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Design and Test of a Superconducting RFQ for Heavy Ions*

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Abstract

A prototype SRFQ resonator optimized for a velocity of β=0.03 and a charge to mass ratio *(q/M)* of 1/6 has been designed, fabricated and tested. This is a short RFQ structure (only $2\beta\lambda$ long) operating at 57.4MHz. The resonator is made of copper, and a 1.5μm thick layer of electroplated Pb-2at.%Sn is used as the superconductor. The electrical characteristics of the resonator derived from detailed 3-D numerical simulations using the MAFIA codes, and also from measurements on the actual resonator are described. The multipactoring levels could be processed away with ease. Quality factor *(Q)* > 1×10^8 is obtained for E_a up to 1 MV/m. Other parameters relevant to superconducting operation are also presented.

1. Introduction

The Radio Frequency Quadrupole (RFQ) combines acceleration and focussing in one element, and is therefore very suitable for acceleration of low velocity ions. A normal conducting RFQ resonator, however, requires a high RF power. This makes a cw operation quite difficult. A superconducting RFQ (SRFQ) resonator could combine the advantages of the RFQ for slow ions with the cw operation and efficiency of superconducting linac structures. The design principles and possible application of the SRFQ as a linac injector were explored recently[1]. This paper briefly describes the design principles, and results of numerical and experimental studies of the characteristics of a prototype SRFQ resonator.

2. Resonator Design

The basic guidelines for our design were the use of the simple, low cost technology of lead (or lead-tin) plated on copper, the acceleration of very heavy ions (such as lead) with a charge to mass ratio (*q/M*) of 1/6 or better and the concept of the RFQlet, a short RFQ resonator. Unlike a conventional RFQ, a RFQlet is designed to accept a pre-bunched beam. It combines the advantages of RFQ focussing with a wide transit time factor curve, low stored energy, small size and flexibility of the independently-phased resonator

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the numerically calculated fields is shown by the crosses. The good agreement with the measurements is evident. The peaks on both ends are due to the fringe fields, which make a non-negligible contribution to the total acceleration. The progressive decrease in the peak fields of the cells is a result of increase in cell length as the beam accelerates along the structure. The bead perturbation shows a noticeable magnetic field at about ±0.1m from the center (see Fig.2). This is perhaps due to the proximity to the inductive support tubes. The transit time curve calculated from the measured field profile peaks at β=0.033 and acceleration in excess of 80% of the peak can be obtained for $0.029\leq \beta \leq 0.040$. The stored energy was calculated as 0.965J at 1MV/m acceleration field(E_a), defined as energy gain per unit charge divided by the total external length (58.5cm) of the resonator.

4. Pb Plating and Superconducting Tests

A 1.5μm thick layer of electroplated Pb-2at.%Sn is used as the superconductor. The resonator can, with an extension collar, was used as the vessel containing the electrolyte. Two L-shaped Pb sheets, and two 1.5 inch diameter hollow Pb pipes were used as anodes. A low current density of ~0.25mA/cm^2 was used to avoid any whiskers. Due to the large surface area involved (~19300cm^2), the entire operation was carried out in an inert atmosphere of dry nitrogen.

In the room temperature RF tests after the plating, several very low field multipactoring levels were seen. The lowest, and the most stubborn level was at E_a=0.94KV/m, and corresponded to an inter-electrode gap of 1.5cm, consistent with the minimum aperture. All the levels could be cleaned with RF processing (maximum of 1.5KW peak/150W average RF power) in about 48 hours. Some higher levels (E_a=60 and 80KV/m) showed up at LHe temperature, but could be quickly processed away. Multipactoring therefore is not a serious problem even with the complex geometry of this resonator. This is a very significant result from the point of view of practical operation of a SRFQ.

Mechanical stability of the resonator is an important requirement for superconducting operation. The resonant frequency excursions due to vibrations was measured to be ~60Hz (peak-to-peak) with considerable disturbance coming from a rather noisy mechanical pump. The frequency excursions reduced to ~20Hz with the pump isolated. These stability figures are reasonable, though not as good as the best linac structures. In principle, the structure could be improved by dampening the mechanical Q. The resonant frequency variation due to the LHe pressure change is 160Hz/psi.

The Q as a function of E_a was measured in a standard fashion using a phase locked loop and critical coupling. The resulting curve is shown in Fig.3. The low field Q is 1.5×10^8 and remains above 1×10^8 up to E_a =1MV/m, achieved with only 3W of RF power. It begins to drop sharply after this (circles in Fig.3). Considerable improvement was made by helium conditioning (squares in Fig.3). Processing with a high power RF

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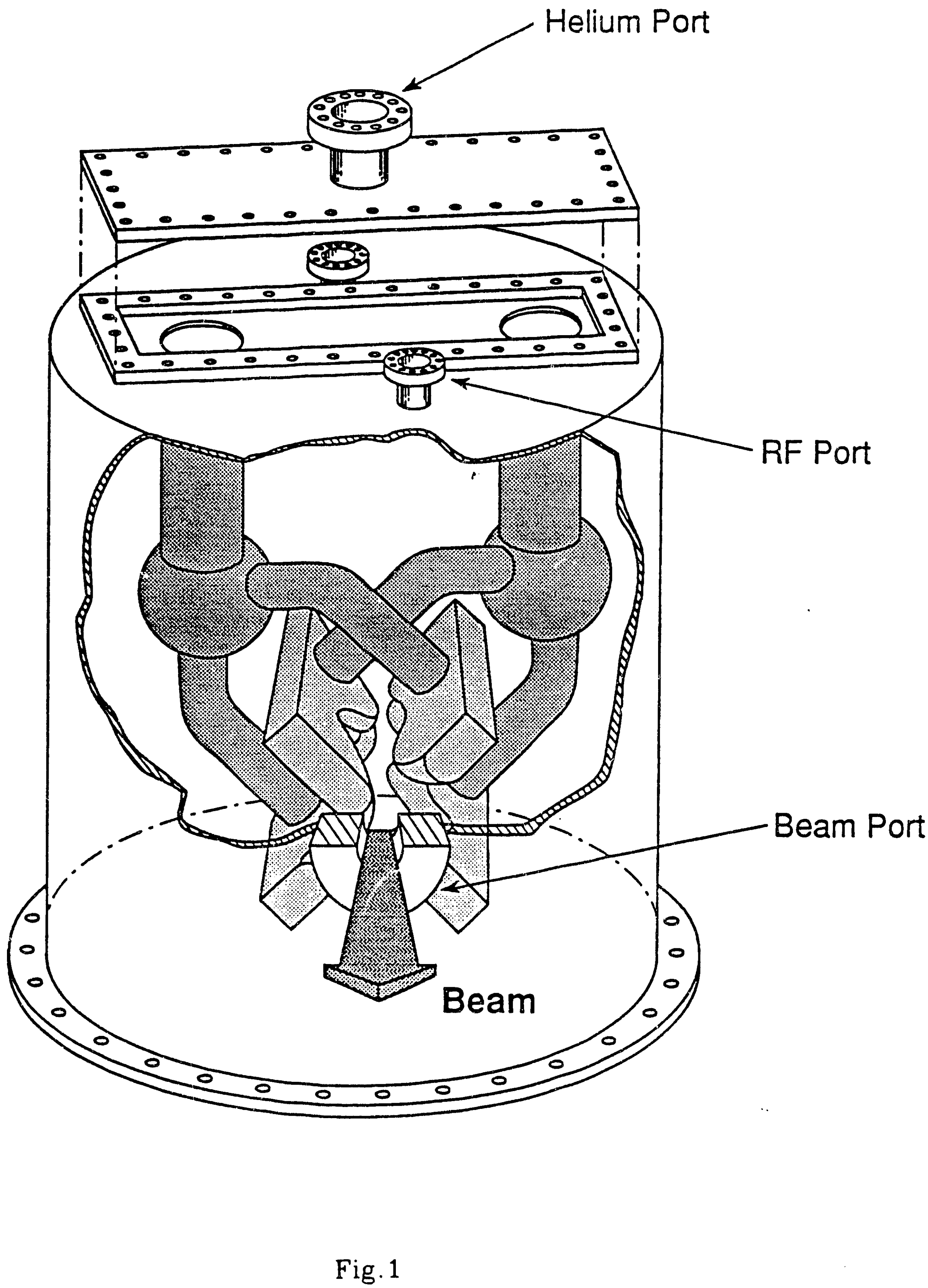
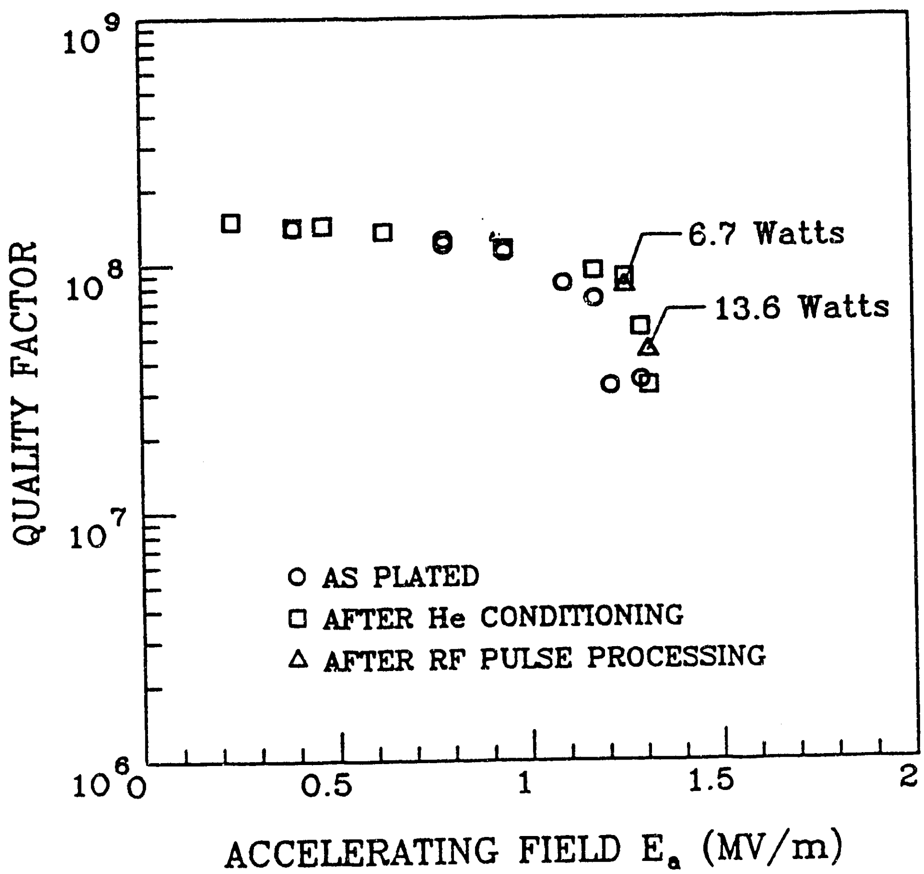


Fig. 1



QUALITY FACTOR
10^9
10^8
10^7
10^6
0
0.5
1
1.5
2
ACCELERATING FIELD E_a (MV/m)
6.7 Watts
13.6 Watts
AS PLATED
AFTER He CONDITIONING
AFTER RF PULSE PROCESSING

Fig.3

END

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