Rf Performances of Superconducting Resonators for the JAERI Tandem Booster

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Abstract

Performance tests for the superconducting resonators of the JAERI tandem booster had been accomplished. In off-line tests, we obtained the maximum electric field gradient of over 10 MV/m and the averaged accelerating field gradient of about 7 MV/m at an rf input power of 4 W. We obtained better performances of newly tested 8 resonators than those of previously reported 20 ones. In this summer, all cryostats were set on the beam line. All resonators were cooled down by two refrigerators and 16 resonators were tested. The Q-degradation occurred to some resonators. But, the averaged field gradient at an rf input power of 4 W was about 5 MV/m.

§1. Introduction

The JAERI tandem booster is composed of 44 superconducting quarter wave resonators(QWRs) of which resonant frequency is 129.8 MHz. In April 1992, the fabrications of the rest of 24 resonators and 6 cryostats had been accomplished and delivered to JAERI. A performance tests of refrigerators had been made and the refrigeration powers had been confirmed. From the end of 1992 to the beginning of 1993, surface treatments by electro polishing for the 24 resonators had been finished. Eight of them were tested at 4.2 K. In this summer, the resonators were cooled down by refrigerators and 16 of them were tested at about 4.5 K.

§2. Surface treatment

The QWRs were manufactured by Mitsubishi Electric Corp. After delivered to JAERI, surface treatments were made. The niobium surfaces of resonators were electro-chemically polished about 10μm. They were rinsed with 15% HF, 10% H_2O_2 solution with supersonic tremors for about 30 min and de-ionized water(18MΩ·cm) with supersonic tremors for more than 60 min. In a clean room, they were sprayed with de-ionized water(18MΩ·cm), rinsed with methanol and dried up naturally with warming to 35~40°C.

In order to get out hydrogen generating from the polishing solution as fast as possible and to decrease the absorption of hydrogen into niobium surface, the nitrogen gas was fed into the polishing solution to rise in bubbles for the

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resonators with the identification number from 17 to 40.

§3. RF performances

3-1 Off-line test

Eight of newly delivered 24 resonators were tested. In off-line tests, the resonators were put in the cryostat for off-line tests one by one. The resonator was baked at a temperature of about 70°C while the cryostat was evacuated for a few days. The resonators were precooled by liquid nitrogen to about 80 K and cooled down to 4.2 K as fast as possible. It took about 5 hours to cool down the resonators to 4.2 K from room temperature.

A typical Q-E_{acc} curve is shown in Fig.1, where the E_{acc} means the accelerating electric field gradient. The distributions of the maximum electric field gradient($E_{acc-max}$) and accelerating electric field gradient at an rf input power of 4 W are shown in Fig.2(a) and 2(b), respectively (the results in 20 resonators had been already reported in the last workshop[1)]). The values of $E_{acc-max}$ exceeded 10 MV/m in 13 resonators and reached 12.7 MV/m in the no.17 resonator. Most of 8 resonators reached their maximum field levels without high power pulse conditioning or helium processing. The value of $E_{acc}(P_{in}=4W)$ was obtained about 7 MV/m in average. The values of $E_{acc}(P_{in}=4W)$ for the newly treated resonators having identification numbers of between 17 and 40 are higher than those of previously reported ones. The bubbling of gaseous nitrogen is possibly effective method for our resonators to avoid the absorption of hydrogen.

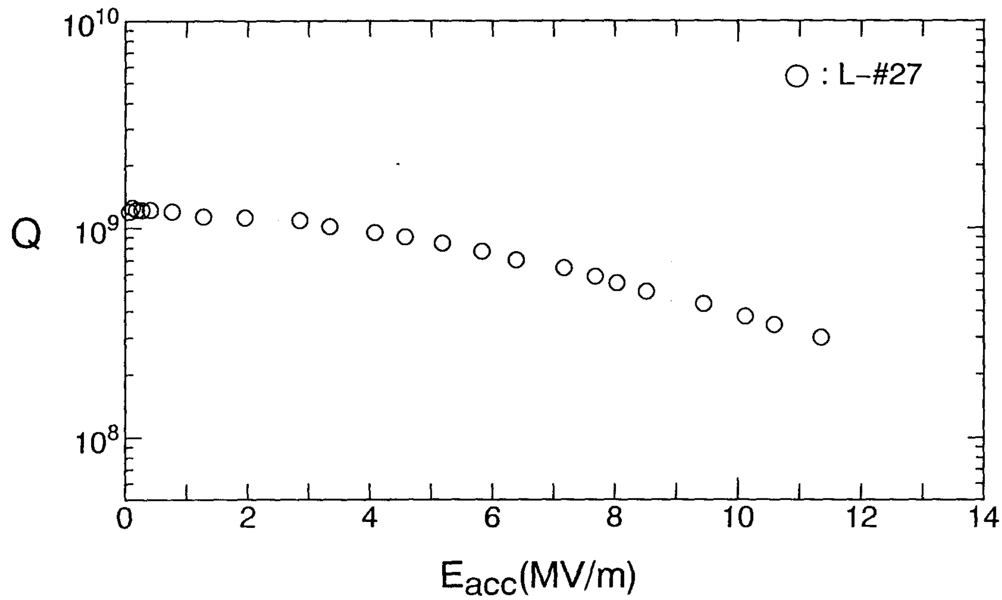

Fig.1 A typical Q-E_{acc} curve of the QWR(no.27) for the JAERI tandem booster.

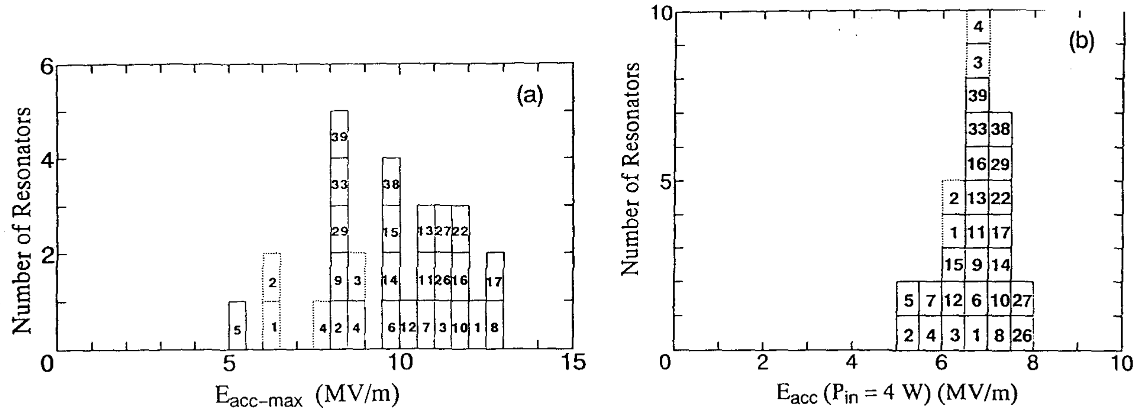

Fig.2 Resonator performances at 4.2 K.
(a) Maximum electric field gradients. (b) Accelerating field gradients at an rf input power of 4 W. Enclosed number is the identification number of the resonator. Numbers enclosed with dotted line are for the buncher and debuncher.

3-2 Q-degradation

The Q-degradation in niobium cavity has been well known.[2)] We investigated this phenomenon with a resonator(no.3) by changing the holding temperature and the holding time. The cooling schemes are shown in Fig.3. We found the followings.

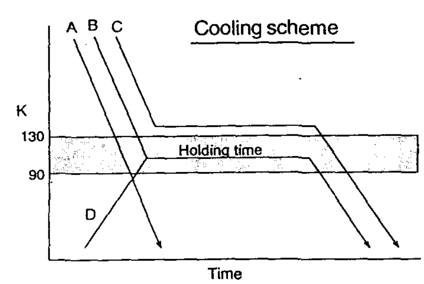

Fig.3 Cooling scheme in thermal cycle.

i) The Q-degradation was not observed by a fast cooling(A).
ii) When the resonator was cooled down to a intermediate temperature of >130 K or < about 90 K, Q-degradation did not occur(C).

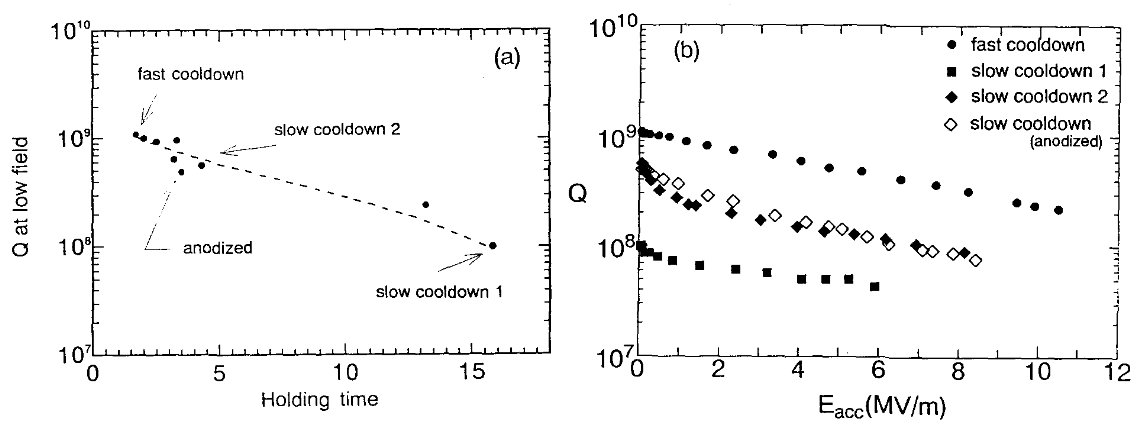

Fig.4 Q-degradation on cooling between 130 K and 90 K.(a) Q-value at low electric field are plotted against the holding time between 130 K and 90 K. These data were obtained with no.3 resonator. (b) Q-E_{acc} curves in thermal cycle.

iii) When the resonator was held at a temperature between 130 K and 90 K, Q–degradation occurred(B,D) and the degree of degradation increased according to the holding time as shown in Fig.4(a),(b).

When the resonator of which surface was anodized by 1 % NH_4OH solution to have about 1000 Å Nb_2O_5 layer was hold about 4 hours in the dangerous temperature region, a Q–degradation was still observed. The anodized layer could not avoid the Q–degradation in this resonator.

3–3 On–line tests

We have equipped two identical refrigerators for the booster. The specifications of the refrigerators are described in the other paper[3] in this workshop.

In a test run, it took about 24 hours to precool the radiation shields to 150 K, took about 36 hours to cool down the resonators and the liquid helium vessels to 4.5 K and about 12 hours to fill the liquid helium vessels in the cryostats with liquid helium. Moreover, it took about 12 hours to fill the vessel in the no.5 cryostat. We needed to adjust the helium flows by the remote controlled valves so as to cool down all cryostats as simultaneously as possible.

We tested 16 resonators at 4.5 K. The results are shown in Fig.5. Severe Q–degradations occurred to some resonators in the first four cryostats, but, not occurred so much in the last six cryostats. It took about 3.5 hours to cool down from 130 K and 90 K for the last five cryostats, while for the first five cryostats, it took about 4 hours. The resonators with identification numbers from 17 to 40 were electro–polished with N_2 bubbling. The two conditions are possibly effective to avoid the Q–degradation. The resonators in the upper stream part were polished more times than those in the down stream part. Times of polishing also possibly concerned the degradation. The buncher, de–buncher and the resonators having earlier identification numbers might not be kept in good condition. The averaged value of $E_{acc}(P_{in}=4W)$ was about 5 MV/m of design value.

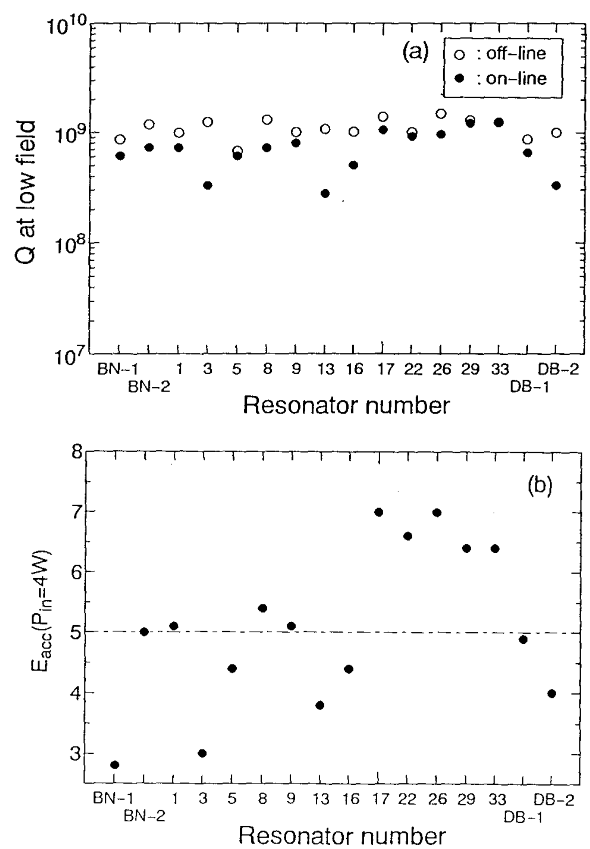

Fig.5 Resonator performances at 4.5 K. (a) Q–value at low electric field. (b) Accelerating field gradients at an rf input power of 4 W.

§4. Summary

We obtained good performances of QWRs from off-line tests. The accelerating field gradient at an rf input power of 4 W reached 7 MV/m in average. A dangerous temperature region which cause Q-degradation exists between about 130 K to 90 K in one of our resonators. The Q-degradation was observed in some resonators when the resonators were cooled down by the refrigerators, however, the averaged $E_{acc}(P_{in}=4W)$ value of 5 MV/m was obtained. We expect the accelerating voltage of 30 MV of the booster.

References

1) S.Takeuchi, T.Ishii, B.J.Min and M.Shibata. Proc. 5th Workshop on RF Superconductivity (1991)395, Hamburg.
2) (for example) B.Bonin, R.W.Röth. Proc 5th Workshop on RF Superconductivity (1991)210, Hamburg.
3) M.Shibata. in the Proc. of this workshop.