FIRST STAGE OF A 40MEV PROTON DEUTERON ACCELERATOR COMMISSIONING

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Abstract

In 2006 the first stage of a 40MeV superconducting linear accelerator for protons and deuterons will be commissioned at SOREQ. This paper will present commissioning of the ECR source after final assembly. Further test results of the beta=0.09 half wave superconducting resonators are presented, and resonator geometry improvements with respect to electron multipacting behaviour will be discussed. An outlook on the project with respect to achieve the final energy of 40MeV will be given.

ACCELERATOR DESIGN

The 40MeV sc linac for protons and deuterons designed and currently built by ACCEL Instruments GmbH [1] is described in [2, 3]. It consists of an ECR ion source, a nc RFQ and six modules housing 46 sc half wave resonators. In the first phase of the project the source, the RFQ and a superconducting prototype module (PSM) with six superconducting resonators is built.

ECR ION SOURCE

The design of the ECR ion source based on a AECL design is described in [4] and consists of following sub-components:

- plasma chamber with acceleration/deceleration-electrodes
- gas flow system including dosing valve
- magnetron providing required RF power at 2.45 GHz
- two HV power supplies providing accelerating and decelerating voltage
- two solenoid magnets defining the ECR zone
- LEBT including vacuum pumping, focussing, bending magnet and beam diagnostics

Table 1: ECR Ion Source Specifications

Parameter	Unit	Value
Particles		H+, H2+, D+
Beam energy	keV/u	20
Beam current	mA	0.040 to 5
Emittance (rms, normalized, 100%)	π mm mrad	0.2

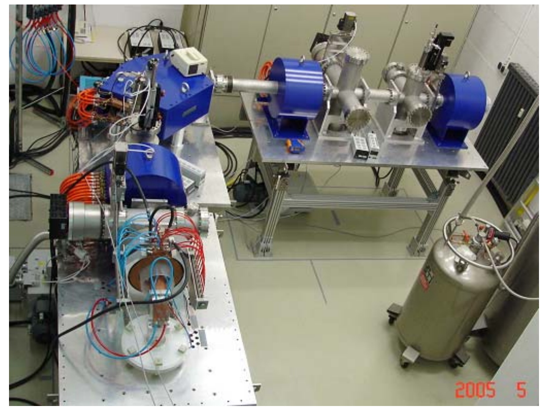

Figure 1: ECR Ion Source with LEBT in the ACCEL test facility.

Commissioning Results

The ion source was assembled and commissioned at ACCELs test facility (figure 1). It is operating with H+ and H2+ at nominal currents, D+ operation will be tested at SOREQ due to radiation safety reasons.

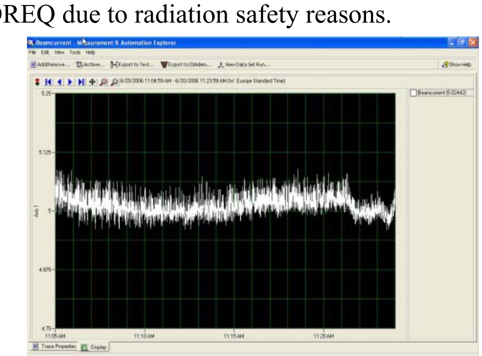

Figure 2: Beam stability measurement (±1% over one hour at 5 mA H+).

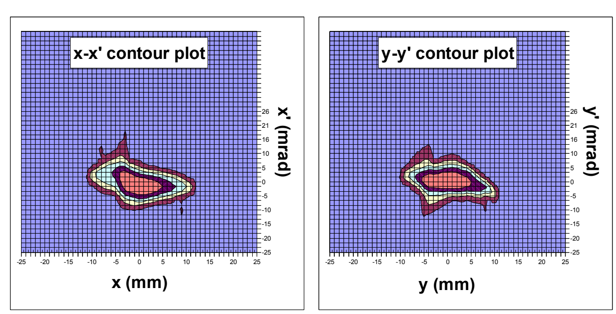

Figure3: Beam emittance measurement ($\varepsilon_{norm,rms,100\%}$ = 0.15 π mm mrad at 5 mA H+).

RFQ ACCELERATOR

The normal-conducting RFQ is designed to accelerate the ion beam in cw-mode from the ion source energy of 20 keV/u to 1.5 MeV/u being the input energy of the superconducting linac. The RFQ built by NTG was tuned at the University of Frankfurt [5] before delivery.

SC CAVITIES TEST RESULTS

The prototype superconducting module houses six 176 MHz half wave resonators (see Figure 4). The main design parameters of those cavities are listed in table 2. The design peak surface gradient is 25 MV/m with a maximum of 10 W dynamic losses. The corresponding unloaded Q value is 4.4×10^8.

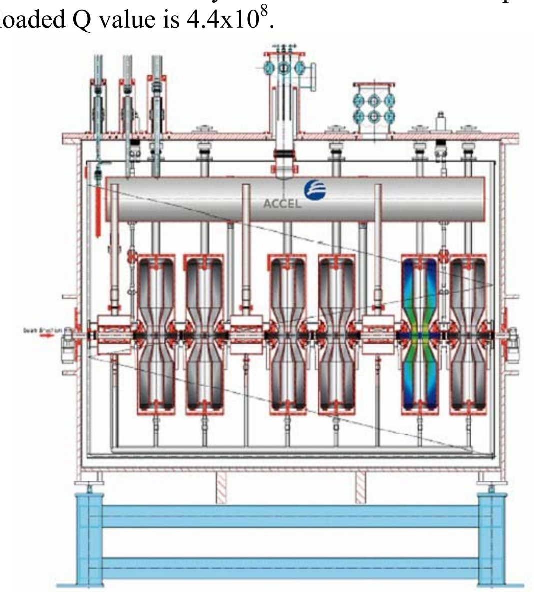

Figure 4: Prototype superconducting module containing six superconducting half wave resonators (β=0.09) and three superconducting solenoids.

Table 2: Parameters of the half wave resonators (β=0.09)

Frequency	176 MHz
E_{acc} (E_{peak}=25MV/m)	8.58 MV
Accelerating length L_{acc}	99 mm
B_{peak} (E_{peak}=25MV/m)	80 mT
Q_0 (4.4 K, low field)	1.1×10^9
Goal Q_0 (E_{peak}=25MV/m)	$>4.7 \times 10^8$

Vertical Test Facility at ACCEL

Prior to module assembly each half wave resonator was tested separately in a vertical test cryostat. For this purpose a test facility was built at ACCEL. In this test facility we can test one cavity per week. A system test of the assembled module can also be done in this facility.

Preparation Prior Vertical Test

After fabrication, the half wave resonators received removal of 120 µm material from the inner surface (damage layer removal) by buffered chemical polishing (BCP 1:1:2). After etching, the cavity is rinsed continuously with de-ionized water until the resistivity of the water reaches values above 17 MΩcm, followed immediately by a high pressure rinsing.

Figure 5: Vertical test facility at ACCEL. The cryostat (left) is filled with helium out of dewars and pre-cooled with LN_2. The superconducting half-wave resonator is equipped with a variable input coupler for the vertical test (bottom).

In order to avoid drying by pumping, a new class 1 area was integrated in the existing clean room to allow drying by laminar flow over night with all flanges opened. In detail, the following steps were performed on the halfwave resonators after the above described removal of the damage layer:

- Frequency and dimensional control
- Degreasing
- 20 µm removal from the inner surface by closed loop BCP (1:1:2)
- High pressure (100 bar) water rinsing for 3 hours
- Drying in class 1 clean room
- Assembly of all flanges and test antennas
- Pump down and leak-check
- Transport under vacuum vertical test insert
- Assembly of pumping system and leak check
- Insert into test cryostat
- Cool down to 4.2 K
- Low power RF test

Vertical Test Results

Figure 6 shows the test results of all six half wave resonators. All cavities exceeded the specification and all measured curves are very close to each other indicating a high reproducibility of the performed preparation. Also shown is the result of a prototype cavity built before the series production of the six resonators for the prototype superconducting module.

Low Field Multipacting in Half Wave Resonators

At the vertical test of the prototype half wave resonator it was observed, that this cavity showed multipacting at very low electrical surface fields of about 0.1 MV/m. It was very difficult to overcome the multipacting barriers and having processed those barriers, they even came back after some hours of high field operation.

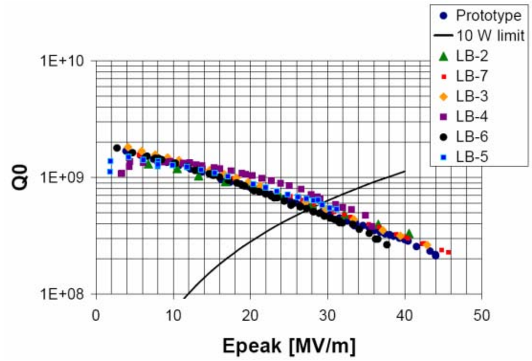

Figure 6: Test results of the half wave resonators produced for the SARAF linac.

During the design of the half-wave resonator two kinds of stable trajectories for possible multipacting were detected.

Type 1: Located at the capacitive region of the resonator (see figure 7). Stable trajectories are observed only at very low field below 0.1 MV/m peak electric field.

Type 2: Located at the high magnetic field region (see figure 7). Stable trajectories are observed at peak electric field levels around 10 MV/m.

For both kind of trajectories the impact energies were calculated and are shown in figure 8. For the type 2 trajectories, the impact energies are quite low and below the threshold (100eV) where the secondary emission coefficient for niobium is above 1. Therefore they were not thought to give any trouble of multipacting during operation.

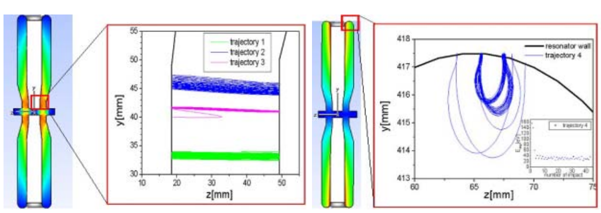

Figure 7: Two kind of stable trajectories detected inside the prototype resonator, type 1 at the high electric field region and type 2 at the high magnetic field region.

The impact energies of the type 1 trajectories are in an energy range between 100 eV and 1000 eV where the secondary emission coefficient is above 1 and therefore multipacting is possible. But as the electric field for stable trajectories was so low, it was felt that the eventual barriers were easy to overcome and thought not to be harmful for operation.

During the vertical test of the half-wave resonators, both predicted barriers were observed. The type 2 multipacting was easy to process and did not come back after it was processed once, but the type 1 multipacting seriously gave trouble during the test. Even after processing the barrier, it came back after operation at higher fields and it took sometimes several hours to process through the barrier again.

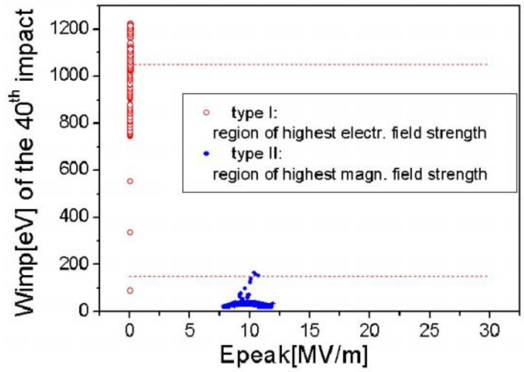

Figure 8: Calculated impact energy of the 40th electron for the two kind trajectories shown in figure 7.

New calculations were performed with slightly different geometry at the high electric field region. The calculations performed with inclined inner or outer wall showed, that no stable trajectories were present in the new cavity design with even only 5° inclination of the inner wall. The series cavities were built with this geometry change.

During the vertical test of the series cavities, also low field multipacting is observed. However the multipacting can be processed now in a time of typically 4 hours. In addition, the multipacting does not come back after high field operation and we can therefore conclude, that the geometry change of the half wave resonators was efficient to reduce the multipacting behaviour significantly and allow for a stable operation of the linac.

OUTLOOK

After the ECR ion source characterization has been finalized, installation and beam commissioning of the source and the RFQ is scheduled for summer 2006. In the fall of 2006 installation and characterization of the PSM is planned.

REFERENCES

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[5] P.Fischer, A.Schempp “Tuning of a 4-rod cw-mode RFQ accelerator”, EPAC’06, Edinburgh, June 2006