TESTING OF IMP LIS-RFQ *

Y. Liu [1 #], Z. Zhang [1,2,] R.A. Jameson[3], A. Schempp[3], H. Zhao[1], W. Zhan[1], H. Zimmermann[3], M. Vossberg[3], L. Sun[1,2],M. Okamura[4], He Yuan[1], S. Sha[1], X. Guo[1], A. Shi[1], Z. Xu[1], W.Yue[1,2], Z. Wang[1,2], X. Du[1,2], C. Zhang[1,2], X. Lei[1]

[1] Institute of Modern Physics (IMP), Chinese Academy of Sciences, Lanzhou 730000, China
[2] Graduate University of Chinese Academy of Sciences, Beijing 100049, China
[3] Inst. Angewandte Physik Goethe Uni. Frankfurt, Max-von-Laue-Str. 1, D60438, Frankfurt am Main, Germany
[4] Brookhaven National Laboratory, NY 11973, USA and RIKEN, Saitama 351-0198, Japan

Abstract

A compact RFQ applying the direct plasma injection scheme (DPIS) [1] for intense pulsed ion beam from a laser-ion source has been built and conditioned in IMP, Lanzhou. It is the first RF linear structure in IMP, in collaboration with IAP, Frankfurt. Much experiences were gained for future development for the HIRFL (Heavy Ion research Facilities in Lanzhou) [2][3]. First results of cold measurements and conditioning as well as challenges in the further steps are shown in the paper.

INTRODUCTION

A compact RFQ designed for intense short pulsed ion beam from a YAG-laser ion source was built in IMP, Lanzhou, with collaboration with IAP, Frankfurt. The set-up, shown in Fig. 1, is an application and studying platform of the direct plasma injection scheme (DPIS) [1], also offering a testing bench for studies, developments and experiences-learning on the heavy-ion LINACs and benefiting for the future ion-species and beam intensity/quality upgrade for the HIRFL. The RFQ was designed to accelerate ~10 μs fully-stripped carbon beam with intensity as high as ~100 mA to 0.6 MeV/u within ~2 meters with about 95% transmission [4][5].

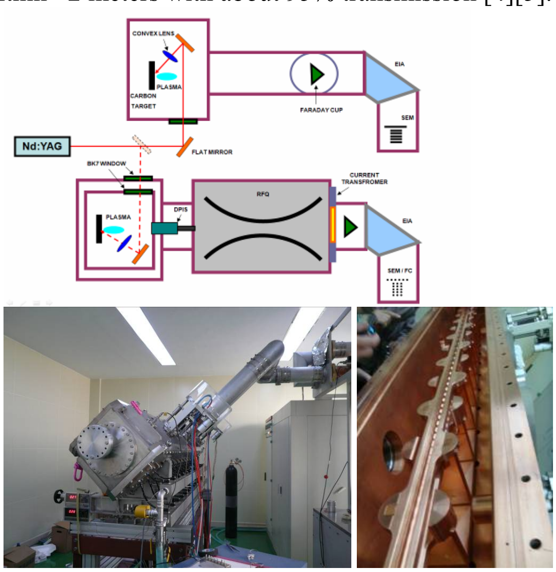

Figure 1: Sketch of the LIS-RFQ experiment setup and photos of the installed RFQ and its resonant structure.

*Work partly supported by NSFC project 10635090
#y.liu@impcas.ac.cn

The RFQ cavity was built by NTG at Gelnhausen, Germany, and installed in IMP, Lanzhou this April. The cold tests were repeated, and conditioning with different power-levels was done in IMP. The final and most crucial next steps towards the beam testing are being undertaken.

COLD TESTS

As the first steps of the testing, check of the availability and the cold measurements of geometry, Q values, shunt impedance and field flatness have been carried out.

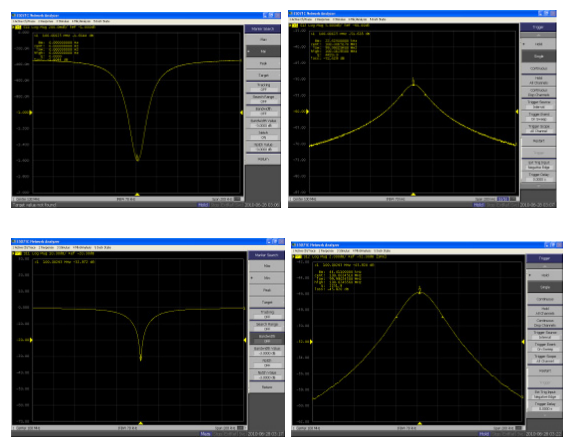

Figure 2: Measurements of the unloaded (upper) and loaded (lower) Q values.

Figure 3: Estimation of shunt impedance with a perturbation capacitor.

The Q values were measured as, (the unloaded) Q_0=4500, (the loaded) Q_L=2300, with the S_{12} signal between the coupler port and one of the pick-up ports, controlling different coupling strength looking at S_{11}

parameter (-1.6 dB and -33 dB respectively) of the coupler port, shown in Fig. 2.

With the measured unloaded Q_0, an 1-pF perturbation capacitor, placed as shown in Fig. 3, measured cavity resonant spectra from S parameters and the formula,

$$R_p = \frac{2Q_0\Delta f}{\pi f_0^{\,2} C_s}, \qquad (1)$$

the total shunt impedance of the RFQ cavity R_p is estimated to be R_p=80 kΩ.

The electric field flatness along the beam path was measured following the Slator's perturbation law, by measuring and analyzing the frequency shifts between with and without the perturbation over the nearby electrodes between every two stems, as shown in Fig. 4a. Comparison of the field flatness measured at IMP and IAP was shown in Fig. 4b/c.

(a) (b) (c)

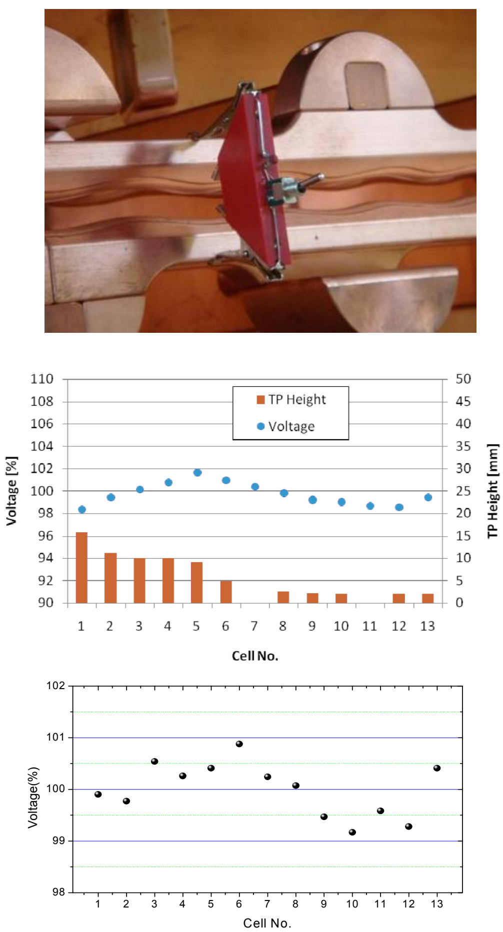

Figure: 4 Field flatness measurements. (a) the perturbation capacitor. Measured results at IMP (b) and IAP (c).

RF CONDITIONING AT DIFFERENT LEVELS

Before power test with the real amplifier, a 1kW commercial broadband amplifier together with a Tektronix AFG3252 arbitrary function generator were used for 1-200 W CW pre-conditioning, as shown in Fig. 5.

The pre-conditioning proved to be very beneficial to the afterward high power conditioning, whose set-up and milestones of the first stage, from June 20 to July 15, were shown in Fig. 6.

One crucial issue is the length of the power feed-through from the amplifier and the RFQ cavity. It is difficult to find the precise effective length of the feed pipe, because of the complicated couping structure at both ends.

In the test done a few days ago in August and early September, conditioned power of 185 kW, corresponding to the designed voltage of ~120 kV was achieved, with pulsed length of 50-500 μs and repetition rate of 1-3 Hz.

NEXT STEPS AND CHALLENGES

Now the RFQ is ready for the beam tests, which is the crucial checkout of the whole system. The laser ion source, timing among laser, optic shutter and the RFQ, beam diagnostic chamber will be available soon.

Beam diagnostic system comprises with a fast current transformer (FCT) and an optional slow Faraday-cup for beam-current and transmission measurement, beam energy measurement with an electrostatic-deflector, a fast Faraday-cup for bunch-length measurement. Optionally there are planned schemes of pencil beam collimators at both ends of RFQ, visual-screen and beam emittance scanner.

An independent temperature cooling/control system with precision of 27 ± 1^0C is ordered to replace the present rough cooling water system shared with HIRFL. Thus better frequency stability is foreseen in the future commissioning and operation.

For such short pulsed beam there are many challenges on the way. For instance now the commissioning team is trying to measure the electrode-voltage with Bremsstrahlung X-ray detected with a highly-purified-Ge detector. The set-up and statues are shown in Fig. 7. The low duty factor, complicated noises from surrounding EM environment and circuit made the measurement very difficult, which will affect the beam test for sure, too.

CONCLUSIONS AND ACKNOWLEDGEMENT

The first RFQ in Lanzhou offers a new platform for the DPIS and laser ion source studies. It will benefit for the LINAC technology development in IMP for better experimental possibilities with improved injection, besides the existing cyclotrons, for the storage rings in the HIRFL. Things seem on the right orbit.

Thankfulness should be given to the colleagues from IAP, BNL, RIKEN, NTG, GSI and involved domestic companies, for offering much advice, experience and support.

Figure 5: Set-up for the 1-200 W CW conditioning.

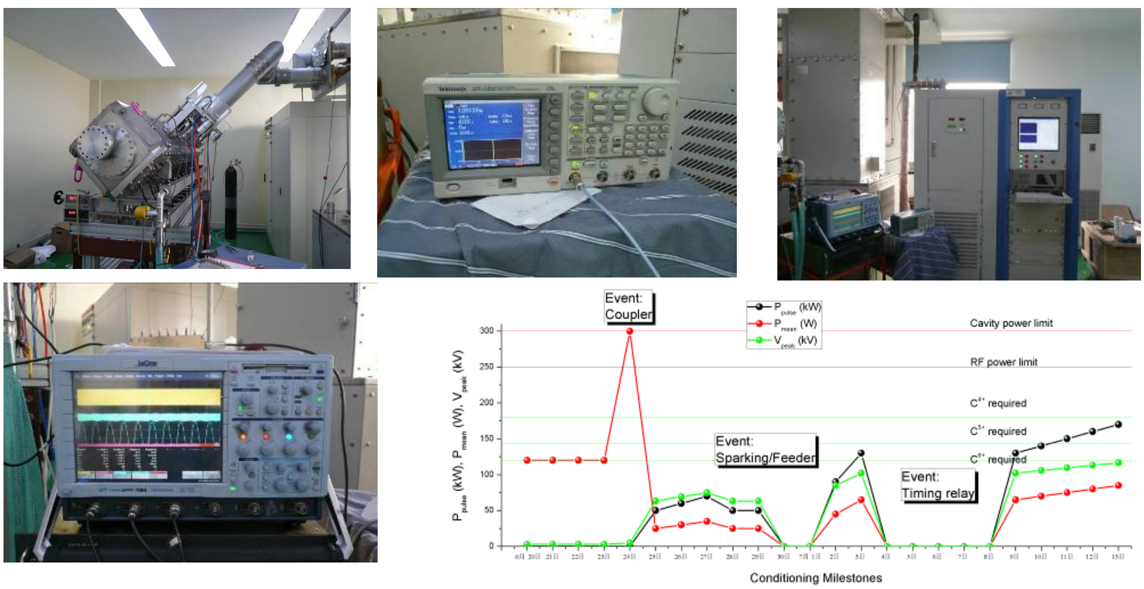

Figure 6: Set-up for the high-power conditioning and milestones of the first stage.

Figure 7: Set-up for RFQ electrode voltage measurement with Bresstrahlung X-ray detection with highly-purified Ge, on-going.

REFERENCES

[1] M. Okamura, T. Katayama, R. A. Jameson, et al, Rev. Sci. Instrum. 73, 761 (2002) .

[2] J.W. Xia, W.L. Zhan, B.W. Wei, et al., Nucl. Instr. and Meth. A 488 (2002) 11.

[3] Y. Liu, J.W. Xia et al., "HIRFL-CSR Commissioning Status and Future Upgrade", HIAT2009, Venice, June 2009, TU13; http://www.JACoW.org.

[4] Z. Zhang, et al. "A two-meter long RFQ for the direct plasma injection scheme at IMP", this proceeding.

[5] Z. Zhang, R.A. Jameson, H. Zhao, et al. NIMA, 2008, 592 (3): 197–200.

[6] P. Fischer, PHD Dissertation, IAP, University of Frankfurt, 2007.