Status of the modulated 3 MeV 325 MHz Ladder-RFQ*

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* Work supported by BMBF 05P15RFRBA.
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Abstract

An unmodulated Ladder RFQ prototype with an electrode length of 63 cm was successfully designed, manufactured and tested during 2014 and 2015 [1]. The successful high power tests of the unmodulated prototype motivated the development of a new beam dynamics with an increased electrode voltage of 96 kV [2]. Consequently, a modulated prototype (s. fig. 1) with an electrode length of approx. 3:3m was designed to accelerate protons from 95 keV to 3:0MeV according to the design parameters of the p-Linac at FAIR. Manufacturing is expected to be completed in May 2018.

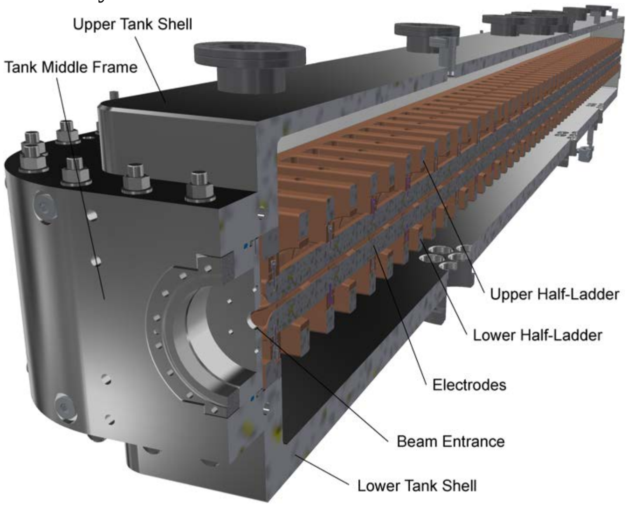

Figure 1: Isometric view of the 3.3 m modulated Ladder-RFQ prototype. Copper carrier-rings guarantee the electrode positioning as well as the RF contact. The ladder structure consists of bulk copper components. Any brazing or welding processes were avoided for the assembly of the main components.

Status of Manufacturing

Manufacturing of the tank components, consisting of an upper tank shell, middle frame and lower tank shell started in September 2017 and has been completed in February 2018. The middle frame has been copper-plated by GSI in 12/2017. The upper and lower tank shell will follow until March 2018. The copper structure is machined in parallel from 02-04/2018. The electrodes will also be completed in April. The whole assembly is scheduled for May 2018.

Compensation of Fringe Fields

The longitudinal electric field in the entrance gap of the RFQ will be beneficially exploited as a pre-buncher (s. fig. 2). Further details will be published separately.

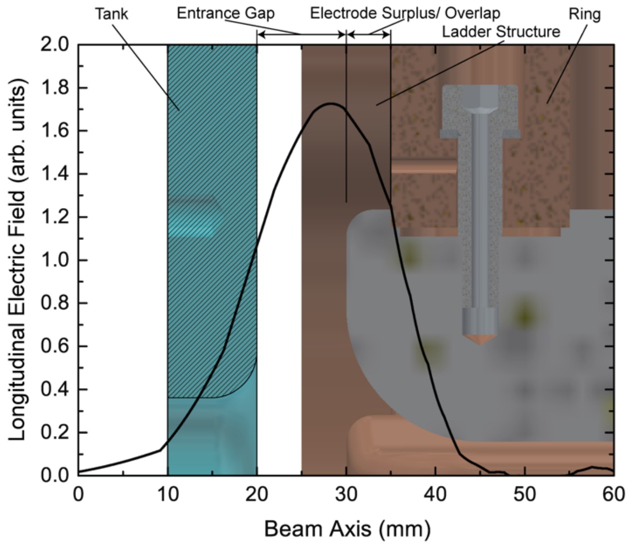

Figure 2: Fringe field in the entrance gap of the RFQ.

Conclusion and Outlook

As soon as manufacturing is completed first low level RF measurements such as frequency, spectra and flatness will be performed in Q2/2018. Accompanied by simulations, the heights of the ladder cells will then be machined to tune the longitudinal voltage distribution and frequency. Simultaneously, the frequency plunger and RF coupler will be designed and built. After the final assembly, the RFQ will be RF conditioned at the end of 2018 as well as high power RF tested at the GSI test bunker [3]. With completion of the p-Linac building, the RFQ can be installed together with the ion source and LEBT to be tested with beam.

References

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[3] G. Schreiber, E. Plechov, J. Salvatore, B. Schlitt, A.Schnase, M. Vossberg, “First High Power Tests at the 325 MHz RF Test Stand at GSI”, Proc. of LIN-AC2016, East Lansing, USA, p. 3745.

Experiment beamline: none
Experiment collaboration: none
Experiment proposal: none
Accelerator infrastructure: p-Linac
PSP codes: none
Grants: none
Strategic university co-operation with: Frankfurt-M

Status of high power components for the FAIR Proton Linac RF systems

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In middle of 2017 the In-kind contracts between GSI/FAIR and CNRS (France) related to radio frequency components for the GSI/FAIR pLinac were concluded.

We continued with the acceptance tests of the delivered components. Related to waveguide parts, we modified and calibrated in total 11 dual directional couplers and 7 six-port couplers. In the end of 2017 the next 6 Klystrons TH 2181 were delivered. Here we explain the test procedures.

In order to operate the Klystrons - at the test bench and later in the pLinac RF Gallery, we need high voltage Modulators. The in-house preparation of a prototype modulator is progressing.

RF system components at test bench

As described in [1], the modification and testing of waveguide directional couplers was continued. Now in total 64 ports are calibrated. The coupling is in the range 60 ±0.4 dB. Especially for the couplers detecting the reflected power, the isolation is better than 100 dB providing a directivity of better than 40 dB. Thus the upgraded dual directional couplers enable a reliable protection of the Klystrons against reflected power and the improved six-port couplers will deliver the signals for precise tuning of the acceleration cavities in the pLinac.

The RF power for the accelerating cavities is sent via WR 2300 waveguides to the tunnel - followed by transition elements to a short coaxial line, which connects to the cavity input couplers. Several variants of transitions and coaxial elements were specified and ordered. Testing these components at the test bench requires pulsed RF power up to 2.5 MW peak delivered by a Klystron, which in turn is powered by a high voltage modulator [2].

The power electronics and electromechanical design of the modulator is complete and component procurement is ongoing. The development of the electronic control system is progressing.

TH2181 Klystrons

The TH2181 Klystron prototype is installed at the test bench. The FAT of the Klystrons #2 - #7 was conducted successfully in two groups of three at the company Thales. Finally in December 2017 the Klystrons were delivered to a GSI storage facility (Betriebshof) as shown in figure 1. Each Klystron has a weight of 4.2 tons. Fortunately, GSI owns a strong fork lifter, which can handle this load. The SAT Aa testing is following a procedure prescribed by Thales, that the Klystron filament current will be applied in a slow ramp while observing the ion pump currents, which represent the vacuum state. This is shown as an example in figure 2. The filament current is increased until the design value of 18 A is reached. The ion-pump current should stay below 10 µA. Both ion-pump currents should be similar, because the ion pumps are connected to the same klystron vessel. All of the klystrons passed the filament test. However, for 3 of the klystrons only one of the ion pumps became active. Thus, these tests have to be repeated in 1 month intervals.

Figure 1: The Thales Klystrons #2-#7 are stored.

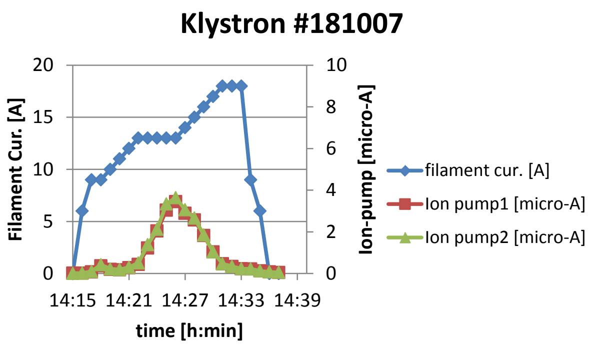

Figure 2: Ion-pump current during filament test.

Outlook

With the delivery of the Klystrons an important milestone towards the pLinac was reached. We will continue our efforts to prepare the RF systems for the pLinac.

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[2] S. Pütz, A. Schnase, G. Schreiber, "Design and Production of Klystron Modulators for the pLINAC", GSI sci. report 2016, p. 459.

Experiment beamline: none
Experiment collaboration: none
Experiment proposal: none
Accelerator infrastructure: p-Linac
PSP codes: 2.7.4.1
Grants: none
Strategic university co-operation with: none

 DOI:10.15120/GR-2018-1

Commissioning of the proton injector for FAIR at CEA/Saclay

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The proton injector for Facility for Antiproton and Ion Research (FAIR) is designed and built at CEA/Saclay (France). It will provide primary proton beam at 95 keV energy and up to 100 mA current into compact proton linac, where it will be accelerated to 68 MeV for further injection into upgraded Heavy Ion Synchrotron (SIS18).

The proton injector itself consists from pulsed ion source operates with a frequency of 2.45 GHz based on electron cyclotron resonance (ECR) plasma production and Low Energy Beam Transport (LEBT) matching the proton beam to the radio-frequency quadrupole (RFQ) [1]. The designed value of emittance at the entrance of RFQ should be lower than 0.3π mm mrad (normalized, rms).

The commissioning of the proton injector is running now at CEA/Saclay and divided in several steps. The first commissioning phase includes beam characterisation direct after accelerated column shown in the Fig.1. The ion source is located at the high voltage platform inside the Faraday cage. The diagnostic chamber is mounted outside of the Faraday cage with different diagnostic tools as: Allison scanner (EMU) for emittance measurements, current transformer (ACCT) and faraday cup (FC) for current measurements and Wien filter (WF) for detection of different ion species.

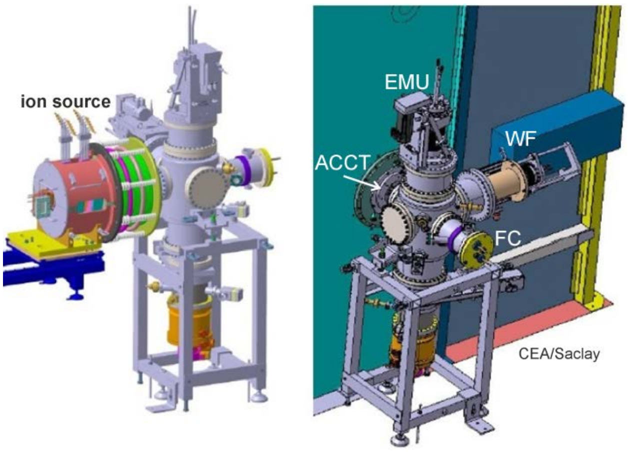

Figure 1: 3-D view of microwave ion source and diagnostic chamber for first commissioning phase.

This commissioning phase is on final stage at CEA. The maximum total extracted current from ion source measured with ACCT is near 150 mA. The measured beam composition with WF shows high proton value in the order of 82-85%. First emittance measurements show good results with emittance narrow to designed value for proton injector.

As a next step it is planned to install LEBT consisting of two solenoids including an iron shielding with two horizontal and vertical integrated magnetic steerers. A diagnostic chamber with different diagnostic tools is mounted between the solenoids. During this phase the measurements will be carried out between solenoids in diagnostic chamber and behind second solenoid. Similar beam characterisation including current, emittance and proton fraction measurements will be done [2].

In the last commissioning phase (Fig.2) chopper chamber with injection cone will be installed. In proton linac electrostatic chopper will be placed between the second solenoid and the RFQ entrance to cut the beam pulse current to 36 µs.

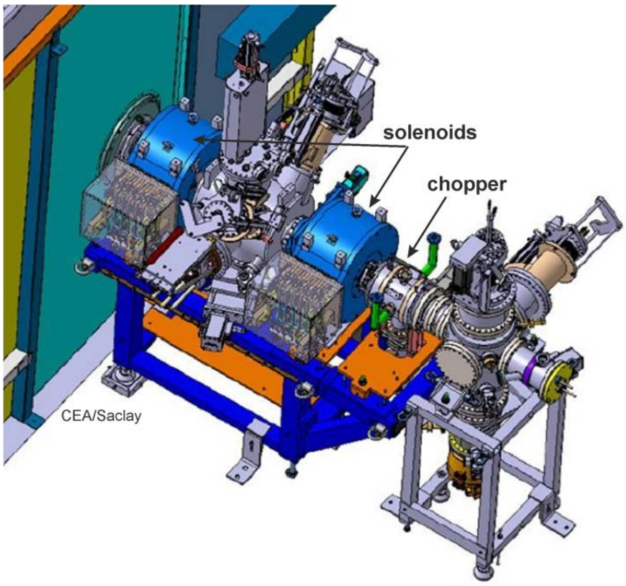

Figure 2: 3-D view of LEBT, chopper and diagnostic chamber.

In this phase the measurements of beam intensity will be done with ACCT behind the pentode extraction system, behind second solenoid and as additional in the diagnostic chamber and at the end of beam line with faraday cup. The emittance and beam composition measurements will be done in this case after the injection cone to feature the beam parameters produced from proton injector. The stability of the ion source including beam fluctuation and pulse-to-pulse repetition rate will be tested during the long time of operation.

After successful commissioning of the proton injector at CEA, it will be transported to GSI for final commissioning in the new proton linac building for FAIR.

References

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