Design of the Superconducting RFQ for PIAVE Linac

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Two superconducting RFQs (SRFQ1 and SRFQ2) have been developed in INFN-LNL. The output beam energy is 578.3 keV/nucleon for $^{28+}U^{238}$. The SRFQ1 was designed based on the 90°-apart-stem structure and the RF characteristics were measured on the half scale model. The important decision in the design is to split the cavity into two sections because the electrode length of SRFQ1 is too long to perform the electron beam welding with the available machine. The field variation within ±1 % is achieved even after the splitting.

Keywords : Superconducting RFQ/ PIAVE /Heavy ion accelerator

RFQ (radio frequency quadrupole) linacs are widely used for ion accelerators. Many laboratories and companies have been constructing RFQ linacs using the normal conducting cavity. The first superconducting RFQ has been developed in INFN-LNL. The power consumption is greatly reduced using the superconducting cavity, which enables to accelerate very heavy ions in the CW mode. The superconducting RFQ will be utilized in the new injector PIAVE (Positive Ion Accelerator for Very-low Energy) [1]. Main specification is shown in Table 1 [2]. There are two superconducting RFQ cavities (SRFQ1 and SRFQ2) in the project. Figure 1 shows the half scale model of SRFQ1.

There are some design constraints in the superconducting RFQ, as follows;

(1) Low magnetic field on the surface (<300 Gauss),

(2) Mechanically stable structure,

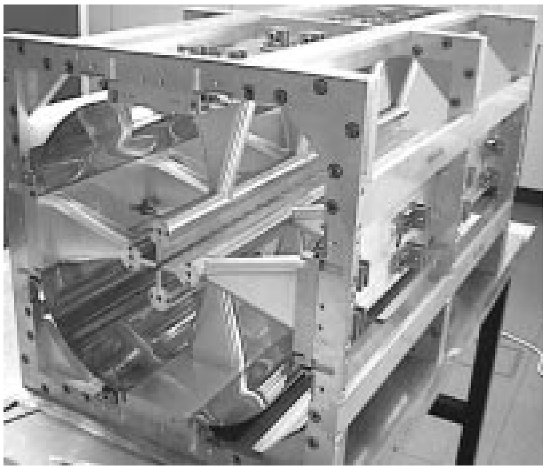

Figure 1. Half scale model of SRFQ1 made of aluminum except for the outer shell.

NUCLEAR SCIENCE RESEARCH FACILITY — Particle and Photon Beams —

Scope of research

Particle and photon beams generated with accelerators and their instrumentations both for fundamental research and practical applications are studied. The following subjects are being studied: Beam dynamics related to space charge force in accelerators: Beam handling during the injection and extraction processes of the accelerator ring:radiation mechanism of photon by electrons in the magnetic field: R&D to realize a compact proton synchrotron dedicated for cancer therapy: Control of the shape of beam distribution with use of nonlinear magnetic field: and Irradiation of materials with particle and photon beams.

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(3) Small stored energy (<4 J),
(4) Short cavity length.
(5) Uniform field distribution along the beam axis,
(6) Good field balance among four quadrants (<1%).

The constraints (1), (2) and (3) are common problems to the superconducting cavity. The surface magnetic field should be well below the critical field of Nb at 4K (1). In order to feed RF power into the cavity, the resonant frequency should not shift (2) and the RF phase should be locked by the feedback control (3). The simulation results for the optimized geometry are shown in Table 1.

The condition (4) is a restriction from the fabrication. The components of the cavity are made of 3 mm thick niobium (Nb) sheet and they are assembled by the electron beam welding (EBW). The cavity geometry is limited by the available EBW machine. But the length of the SRFQ1 is 1378 mm, which is too long to perform the EBW. We decided to split the cavity into two sections. Each section is assembled separately and the outer shells of the two sections are finally welded by the EBW. The vane electrodes inside the cavity are still separated with 1 mm gaps.

The conditions (5) and (6) are general tasks for an RFQ design. We adopted the 90°-apart-stem RFQ structure [3]. It has a good field balance among the quadrants. Figure 2 shows the simulation results of the transverse electric field distribution along the beam axis. The broken line is a result in the original design. The big field steps exist at the vane cutting points. The solid line shows the field distribution when Nb strips are welded on the vane cutting point for the RF contacts. The field deviation becomes 0.3 %. Figure 3 shows the field distribution of the half scale model. It is measured by the standard bead-pull method. The split vanes are connected by Al strips and screws in the model. The field imbalance among the four quadrants is within ±0.8 %, which is induced by the misalignment of the vane electrodes. The total field deviation is within ±1.0 %. It is acceptable value from a point of view of the beam dynamics.

We have finished the cavity design of the SRFQ1 to satisfy the design constraints. The fabrication of the Nb components is in progress.

References

[1] G. Bisoffi et al., "Prototype of a Superconducting RFQ for a Heavy Ion Injector Linac", Proc. of the 1997 Particle Accelerator Conference, Vancouver

[2] A. Pisent et al., "Complete Simulation of the Heavy Ion Linac PIAVE", Proc. of the 1997 Particle Accelerator Conference, Vancouver

[3] V.A. Andreev et al., "90°-apart-stem RFQ Structure for Wide Range of Frequencies", Proc. of the 1993 Particle Accelerator Conference, Washington

Table 1. Main specification of the SRFQs and the simulation results

	SRFQ1	SRFQ2
RF Frequency [MHz]	80.0	80.0
Output energy [keV/u]	341.7	578.3
Vane length [mm]	1378.0	746.1
Stored energy [J]	2.1	3.6
E_{max} [MV/m]	25.5	25.5
B_{max} [Gauss]	249	241
Field variation [%]	0.3	0.5

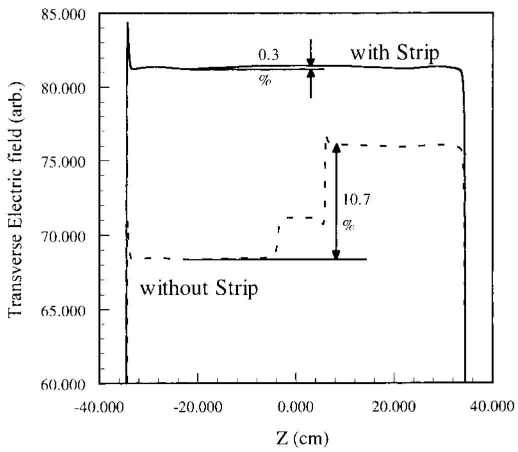

Figure 2. Simulation results of the transverse electric field distibution along the axis. The broken line corresponds to the original design. The solid line shows the field distribution with the Nb strips on the vane cuting points.

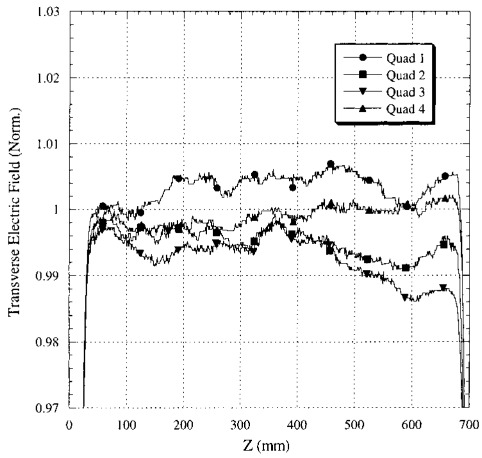

Figure 3. Field measurement results of the half scale model. The ordinate is the transverse electric field in four quadrants.