed into the RHIC tunnel during summer/fall of 2012. With RF power and controls planned to be ready by the end of the year we plan testing the cavities in early 2013.

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704 MHz Accelerating Cavity

20 MV accelerating cavity is fabricated by Advanced Energy Systems. The copper prototype is of the accelerating structure is shown in Fig. 3. A RFQ is in place for bids on the cryostat for the linac.

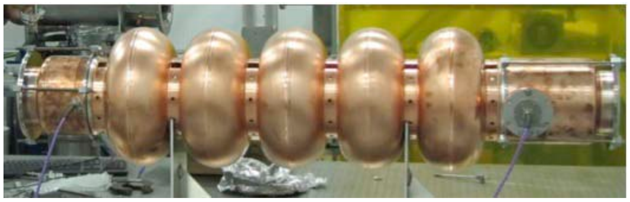


Fig. 3. Copper prototype of 704 MHz accelerating structure.

GUN SECTION

The design of the low energy section was modified to improve beam performance (see Fig. 4). Six solenoids provide the transverse focusing of the beam. The changes improved both the beam and the uniformity of the peak current in the compressed bunch. More on the design of this section can be found in [4].

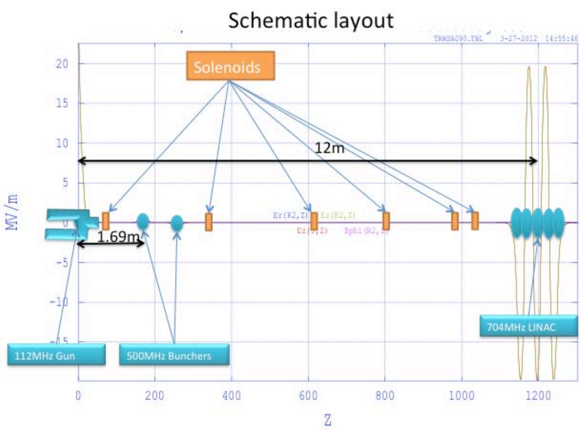


Fig. 4. Low energy section with increased distance from the gun to the accelerator cavity.

JLab CeC team continues developing DC gun as a back-up option by testing first alkali-antimonide photocathode inside the 200 kV inverted photo-gun.

MAGNETS

Five of the six solenoids will be identical to R&D ERL design [11]. A new design of a solenoid would accommodate the physical constraints imposed by the gun. The steering in the low-energy section will be done by three trims identical in the design with that in the R&D ERL.

Accelerated to 22 MeV electron beam will be bent by three 45°-dipole magnets, whose design is in progress. Two identical dipoles with opposite polarity (and fed in series with the rest of the magnets) will be placed on the ion path to compensate null the effects on the ion beam. The later would allow commissioning of the CeC accelerator in parallel with regular operation of RHIC complex.

Ten quadrupoles (again identical to those in the R&D ERL) will focus the electron beam though the CeC section. The corrector windings in will steer the e-beam. The eight quadrupoles will provide optimal focusing in all three section of the CeC. The last two quadrupoles will be used to increase beam size in the dump and to reduce power density at its surface.

DIAGNOSTICS

The diagnostics [10] include nine BPMs for monitoring beam position, two integrating current transformers for monitoring current and beam transmission, four flags to measure beam size (as well as emittance and energy spread), two pepper pots for measuring emittance of low energy beam in the 2 MeV section. Beam loss monitors will be employed to control irradiation of the helical wiggler. The longitudinal profile of ion beam will be observed using the wall current monitor with 6 GHz bandwidth. Tuning the FEL will be done with IR diagnostics (at wavelength of 13 microns). We are finalizing the suite of the IR diagnostics, which includes monochromator, IR camera, HgCdTe sensor and power meters.

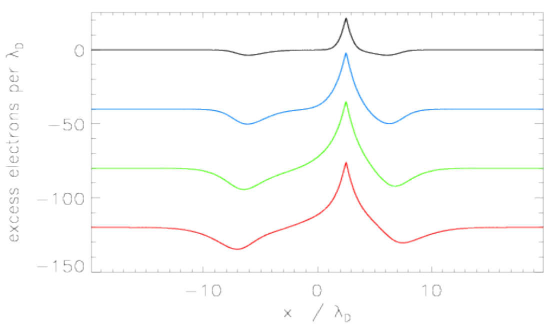
WIGGLER

We used BNL's PD and LDRD funds to proceed with prototyping of helical wiggler and procurement of cryogenics system for CeC experiment. The wiggler prototype would be assembled and magnetic measurements would start in June 2012.

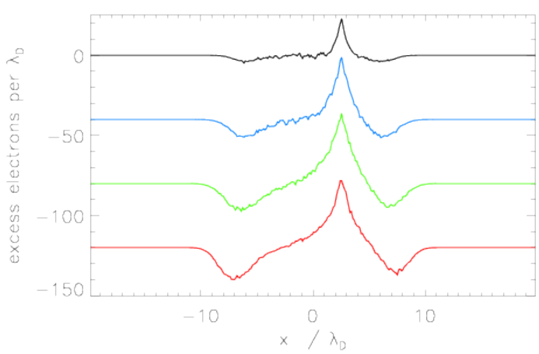
Fig. 5. Picture of the magnet holders for the prototype of helical wiggler.

SIMULATIONS

Tech X is making progress towards the start-to-end CeC simulation package using VORPAL δf algorithm and Genesis 3D FEL code [9]. Present capabilities include simulating of the entire CeC process with uniform focusing of the e-beam. Implementation of focusing elements (quadrupoles) into the modulator and the kicker is in progress. In addition, an attempt to develop an alternative 3D FEL code allowing use of particle's distribution from VORPAL is in progress. Comparison of Vlasov equation with δf PIC showed good agreement [5-8].



a)



b)

Fig. 6. Comparison between solution of Vlasov equation (a) and VORPAL simulations (b).

OTHER SYSTEMS

We are making steady progress with procurements of the cryogenic system and the driver laser. The will provide flattop pulses with variable duration from 100 to 500 picoseconds, and leading and falling edges below 150 picoseconds. The optical peak power shall exceed 1 kW at 532 nm. The laser will be synchronized with RHIC timing system via a low-level RF system.

PLANS

We plan to continue optimization of the low energy path and beam dump area without changing the geometry of the accelerator. The 500 MHz cavities will be tested at full power in early 2013. SRF gun is planned for installation during RHIC shutdown in 2013 to be commissioned during RHIC's Run 14. The accelerator cavity, wiggler, beam dump and balance of equipment will be installed during in 2014.

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