RF Characteristics of 433 MHz RFQ

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Abstract

RF high power tests of the RF-Quadrupole linac at Kyoto University are carried out. In these tests, the vane voltage and electric field distribution are measured. The present paper describes the RF system of the RFQ and the test results.

1. Introduction

At Kyoto University, we have developed the RF-Quadrupole linac (RFQ) (1). This RFQ is a four vane type and its operating frequency is chosen at 433 MHz for compactness and high efficiency. The output energy is 2 MeV and it is injected to a drift tube linac operated at the same frequency. Accelerating ion species are H^+ and H^-. Both the ion sources are multicusp field type and have been tested. The parameter of the RFQ is shown in Table 1. A low power measurement and a field tuning of the RFQ cavity had been already reported(2). We carried out the high power test of the RFQ cavity.

Output energy	2.0 MeV
Operating Frequency	433.3 MHz
Vane length	2195 mm
Minimum bore radius	2.0 mm
Intervane voltage	80 kV
Maximum electric field	1.8 Kilpatrick
Q value	4900

Table 1 Parameter of the RFQ linac

2. RF system of the RFQ

Figure 1 shows a block diagram of the RF system for the RFQ linac. A klystron is available as the power source of the RFQ because of its high operating frequency. The operation parameters of the klystron (L5773) are given in Table 2.

An RF power from the klystron goes through a waveguide (WR 2100) and couples into the RFQ cavity by a loop coupler. This coupler is movable longitudinally and set at the critical coupling.

Frequency	433.3 MHz
Peak RF power	1.2 MW
RF pulse width	60 μsec
Maximum repetition	180 Hz
Maximum duty factor	1 %
Beam voltage	90 kV

Table 2 Operating parameter of the klystron (L5773)

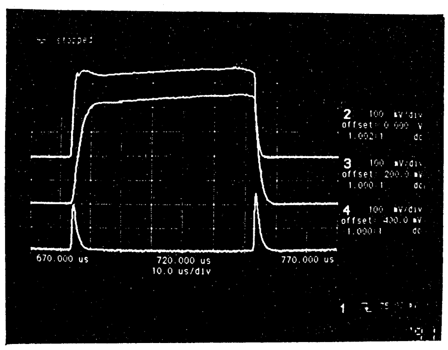

Figure 2 Wave form of the RF pulse. The input power, the stored power and the reflection power in the RFQ (top to bottom).

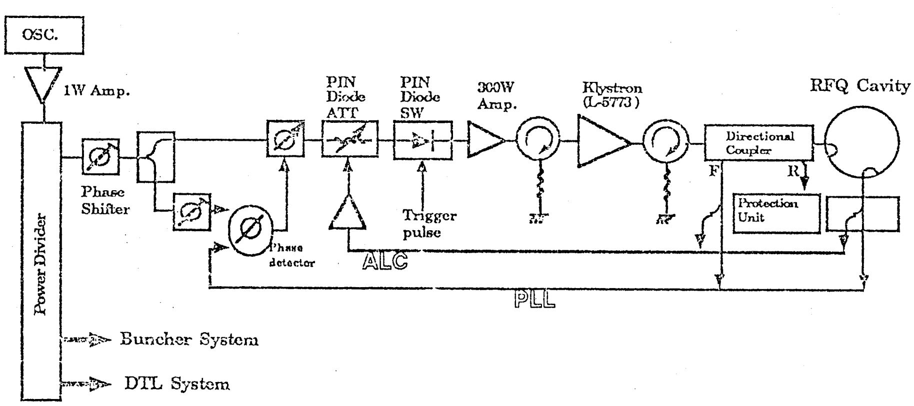

Figure 1 Block diagram of RF system for the RFQ

3. High power feed test

For the RF conditioning of the RFQ cavity, we started to feed the power at the low repetition rate (18 Hz) with 60 μsec pulse width and gradually increased the peak power level.

The input and reflection power of the RFQ were picked up by directional coupler (-60 dB coupling) and measured by the oscilloscope through an RF detector. Figure 2 shows the wave form of the RF pulse at the input RF power of 530 kW. We set mirrors on the beam line chamber before and after the RFQ to observe the discharge light in the RFQ and monitored by a video cameras.

Figure 3 shows the feedable RF power to the RFQ cavity as a function of time. The vacuum pressure was 1.0×10^{-6} torr at the center of the cavity. Finally we succeeded to feed the 600 kW power to the RFQ after the 25 hours. But much longer time was required so that the discharge was almost stopped.

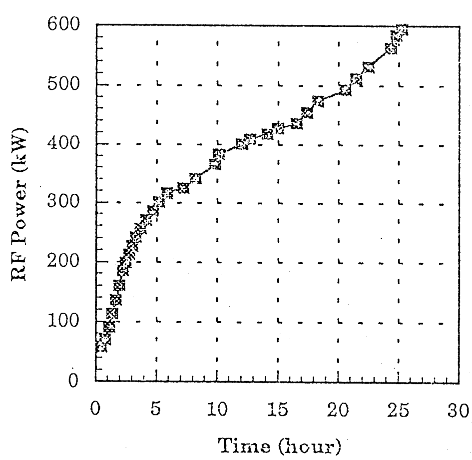

Figure 3 RF power limit as a function of time

4. X-ray measurement

The operating frequency of the RFQ is so high (433 MHz) that it is difficult to measure the vane voltage directly. We used the method of an X-ray energy spectrum measurement. Almost of the X-ray from the RFQ is supposed to be the bremsstrahlung of the electron which is emitted by the electric field on the vane surface. So the maximum energy of the X-ray is corresponded to the vane voltage . The X-ray energy spectrum is measured by a pure-Ge counter. Figure 4 shows the measured energy spectrum of the X-ray with the input power of 530 kW. A stainless steel plate is put in front of the detector to avoid pile up by the low energy X-ray.

Figure 5 shows the relation between the input RF power and the vane voltage which is estimated by the method. The horizontal axis shows square root of input RF power. The design vane voltage (80 kV) is attained at 530 kW RF power. The required power estimated from SUPERFISH[3] result and the measured Q-value, is 540 kW, which is consistent with this experiment.

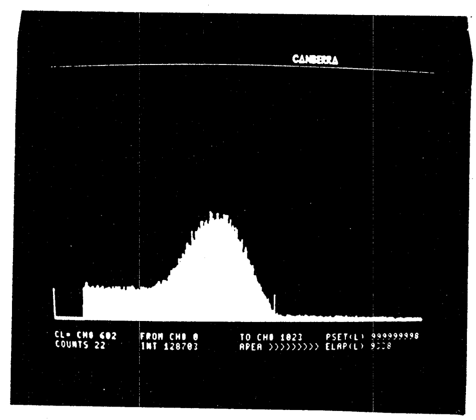

Figure 4 Energy spectrum of the X-ray

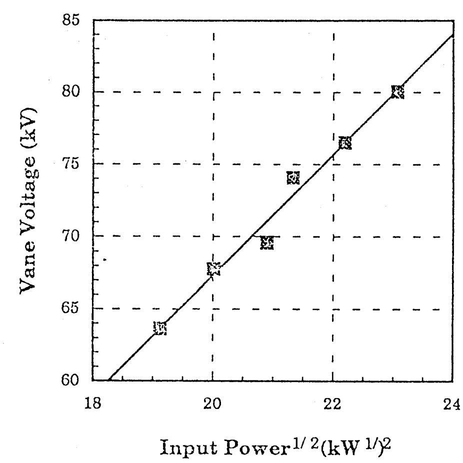

Figure 5 Measured vane voltages with the various RF powers

5. Electric Field Distribution

An electric field distribution and a resonant frequency in the RFQ cavity must be stable at the high power operation. We measured them with the various RF power and duty factor.

In our RFQ, a tuning of the electric field distribution was attained by 24 side tuners. The distribution was measured by the bead pull perturbation method and 24 pickups at a low RF power. The pickup outputs were calibrated by the result of the perturbation measurement. The deviation of the distribution was within ± 3.5 %. [2]. At the high power test, we monitored the field distribution by the pickups.

Figure 6 shows the transverse field distribution as a function of time. The pulse width of the input RF was 60 μsec. The RF power was increased from 200 kW to 500 kW and the repetition rate was also increased from 18 Hz to 180 Hz. The four pickups are located at each 4 quadrant and at the center of the cavity. Figure 7 shows the longitudinal field distribution as a function of time in the same condition. The six pickups are located at the same quadrant. A large deviation of the two pickup outputs (z=2, z=3) in the figure 7, was caused by the trouble of RF relays in the pickup monitor system. From the results, no dependence of the field distribution was found on the RF peak power and duty factor.

At the beginning and end of the experiment, the resonant frequency was changed -19 kHz. In this case, the feed back control of the cooling water temperature wasn't utilized and the cooling water temperature rose 1.6 °C. Because the resonant frequency change by the cooling water temperature was -8 kHz/°C , this result was reasonable.

6. Summary

We succeeded to feed RF power to attain the 80 kV vane voltage . We also confirm that the distribution of the field is stable at the high power. We are planning to test the control of the RF amplitude (ALC) and phase (PLL).

References

(1) Y.Iwashita et al., Proc. of '90 Linear Accel. Conf. (1990) 746.

(2) H.Okamoto et al., Proc. of '89 Linear Accel. Meeting in Japan (1989) 746.

(3) K.Halbach and R.F.Holsinger, Particle Accelerators 7 (1976) 21

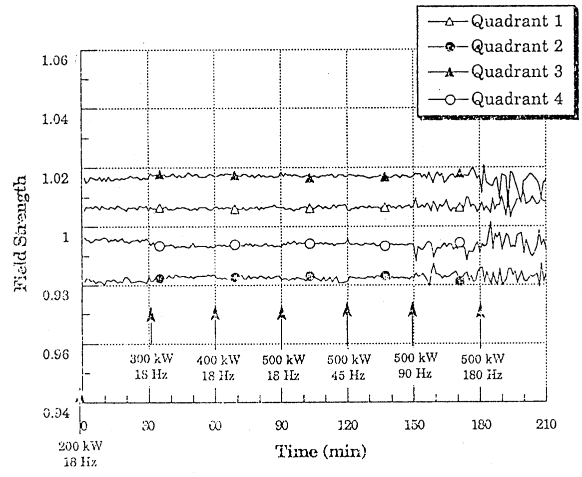

Figure 6 Transverse field distribution normalized by a mean value as a function of time

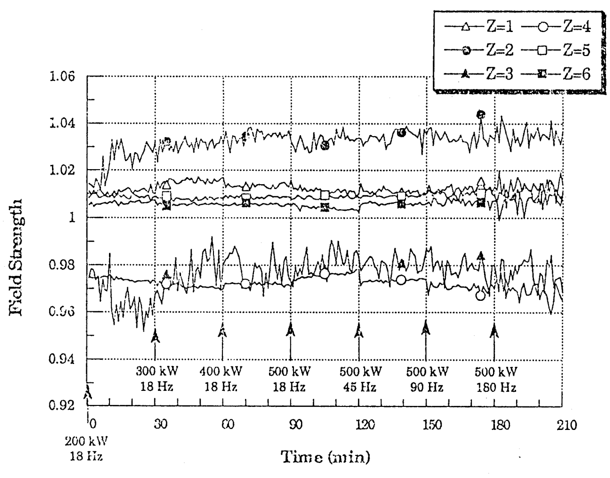

Figure 7 Longitudinal field distribution normalized by a mean value as a function of time