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PERFORMANCE OF CEC POP ACCELERATOR*

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Abstract

Coherent electron cooling experiment is aimed for demonstration of the proof-of-principle demonstration of reduction energy spread of a single hadron bunch circulating in RHIC. The electron beam should have the required parameters and its orbit and energy should be matched to the hadron beam. In this paper we present the achieved electron beam parameters including emittance, energy spread, and other critical indicators. The operational issues as well as future plans are also discussed.

INTRODUCTION

An effective cooling of ion and hadron beams at energy of collision is of critical importance for the productivity of present and future colliders. Coherent electron cooling (CeC) [1] is a novel cooling method which would outperform existing techniques by orders of magnitude.

A dedicated experimental set-up, shown in Fig. 1, has been under design, manufacturing, installation, and finally commissioning during last few years [2-5]. The CeC system is comprised of the SRF accelerator and the CeC section followed by a beam dump system. It is designed to cool a single bunch circulating in RHIC's "yellow" ring (indicated by yellow arrow in Fig. 1). A 1.5 MeV electron beam for the CeC accelerator is generated in a 113 MHz SRF quarter-wave photo-electron gun and first focussed by a gun solenoid. For beam compression energy chirp is provided by two 500 MHz copper RF cavities, and bunch is ballistically compressed in 9-meter long low energy beamline comprising five focusing solenoids. A 5-cell 704 MHz SRF linac accelerates the compressed beam to 15 MeV. Accelerated beam is transported through an achromatic dogleg to merge with ion bunch circulating in RHIC's yellow ring. The design and demonstrated beam parameters are shown in Table 1.

Table 1: CeC System Parameters

Parameter	Design	Achieved
Kinetic energy, MeV	21.95	15
Bunch charge, nC	0.5-5	9.0
Peak current, A	100	50
Bunch length, ps	10	12
Beam current, µA	400	120

In CeC interaction between ions and electron beam occurs in the common section: in the modulator, each hadron induces density modulation in electron beam that is amplified in the high-gain FEL; in the kicker section, the hadrons interact with the self-induced electric field of the electron beam and receive energy kicks toward their central energy. The process reduces the hadron's energy spread, i.e. cools the hadron beam. Fourteen quadrupoles are used to optimize the e-beam interaction with the ion beam and FEL performance.

Finally, the used electron beam is bent towards an aluminium high-power beam dump equipped with two quadrupoles to over-focus the beam.

COMMISSIONING OF THE CEC SYSTEM

The CeC accelerator superconducting RF system uses liquid helium from RHIC refrigerator system, which operates only during RHIC runs, typically from February till end of June every year. Hence, the commissioning and operation of CeC accelerator is synchronized with RHIC runs.

The commissioning of the CeC accelerator was accomplished during three RHIC runs: Runs 15, 16 and 17.

During the run 15, only SRF gun and a part of the low energy beam line had been installed and commissioned. The installation of the equipment was continued during the RHIC maintenance days. We went through a steep learning curve of how to condition and operate an SRF gun with CsK_2Sb photocathode and how to prevent its QE degradation. The run was very successful and the SRF gun generated electron bunches with 1.15 MeV kinetic energy and 3 nC charge per bunch.

The major installation of the CeC system, including all common section with FEL, occurred during RHIC shutdown in 2016. We had received and installed 5-cell SRF linac cryostat from Niowave Inc, and three helical wigglers for our FEL amplifier from Budker INP, Novosibirsk, Russia [6].

We encountered strong multipacting zone in the range from 28 kV to 40 kV of the gun accelerating voltage, which was hard to pass. This zone multipacting was spoiling the gun vacuum and was ruining photocathode's QE, more details about can be found in [7-8]. As the result of our experiences we increased the power of our transmitter to 4 kW and also developed a dedicated LLRF procedure providing for a single-shot pass through the most dangerous 40-kV multipacting barrier. After the passing the barrier, the gun was kept at operational voltage all the time and was intentionally turned down only for access to the RHIC IP2, where the gun is located.

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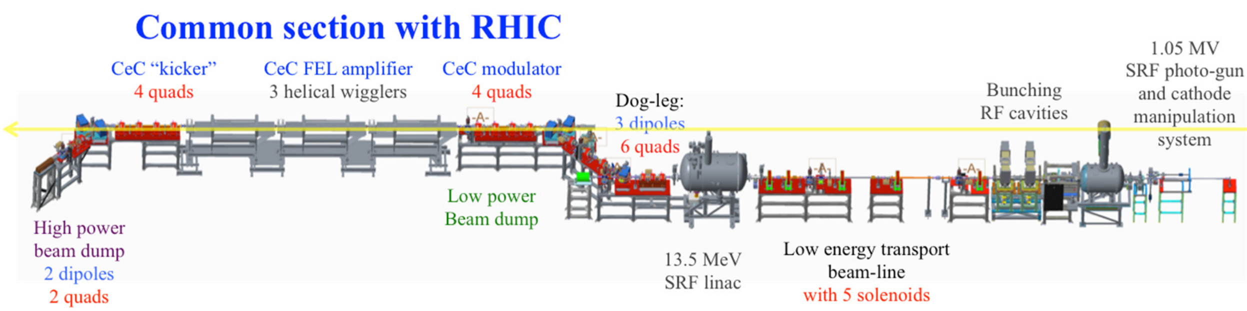

Figure 1: Layout of the CeC proof-of-principle system at IP2 of RHIC.

BEAM DIAGNOSTICS

Beam diagnostics includes 12 electron BPMs tuned except one to the 500 MHz. One BPM located between bunching cavities was tuned to 350 MHz to avoide interference from the RF field leakage. We had also three hadron BPMs tuned to 9 MHz. All BPMs are manufactured by the Instrumentation Technologies.

Current measurement was performed with two integrating current transformers: one after the gun and another in front of the high-power dump. Both dumps are equipped with Faraday cups for independent charge measurement.

Transverse beam parameters were measured with six profile monitors equipped with YAG:Ce screens. The profile monitor in the end of the low-energy transport beamline (LEBT) has also insertable slits for beam emittance measurement.

Beam energy in the LEBT section was measured with solenoid by observing rotation of the beam motion [9]. Accelerated beam energy was measured using calibrated dipole and the profile monitor in the dogleg section. Energy spread was measured using the same profile monitor. Bunch length was found from the growth of the energy spread when beam is accelerated off-crest.

BEAM PARAMETERS

Operational beam energy was 14.3 MeV. For its measurement the beam was aligned with centres of the quadrupoles in the triplet and centred on the profile monitor with dipole. The dipole field and, hence, beam rigidity were calculated from the dipole current. The image of the compressed beam is shown in Fig. 2.

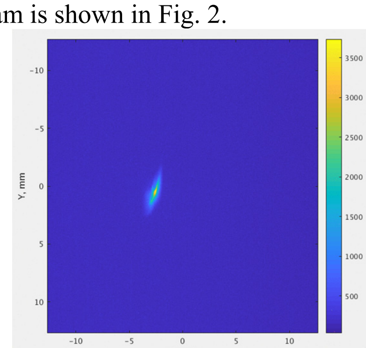

Figure 2: Image of the compressed and accelerated beam in the dogleg profile monitor. The dispersion is 1.2 meters and beam energy spread is $3x10^{-3}$.

Maximal beam charge observed was 9 nC. During operation the charge per bunch was 0.5-1.0 nC. The emittance for this charge is shown in Fig. 3.

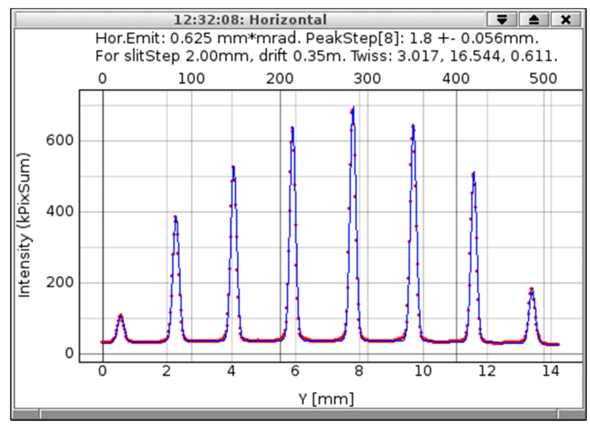

Figure 3: Emittance measurement of 0.75 nC bunch with slits.

The CW average current was with 78 kHz repetition rate and was 120 µA as shown in Fig. 4. Cathode lifetime was very good – we have used one cathode for almost two months.

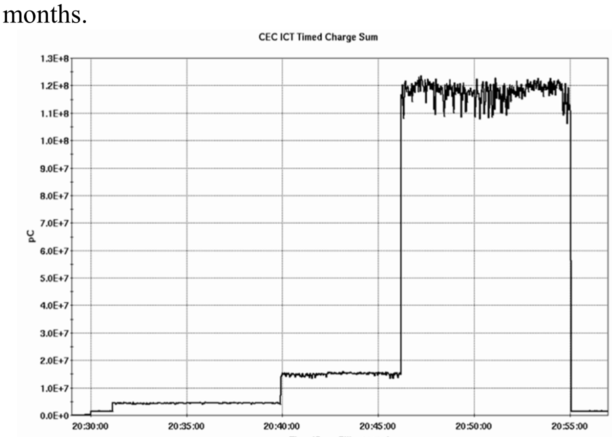

Figure 4: Current log during CeC operation.

CONCLUSION

The CeC accelerator demonstrated beam parameters suitable for the experiment.

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