FABRICATION, TREATMENT AND TESTING OF A 1.6 CELL PHOTO-INJECTOR CAVITY FOR HZB*

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Abstract

As an amendment to a CRADA (Cooperative Research and Development Agreement) between Forschungszentrum Dresden (FZD) and JLab we have fabricated and tested after appropriate surface treatment a 1.6 cell, 1300 MHz RRR niobium photo-injector cavity to be used in a demonstration test at HZB. Following a baseline test at JLab, the cavity received a lead spot coating of ~8 mm diameter deposited with a cathode arc at the Soltan Institute on the endplate made from large grain niobium. It had been demonstrated in earlier tests with a DESY built 1.6 cell cavity – the original design – that a lead spot of this size can be a good electron source, when irradiated with a laser light of 213 nm. In the initial test with the lead spot we could measure a peak surface electric field of ~29 MV/m; after a second surface treatment, carried out to improve the cavity performance, but which was not done with sufficient precaution, the lead spot was destroyed and the cavity had to be coated a second time. This contribution reports about the experiences and results obtained with this cavity.

INTRODUCTION

The Helmholtz-Zentrum Berlin (HZB) is in need of a successor to the synchrotron light source BESSY II currently in operation in Berlin. It is proposing an ERL based light source providing a 100 mA average current with a 1 mm mrad normalized transverse emittance. In order to demonstrate a beam with such qualities, the implementation of a fully integrated ERL facility - B*ERL*inPro [1], is being pursued, including all major systems found in ERLs like electron gun, booster section, merger beamline, main linac, return loop and high power beam dump. To maintain high flexibility, the electron source must be able to generate pulses with bunch charges ranging from a few pC up to 1 nC with repetition rates from several MHz to GHz. Superconducting radio-frequency (SRF) injectors have the highest potential as electron sources to serve this ambitious parameter range, as they are able to operate at 100% duty factor. Hence SRF systems can fulfill the ERL electron source requirements. The first stage of the development at HZB aims at the design of an all superconducting high brightness gun. This gun contains a 1.3 GHz 1.6 cell gun cavity, where the back wall has a small area coated with Pb, a superconductor, which is used as the photo-cathode [2]. This choice of material eliminated the use of a complicated mechanical choke joint design to minimize rf losses of a normal conducting cathode material such as e.g CsTe. The schematic layout of the assembly is shown in Figure 1:

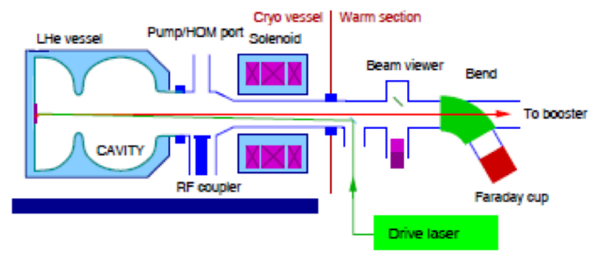

Figure 1: Schematic of the all superconducting electron source [1].

At this stage the goal of the program is to demonstrate a "robust" system capable of delivering an average beam <1 mA with a of 77 pC bunch charge and a normalized emittance of 1 mm mrad.

CAVITY DESIGN AND FABRICATION

The injector cavity is designed as a 1.6 cell structure at 1300 MHz, using the cell shape of the TESLA design. A similar cavity has already been tested successfully. At the beam pipe a TTF-III input coupler as well as a pick-up probe have been included. Also the end dish of the integrated helium vessel is attached there. The cavity parameters are listed in table 1; the field distributions and the cavity itself are shown in figure 2:

Table 1: Cavity Parameters

Frequency π – mode	1300 MHz
E_{peak}/E_{acc} ($\beta = 1$)	1.86
H_{peak} / E_{acc}	4.4 mT/(MV/m)
Geometry Factor	212 Ω
R/Q (Linac, $\beta = 1$)	190 Ω

The cavity cells have been fabricated from poly-crystalline RRR ~300 niobium, whereas the flat endplate has been machined from large grain niobium of similar purity. Since the cavity has no tuner and the requirements for the stability of the cavity had to be strengthened, the endplate was stiffened with 8 radial niobium bars of 10 mm height and 3 mm width welded across the endplate diameter. This resulted – as the simulations and the subsequent tests have shown – in a pressure sensitivity of

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~100 Hz/mbar, sufficient for the anticipated horizontal tests in the HoBiCaT cryostat [3].

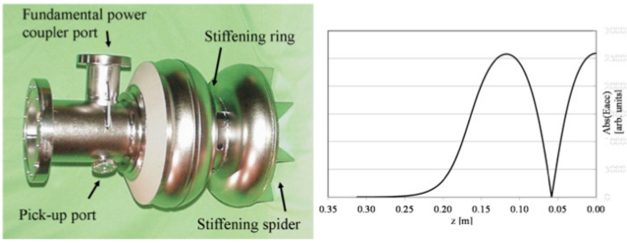

Figure 2: Cavity and field distribution.

Some of the difficulties in the fabrication process – standard deep drawing of cells, electron beam welding of iris and equator welds as well as beam pipe-flange, HOM, pick-up probe, and end-dish-assemblies – occurred in trimming the cells to the right frequency and tuning the cavity to a flat field profile since a standard field profile measurement, where a perturbing object is moved along the axis of the cell structure, could not be performed because of the shorting endplate. In the case of this cavity, a perturbing object had to be lowered carefully from the beam pipe into the cavity volume and in an iterative process between mechanically deforming the cell structure and the end plate a field flatness of ~95% and a room temperature frequency of 1300 MHz was achieved. This frequency allowed for a material removal during surface preparation of ~150 micron to hit a frequency of 1300 MHz at 2 K.

CAVITY PREPARATION AND TESTING

Standard preparation procedures such as bulk BCP of ~100 micron, hydrogen degassing at 600 C for 10 hrs, final BCP of 50 micron, high pressure water rinsing with ultrapure water, clean room drying and clean room assembly (class 10) were applied to the cavity for the initial baseline test prior to the deposition of the lead spot in the center of the endplate. Prior to cooldown the cavity was evacuated on the test stand (figure 3) for app. 12 hrs reaching a vacuum of p~3x10^{-8} mbar. The cavity performed reasonably well as shown in figure 6.

In a next step the NbTi helium vessel was welded to the helium vessel end dish provided by Research Instruments (RI) as indicated in figure 2, which was already part of the beam pipe. The helium supply lines where not added at this stage, because of their bulkiness and space limitations in the deposition system and later in the high pressure rinsing at JLab. However an important step in the helium vessel welding was the precise attachment of the NbTi blocks on the periphery for locating and suspending the cavity in the horizontal cryostat.

Figure 3: Cavity assembled to cryogenic test stand.

Subsequently the cavity was shipped to the Andrzej Soltan Institute for the deposition of the 8 mm diameter cathode spot. This happens as an arc deposition – “in situ”, the cavity is the vacuum chamber for the arc – and the lead ions are guided by a magnetic transportation system to the end plate. To avoid contamination by stray lead ions, the cavity interior surface is shielded. The deposition itself is carried out in a pulsed mode and at the beginning of the procedure the baked cavity showed a vacuum of <10^{-9} mbar. The system and the lead spot inside the cavity are shown in Figure 4.

In the first test with the cathode spot – after a high pressure rinse cycle at JLab – a peak electric field of E_p~29 MV/m with a somewhat lower Q-value was measured.

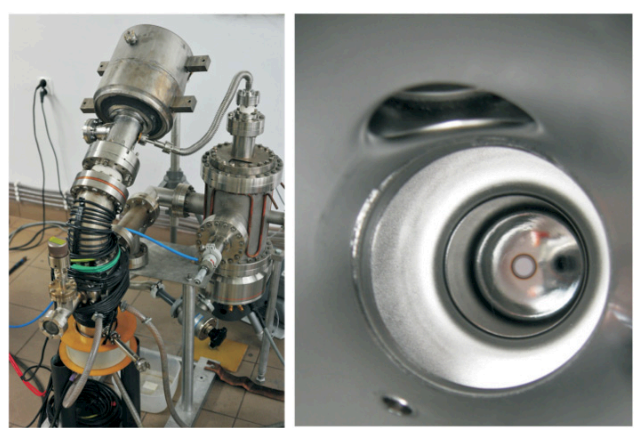

Figure 4: Arc deposition system at the Soltan Institute (left) and the 8 mm lead spot deposited at the endplate of the 1.6 cell cavity (right).

In an attempt to improve the cavity performance the lead spot was covered for a further surface treatment with a mask made from Teflon as shown in figure 5 and the cavity interior was BCP’d for app. 5 min. Unfortunately, this treatment was not done with the appropriate precaution and the lead spot was partially destroyed.

Figure 5: Mask for protecting the lead spot during bcp of the cavity interior.

After complete removal and another baseline test, the cavity was returned to Poland, the spot was re-deposited and another cold test had to be performed. In this case the lead spot received a weak BCP with a 1:1:4 solution of $HF/HNO_3/H_3PO_4$ and the cavity was baked at ~95C on the test stand for ~12 hrs. This procedure produced acceptable results for the integration test in the horizontal cryostat (Test #4).

A summary of the test results is shown in figure 6.

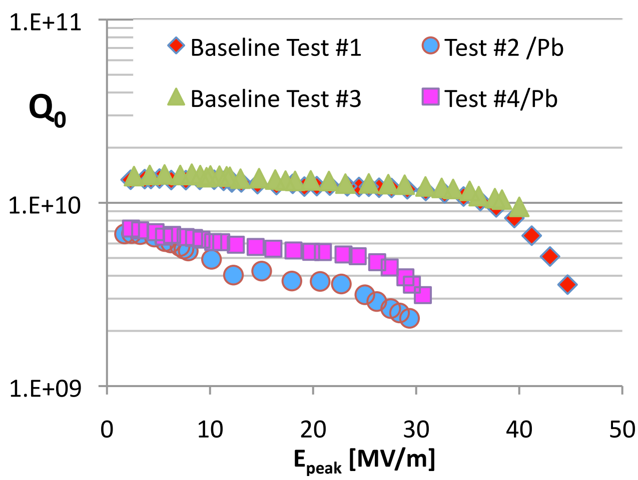

Figure 6: Summary of test results.

ASSEMBLY AND SHIPPING TO HZB

After the final test the cavity was carefully vented with dry, filtered nitrogen on the vertical test stand and removed from it inside the clean room. The helium vessel had to be completed with the riser pipe, manifold and Ti conflat flanges for the helium distribution. During this operation the cavity was hermetically sealed with blank flanges and metal gaskets. A leak check of the helium vessel confirmed that the welding of the complete vessel was successful and no leak could be detected. After several hours of evacuation a vacuum $<1x10^{-7}$ mbar with a leak rate $<2x10^{-10}$ mbar l/sec was achieved.

The attachments to the cavity needed for the horizontal test at HoBiCaT consisted of the fundamental power coupler provided by RI, the calibrated pick-up probe and the VAT gate valve at the beam pipe. All pieces were properly cleaned and attached in the class 10 clean room with $AlMg_3$ gaskets. A leak test of the cavity assembly confirmed a leak tightness to the same values as measured on the helium vessel

Finally the whole assembly was securely packed into a transportation container, designed and provided by HZB (see Figure 7) and shipped there under vacuum. The assembly for the horizontal test is under way.

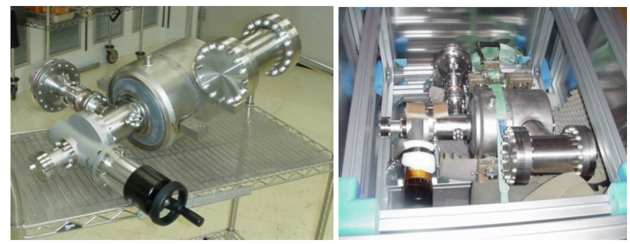

Figure 7: Cavity assembly (left) with gate valve, fundamental power coupler, field probe and helium vessel manifold; assembly in shipping container (right)

ACKNOWLEDGEMENT

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