PROTON ACCELERATION TESTS ON THE 4-ROD RFQ & QWR

Hiroshi Fujisawa
Ion Equipment Div. Nissin Electric Co., Ltd.

Yoshihisa Iwashita and Hidekuni Takekoshi
The Institute for Chemical Research, Kyoto University

Abstract

A quarter wave resonator (QWR) was constructed as a post-accelerator of our 4-rod RFQ [1]. It has twin-gap structure and designed to operate at 100MHz, whict was the resonant frequency of the RFQ. The effective shunt impedance of the QWR was calculated to be 1.2 M ohm and the measured unloaded Q value was approximately 1300, 60% of the theoretical estimate. By adjusting the phase relationship of the two resonators ,the beam energy was observed to be varied by 10% at 200 W RF power into the QWR.

Introduction

One of the disadvantages of RFQ is the fact that we don't know how to vary the beam energy . This must be circumvented, for instance, by adding a post-accel/decel structure to the RFQ in order to make it commercially more attractive accelerator component. We have chosen a QWR for such application because it has simple structure and can be built at low cost. The geometrical parameters were checked with a cold-model and a hot-model was constructed and tested in our 4-rod RFQ proton acceleration test-stand.

QWR

The geometrical parameters of the QWR were chosen such that the structure can be built with easily available copper materials. We checked the length-frequency relationships with the cold model. Fig.1 shows the results. "Length" is the measured distance between the center of the drift tube and the position of the movable short plunger and "C_p" was approximated with the capacitance of the parallel conducting discs . The resonant frequency was measured with a network analyzer. Notice how well The results fit with the well known equation [2] :

$$\frac{1}{2\pi\cdot f_{res}\cdot C_p} = Z_0\cdot\tan(2\pi L/\lambda)$$

,where f_{res} : Resonant frequency (Hz)
C_p : Load capacitance (F)
Z_0 : The characteristic imp. of the coaxial (ohm)
L : The length of the coaxial (m)
λ : **Wavelength in vacuum (m)**

Fig.2 is a schematic drawing of the QWR. The design parameters of the hot model are listed in table 1, along with the calculated values for the transit time factor, shunt impedance, and unloaded Q-value [3]. RF power was inductively coupled to the QWR at the shorted-end of the coaxial. Situated opposite to the drive loop is a tuner for the fine adjustment of the resonant frequency. The tuning range was about 200 KHz with 1.5 cm diameter loop. A-5-mm-thick-triangler-BN plate was inserted and fixed near the opening end of the coaxial. This arrangement made the alignment of the beam line easier and significantly reduced the fluctuation of the resonant frequency arising from the mechanical vibrations of the inner conductor

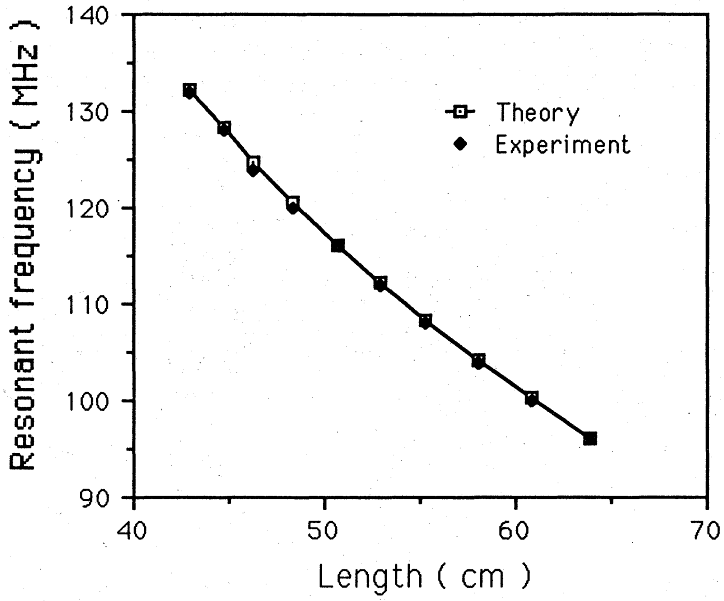

Fig.1: A plot of the resonant frequencies as a function of the coaxial length of the QWR. This is the results of a cold model.

Resonant frequency	100 MHz
Gap length, g	5 mm
Diameter of drift tube, dd	40 mm
Bore diameter, db	14 mm
Gap-gap Length, dg	21.9 mm
O.D. of inner conductor, d	12.7 mm
I.D. of outer conductor, D	46.8 mm
Length, L	640 mm
Width, W	83 mm
Transit time factor	0.821
Shunt impedance	1.2 M ohm
Unloaded Q value	2200

Table 1: Design parameters and the results of calculations of the QWR.

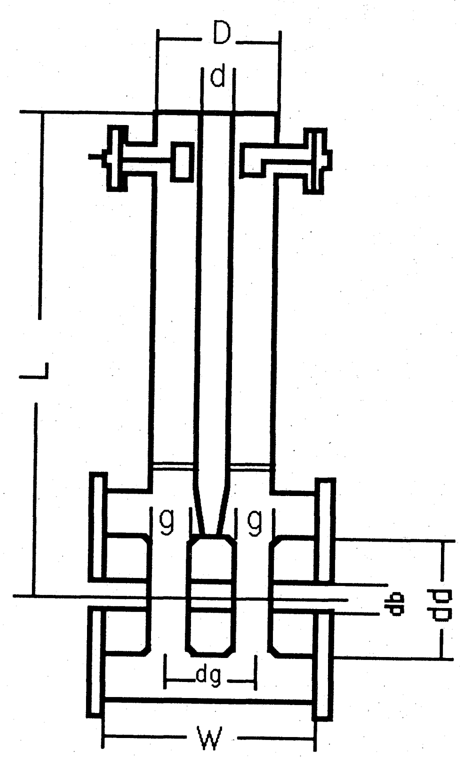

Fig.2: Schematic drawing of the QWR.

Test-stand

Fig.3 is a schematic drawing of the test-stand. The phase relationship of the RFQ and QWR was varied by adjusting the voltage-controlled phase shifter and monitored with an oscilloscope. A stub-tuner matched the impedance between the final stage amplifier (F.S.A.) and the QWR. A typical VSWR was 1.7 at 200 W input. We added an electrostatic Q-triplet lens at 5 cm downstream of the exit of the RFQ to match the beam. The Beam energy was measured with a high resolution magnet analyzer and the beam current was detected with an electrostatically-shielded Faraday system.

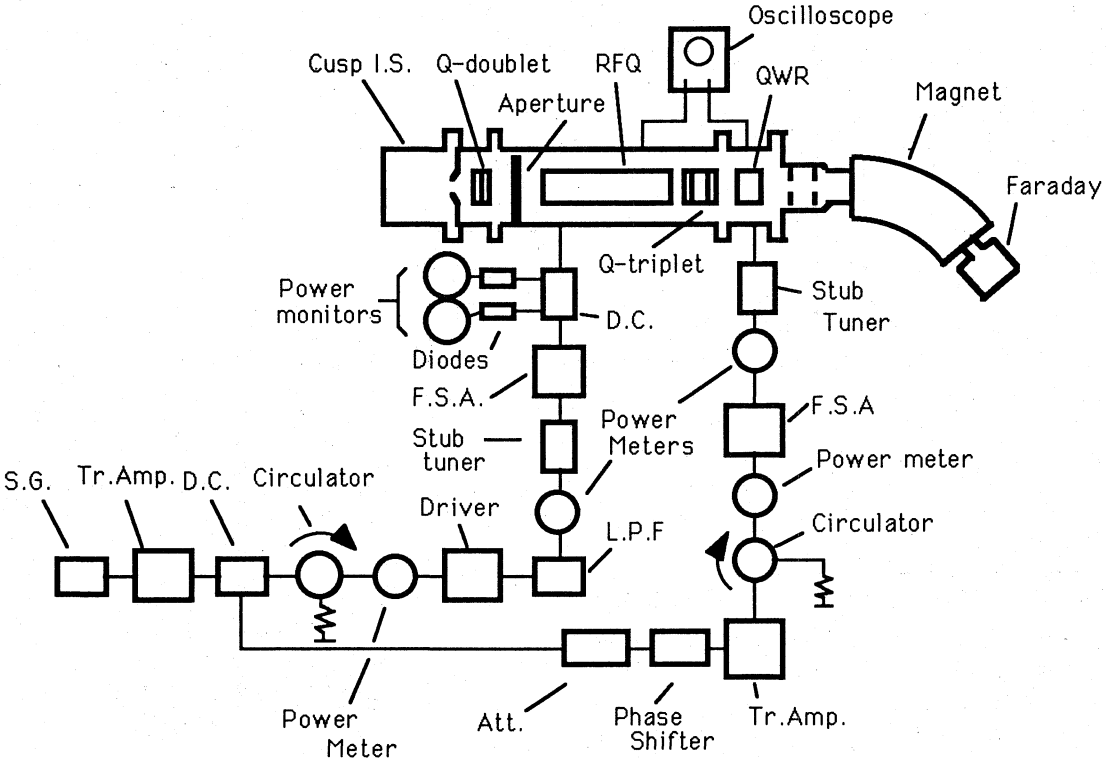

Fig.3 : Schematic representation of QWR test-stand.

Results

Fig.4 shows a typical momentum spectrum of the proton beam at "In-phase" (0 deg.) and "Out-of-phase" (180 deg.) situations in one excitation condition of the QWR. The reference corresponds to the beam energy at the output of the RFQ, normally 100KeV. The beam energies of the peak intensity were determined from the spectra and the absolute values of the energy gain were plotted in fig.5 along with the theoretical ones .

Since the drift length between the Q-triplet and the QWR is rather long (about 70 cm) in our test-stand, we expect that a beam-bunch spreads out as it reaches the QWR. A simple calculation shows that this would correspond to the phase broadening of 140 deg. for 5% initial energy spreads (FWHM) at the RFQ exit. If the beam is " rectified " completely to DC, the momentum spectrum would look like a "twin-peaked" one as described in Ceperley's paper [4]. A QWR should be placed right next to the RFQ ,however, we didn't go further to study this arrangement because of the physical limitations of the test-stand.

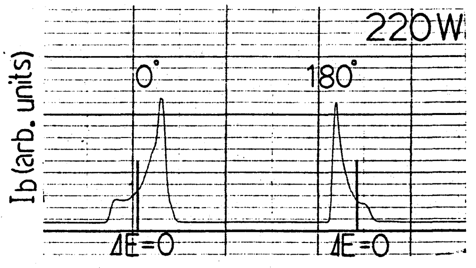

Fig.4: A typical momentam spectrum of the output beam of the QWR . 220 w RF power is delivered into QWR in both "in-phase" (0 deg.) and "out-of-phase" (180 deg.) situations.

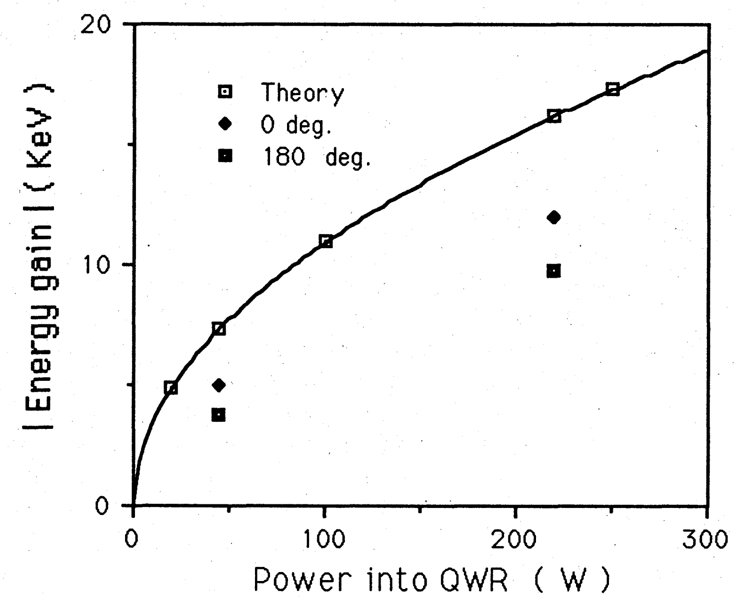

Fig.5: Plot of the absolute energy gain as a function of the input power to the QWR. The theoretical curve is determined from the shunt impedance, 1.2 M ohm.

References

[1] T.Ogawa and Y.Iwashita, "Model Study of a 4-Rod Structure of RFQ Linac", Bull. Inst. Chem. Res., Kyoto Univ., 65 (1987).

[2] I.Ben-Zvi and J.M.Bernnan, "The Quarter Wave Resonator as Superconducting Linac Element", Nucl. Instr. Meth., 212, 73-79(1983).

[3] Ibid.

[4] P.H.Ceperley et al., "Beam Tests of a Super Conducting Niobium Cavity for a Heavy Ion Accelerator", Nucl. Instr. Meth., 136, 421-423(1976).