A RF system for the BTA

Y.TOUCHI, * M.MIZUMOTO, K.OHTOMO, Y.FUKUMOTO,
K.HOSHIKA, S.TATUMI, Y.KUMATA, H.MURATA
Sumitomo Heavy Industries, LTD
Niihama, Ehime 792, JAPAN
* Japan Atomic Energy Research Institute
Toukai, Ibaraki 391-11, JAPAN

Abstract

A RF system was designed to generate 1MW peak power (pulse width is 1.2ms and repetition rate is 100Hz) at 201.25MHz for the Basic Technology Accelerator (BTA). A tetrode of EIMAC 4CM2,500KG is used for the final amplifier. Both the input and the output circuits are 3/4 wave length coaxial cavities.

The peak power of 1MW at 0.6% duty and 830kW at 12% duty was obtained in a high power test using with a dummy load. Combining a RF system with an ion source and a RFQ linac, 2MeV proton beam of 52mA peak current was accelerated successfully.

1. Introduction

The first step of the JAERI OMEGA (Options Making Extra Gains of Actinides and Fission Products) project, the research and development works for the BTA, has been carried out[1]. The BTA consists of a radio frequency quadrupole(RFQ) linac and two drift tube linacs(DTL). Figure1 shows a block diagram of the BTA RF system.

In the case of high current beam accelerating, the beam loss might cause a serious problem, like induced radiation and heavy sparks by heating up of the accelerating electrode. The required phase and voltage stability are +/-1° and 0.1% respectively, so as to maintain sufficient beam transmission.

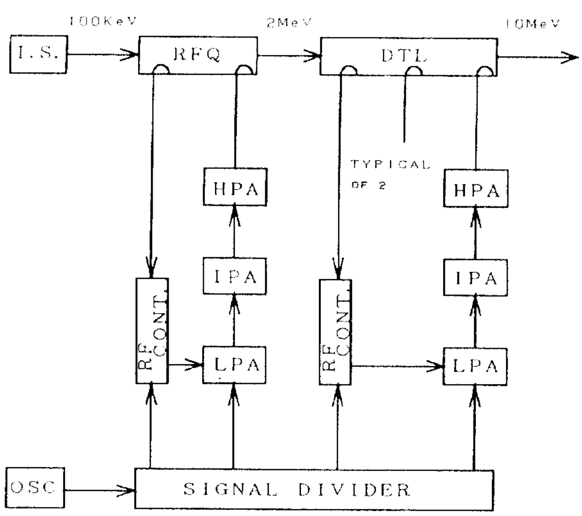


Fig.1 BTA RF system

The RF system for a high current beam acceleration is described. Results of beam accelerating test, combining the RF system with an ion source and a RFQ linac, are also described.

2. High power amplifier

The amplifier chain is composed of three stage amplifiers. The 1st stage is a solid state amplifier. The 2nd stage is a tetrode amplifier with SIEMENS RS2058CJ. The final stage is tetrode amplifier with EIMAC 4CM2,500KG. We describe a final stage amplifier(HPA) in this section.

We use EIMAC 4CM2,500KG power grid tube for the final stage amplifier to achieve the maximum peak power of 1MW at 201.25MHz. This tube had been tested at JAERI with using a modified JT-60 ICRH amplifier, and had achieved 1.7MW at 131MHz during 5.4 seconds[2]. In our case, however, the frequency is much higher than this test, then the additional RF heating on the screen grid might cause excessive out gas in the tube and finally the tube can be broken. The RF heating on the screen grid is proportional to the 2.5 powers of frequency. We had calculated this phenomenon and decide the operating condition in cooperation with EIMAC engineers. Table 1 shows the calculated parameter and the test result, upper is calculated value and lower is test result. The vacuum condition of the 4CM2,500KG, under the operation of 850kW 12% duty, was below $2x10^{-7}$ Torr. This value is much lower than the limited value of $3x10^{-5}$ Torr.

Table 1
Operating parameter of 4CM2,500KG

Ep kV	Ip A	Eg2 kV	Ig2 A	Eg1 V	Ig1 A	Pout kW	gain dB
18	89	1.1	1.3	-400	3.4	1000	13.7
18	92	1.2	3.6	-350	3.4	997	12.6

upper is design value, under is experimental data

A photo of the HPA without outside panels is shown in Figure2. The HPA is designed to operate in grounded grid configuration. Both the input and the output circuits are 3/4 wave length coaxial cavities. 4CM2,500KG is located on the top of the output cavity for an easy maintenance.

The electric field of the output cavity estimated with using a three dimensional simulation program (MAFIA) is shown in Figure3. The electric field is maximum at a corner, then we designed a corner radius to avoid arcing. When we operate 4CM2,500KG in 14kV of the anode rf voltage, the maximum electric field is about 0.6MV/m. A self oscillation near 1GHz had been reported in the ICRH amplifier. Some ferrites are often installed in the output cavity to deterrent the oscillation. In our case, however, it is difficult to use a ferrite for dumping the higher mode frequency's component without dumping the fundamental frequency's (201.25MHz). Then we made long and slender holes on the shorting plate and the upper plate of the output cavity. Any oscillation had not been observed during a dummy load test and a beam accelerating test.

The G1-G2 circuit is designed to minimize the feedback voltage from the anode to cathode, so as to realize a stable operation. We measured the isolation value from the anode to cathode with changing the position of the shorting plate of the G1-G2 circuit. The isolation was changing from 20dB to 40dB. We adjusted it in the best position, and achieved a stable operation of 4CM2500KG in a power test.

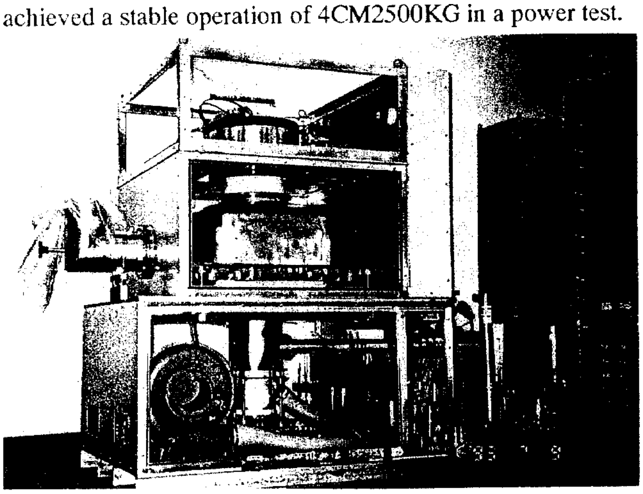


Fig.2 Photo of the HPA without out side panels

3. RF control system

The voltage and the phase stability, during the acceleration of the beam, should be controlled to 0.1% and +/-1° respectively. The beam loading in the RFQ linac is about 200kW. In consideration of such a high beam loading, we designed the RF control system. This RF controller has an analog feed-forward circuit combined with an analog feedback circuit. The simplified schematic drawing of the RF control system is shown in Figure4. The RF control system is composed of a voltage control circuit, a phase control circuit and an auto frequency control circuit.

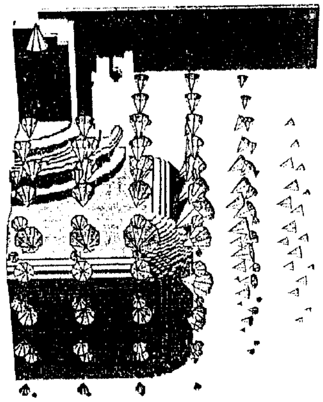


Fig.3 Electric field of the output cavity

The phase control circuit and the voltage control circuit can be disturbed each other, if we try to control both parameter at the same time. We designed the phase control circuit so as to avoid this kind of trouble. The base control voltage of phase is hold in the last pulse, and then add the error component refer to the reference value during present pulse.

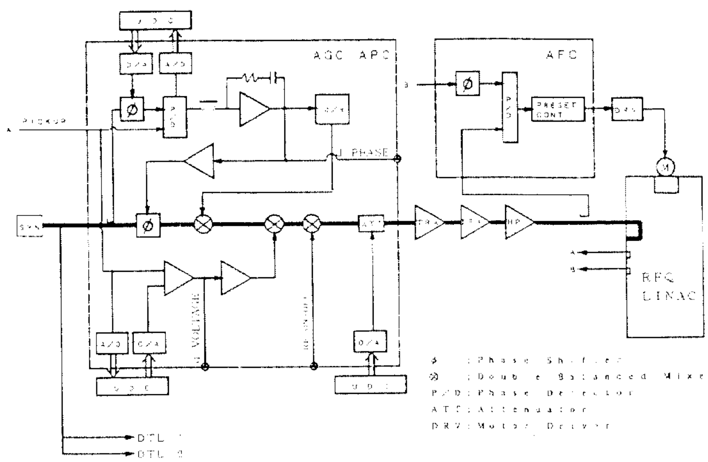


Fig.4 RF control system

4. Power test

We tested the amplifier combining with a dummy load before feeding power to the RFQ linac. The peak power of 1MW at 0.6% duty and 830kW at 12% duty were obtained. The 1MW operation is limited below 0.6% duty, because arcing in the output cavity was happed after about 20 minute operation. We are inspecting this phenomenon and will try some modification.

The high power test was performed to feed the sufficient power into the RFQ. In the early stage of operation, however, the multipactoring occurred on the RF coupler, and the insulating ceramics was broken. The value of f(MHz)xl(cm) between the kovar and the inner surface happen to satisfy a

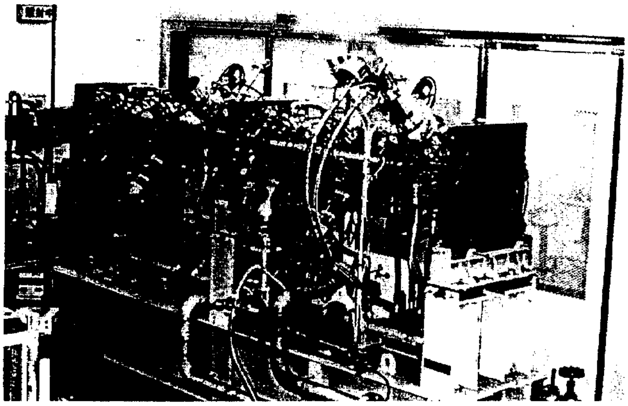


Fig.5 Photo of the RFQ

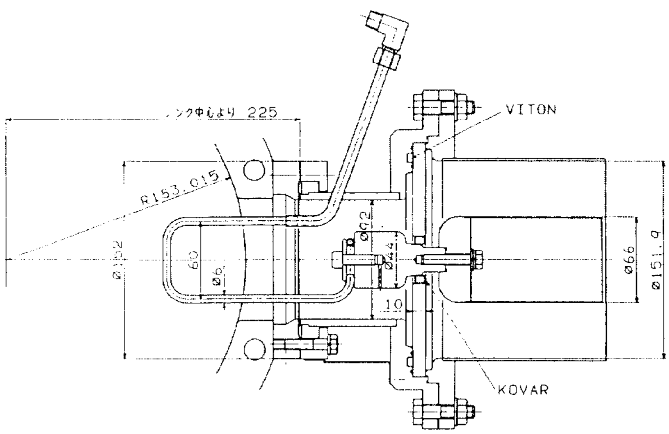


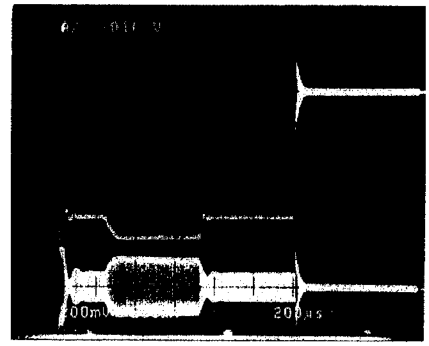
Fig. 6 Drawing of the first RF coupler

most serious condition (fxl=140). Then we modified the structure of the RF window and used a viton O ring in place of the metallize vacuum seal. The photo of the RFQ is shown in Figure5, and the drawing of the first RF coupler is shown in Figure6. The sufficient power for the RFQ, to generate an accelerating voltage and to compensate the beam loading, had been delivered through the modified RF window successfully.

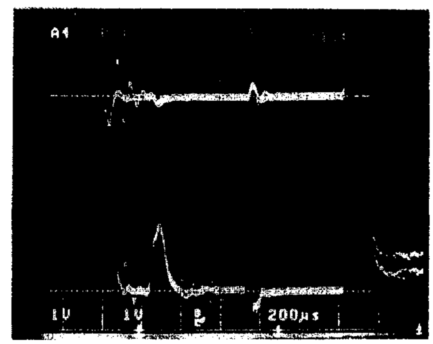
5. Beam test

52mA proton beam was accelerated to 2MeV in the beam accelerating test combining the RF system with an ion source and the RFQ linac. We confirmed a behavior of the RF system, and investigated the influence of the beam loading for the HPA. Figure7-1 shows a out put power of the HPA measured with directional couplers. Figure7-2 shows a voltage error signal and phase error signal. Since the beam current was a half of the design value, the HPA generated an additional power of 95kW for the beam loading, and kept a stable operation. The beam transmission was not measured correctly.

The feed-forward circuit was not used in this test. The delay for stabilizing a voltage level and a phase error is 50 micro second and 150 micro second respectively. As we say previously, in the case of high current beam acceleration, the beam loss cause a serious problem like induced radiation. We are going to test the feed-forward circuit to make the delay time minimal, and then achieve better beam transmission.



(Beam loading = 95kW)
Fig.7-1 Out put power of the HPA



(1% / div , 3° / div)
Fig.7-2 Voltage and Phase error signals

6. Conclusion

We have succeeded to accelerate the proton beam of 52mA, a half of the design value, by the RFQ linac combining with the RF system.

We are going to solve the arcing problem in the HPA and to test the feed-forward circuits, so as to achieve the full beam current test (100mA) in JAERI. We expects the full beam current test will be carried out by this November.

7.References

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