FIRST RESULTS OF THE SRF GUN TEST FOR CeC PoP EXPERIMENT*

I. Pinayev#, Z. Altinbas, S. Belomestnykh, K. Brown, J.C. Brutus, A. Curcio, A. Di Lieto, C. Folz, D. Gassner, M. Harvey, J. Jamilkowski, Y. Jing, D. Kayran, R. Kellerman, R. Lambiase, V.N. Litvinenko, G. Mahler, M. Mapes, W. Meng, T. Miller, M. Minty, G. Narayan, P. Orfin, T. Rao, J. Reich, B. Sheehy, J. Skaritka, L. Smart, K. Smith, L. Snydstrup, V. Soria, R. Than, C. Theisen, J. Tuozollo, E. Wang, G, Wang, B. Xiao, T . Xin, W. Xu, A. Zaltsman, BNL, Upton, NY 11973, USA

Abstract

We have started the first tests of the equipment for the coherent electron cooling proof-of-principle experiment. After tests of the 500 MHz normal conducting cavities we proceeded with the low power beam tests of a CW SRF gun. The results of the tests with record beam parameters are presented.

INTRODUCTION

The coherent electron cooling experiment (CeC PoP) [1, 2] is expected to demonstrate cooling of a single hadron bunch in RHIC. A superconducting RF gun operating at 112 MHz frequencies generates the electron beam. 500-MHz normal conducting cavities provide energy chirp for ballistic compression of the beam. 704-MHz superconducting cavity will accelerate beam to the final energy. The electron beam merges with the hadron beam and after cooling process is steered to a dump. The FEL-like structure enhances the electron-hadron interaction. The electron beam parameters are shown in the Table 1.

Table 1: Parameters of the Electron Beam

Parameter	Value
Energy	22 MeV
Bunch charge	1-5 nC
Normalized emittance	< 5 mm mrad
Energy spread	$< 10^{-3}$

GUN DESIGN

The CeC PoP gun has quarter-wave structure and operates at 113 MHz. Its design is shown in Fig. 1. The gun cavity is placed inside cryostat with thermal and magnetic shields. The cathode stalk is inserted into cone and is kept at room temperature. Such design allows having at room temperature a CsK_2Sb cathode, which is inserted inside of the stalk. The stalk itself serves as a cavity field pick-up.

The hollow fundamental power coupler (FPC) is inserted from the flat side of the cavity and let the generated beam go outside. The RF power is provided by a 2-kW solid-state amplifier. The FPC is surrounded by a gun solenoid, which is the first focusing element.

The cavity is coarsely tuned with two manual tuners while the fine frequency change is performed with help of the FPC, which is placed on a translation stage.

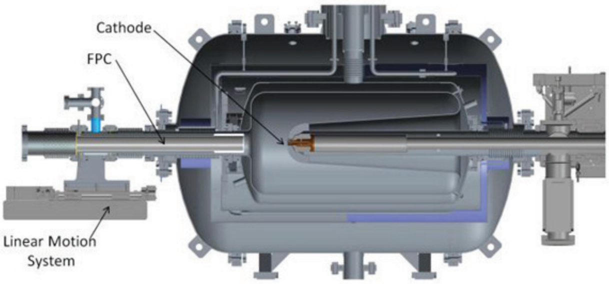

Figure 1: Layout of the superconducting gun.

The fundamental power coupler is followed by a laser cross which serve for launching of the drive laser beam onto the cathode and allows to serve the cathode as well.

TEST SET-UP

The tests performed were done with partially installed equipment and the components are shown in Fig. 2. The main systems components are:

- cathode manipulation system with “garage”, which serves for storage and insertion of the photocathodes.
- the gun itself.
- six solenoids for beam focusing.
- two copper 500 MHz cavities for energy chirp.
- beam diagnostics.
- drive laser.

A brief description of each system is below.

Drive Laser

The drive laser is Picolo AOT-1 built by Innolas. It generates up to 6 μJ pulse at 532 nm wavelength. The pulse duration is 0.7 ps and maximal repetition rate is 5 kHz. The initial r.m.s. spot size on the cathode is 1.5 mm. This laser is used for the test only an will be replaced with a new one capable to generate 78 kHz pulses with 1 kW peak power and tunable pulse length.

Diagnostics

The beam diagnostics include integrated current transformer (ICT) with sensitivity of 0.8 nV s/nC. During test the ICT output was connected to the LeCroy digital oscilloscope. The ICT is installed immediately after the laser cross allowing observing beam leaving the gun.

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#pinayev@nnl.gov

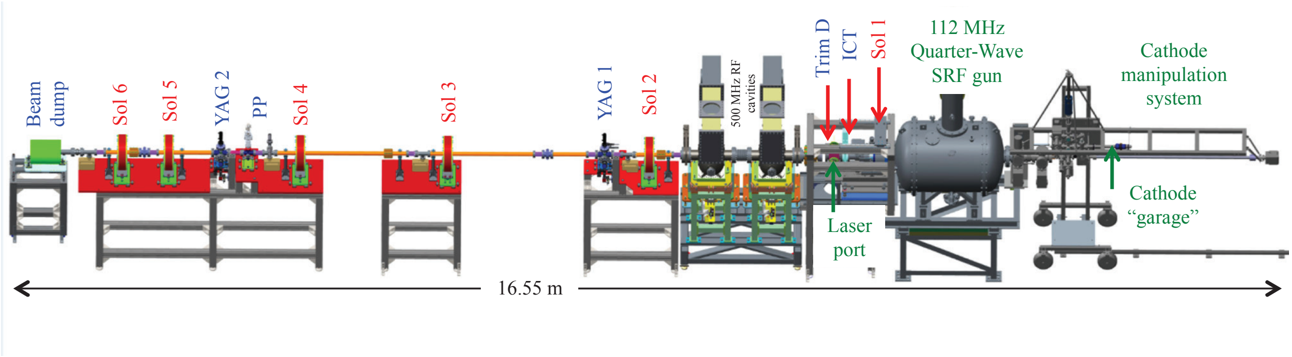

Figure 2: Rendering of the test set-up for the gun test. The overall length is about 16 meters. The gun on the right has cathode launch mechanism attached.

The transverse beam profile can viewed with two profile monitors equipped with 1.3 MP GigE cameras. In front of the second profile monitor there is a set of slits for the emittance measurement of the beam.

Beam position can be monitored with two BPMs with Libera Single Pass E+ receivers.

The beamline was terminated with low power (uncooled) beam dump, which also can serve as Faraday cup.

TEST PREPARATION

There was substantial amount of preparation job performed before he successful beam observation. The main hurdle was multipacting in the cavity and cathode stalk. One of the problematic spots was fundamental power couple, which is inside the first solenoid and has a bellow in the same location. The multipacting was suppressed by lengthy conditioning. We also observed multipacting after insertion of the photocathode. The multipacting zone was on the cathode side also coated with photoemissive material, which has tremendous secondary emission coefficient. We withdraw a cathode a performed laser cleaning of the side. Such operation required rejuvenation of the cathode by heating to 80ºC [3].

In order to suppress the cold emitters we employed helium processing of the cavity surface by letting small amount of helium into the cavity exciting it with available power.

We also observed substantial pressure spikes during the cathode transfer. We added a few NEG cartridges to improve vacuum in the system.

It needs to be mentioned that we have access to the system only for one day each two weeks during RHIC maintenance. Such circumstances substantially delayed project progress.

BEAM OBSERVATION

The tests were performed at the end of RHIC in parallel with condition of one of the RF cavities. We have much easier access to the tunnel.

We were able to observe beam charge after phase scan. The charge value was 0.5 nC. We found that beam current is limited by the space charge forces and increased the laser sport size by 50%. After this operation we were able to observe 3-nC beam charge (see Fig. 3).

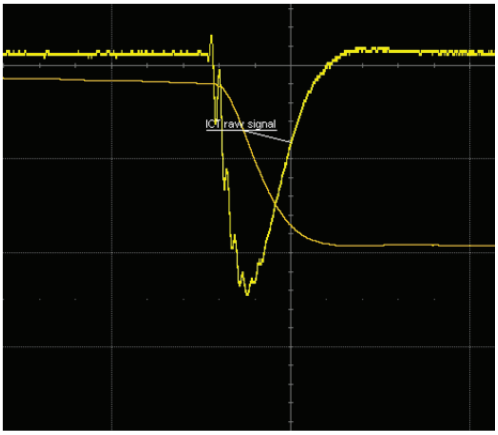

Figure 3: Trace of the ICT signal on the LeCroy oscilloscope. The pulse area indicated by built-in application is 3.6 nV s.

We increased the pulse rate to the maximum and generated 15 μA photocurrent. We tried to observe beam on the first profile monitor but were able to see only faint image on the edge of the fluorescent screen.

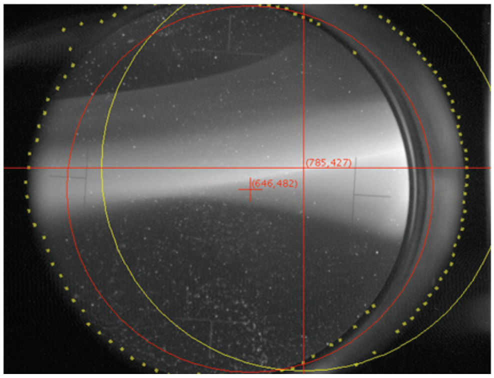

Figure 4: Image generated by dark current on the first beam profile monitor.

We found that one ion pump next to the laser cross has substantial, 200 Gs, stray magnetic field. The yoke of the pump was removed to avoid the beam steering. Unfortunately, by this time the quantum efficiency of the cathode was essentially zero. Nevertheless we were able to observe dark current on the first and later on the second profile monitors.

ENERGY MEASUREMENT

We performed calibration of the field pick-up by measuring beam displacement on the first profile monitor with varying of calibrated trim placed after the first solenoid. No other focusing elements were utilized. The dependence of beam position on the trim current is shown in Fig. 5.

Using this measurement as the calibration point, we determined that we generated photo-emitted electron beam with kinetic energies between 1.6 and 1.7 MeV according to our logged RF pick-up data. We used an expected ratio of 1.02 between the energy of photoelectrons emitted at 78.5° of RF phase, compared with energy of dark current beam peaking at the crest (e.g. at 90°). We also used this calibration to determine that in pulsed mode of SRF gun operation the kinetic energy of the beam exceeded 2 MeV.

CONCLUSION

We had proven experimentally that SRF gun can operate with high efficiency CsK_2Sb photocathode and generate CW electron beam with record-high charge per bunch, which is accelerating in record high field.

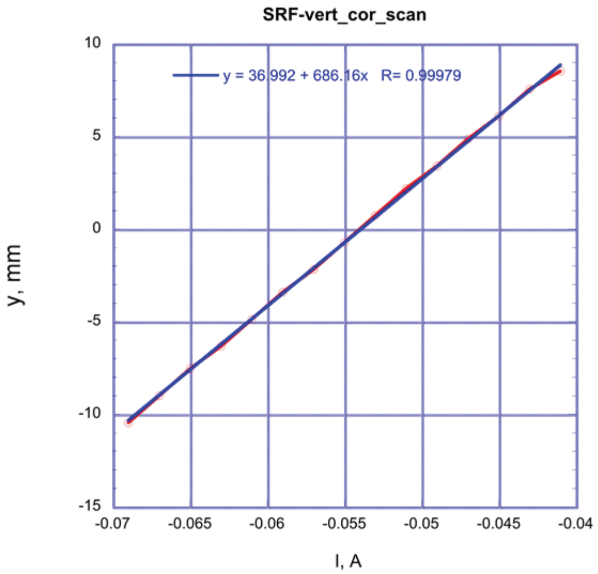

Figure 5: Dependence of beam position on the first profile monitor on the vertical trim current. The corresponding RF voltage is 1.6 MV.

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