Proceedings of the 1979 Linear Accelerator Conference, Montauk, New York, USA

C-BAND SUPERCONDUCTING CAVITY RESEARCH AT KEK

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Summary

Fabrication and surface preparation techniques have been studied on C-band TM_{010} niobium single cavities. A Q_0 of 10^{10} and effective accelerating field strength of 10 MeV/m have been obtained by electro-polishing, anodizing and vacuum firing.

Electron acceleration has been tested with a nine-cell π-mode structure. A preliminary test resulted in an accelerated beam at 0.64 MeV with 70 keV injection energy, corresponding to an effective accelerating field strength of 3 MeV/m.

Introduction

Superconducting cavity research is being carried out at KEK to obtain further understanding of rf superconductivity, and explore the feasibility of applying superconducting rf structures to a future accelerator such as a large electron storage ring. Cavity geometry, cavity fabrication techniques and surface preparation methods have been investigated to obtain high quality factor Q_0 and high accelerating rf fields in a pure niobium TM_{010} single cavity.

C-band (6 GHz) has been chosen as the microwave frequency because the size of cavities are convenient to handle, and microwave equipment is commercially available, as this frequency band is being used for the satellite communication.

Electron acceleration by a nine-cell C-band structure has been demonstrated and used to study problems typical of superconducting accelerators.

In the future TRISTAN[1] project, the orbit bending radius will be at most about 250 meters, which comes from the limited area of KEK campus. If a normal conducting rf structure is applied to the electron ring of TRISTAN, the electron and positron energies will be limited to ∿20 GeV due to the huge rf power requirement. To obtain higher energy for the electron ring, the feasibility of a superconducting rf structure is now being considered at KEK, and 500-MHz niobium cavity research has been started.

This report describes the results obtained up to the present for C-band cavity research.

Single Cavity Experiments

Cavity geometry

From the viewpoint of the reduction of surface electric and magnetic fields, and concern about electron multipactoring, several kinds of cavity geometries were studied, both by LALA computation and experiment. Three typical geometries are shown in Fig. 1. Type A is round-cornered with the beam-hole edge of circular cross-section. Type B is sharp cornered[2] with the beam-hole edge of elliptical cross-section,[3] and Type C is a spherical cavity with the beam-hole edge of elliptical cross-section. Beam-hole diameter is 10 mm for Type A and 15 mm for Type B and C.

Cavity fabrication and surface treatments

Each half cavity was machined from solid niobium rod and electro-polished, removing 100-150 μm from the surface, and welded together to form complete cavities. They were electro-polished again slightly, anodized at 50 volts in NH_4OH solution and heat-treated at 1500-1600°C in 10^{-8} Torr vacuum.

For the 500 MHz, it is planned to form the half cavities by spinning or coining. C-band cavities are also under preparation by spinning.

Most of the cavities were welded by electron beam welding; argon arc welding was also tested. The welding torch and rotating jib were mounted in a vacuum vessel, which was filled with pure argon gas after first evacuating the vessel. Argon arc welded cavities showed almost similar rf test results compared to the electron beam welded cavities.

After firing in a vacuum furnace, cavities were assembled to a coaxial window. This process was done mostly in the air, after which the cavities were evacuated and pinched off.

Results of single cavity tests

Fifteen cavities were fabricated and tested. Some cavities were tested several times after reprocessing each time by anodizing and firing.

Figure 2 shows the results for these tests. Open circles are for cavities of Type A, triangles are for Type B and squares are for Type C. Black dots represent multipactoring breakdown for Type A.

Figure 3 shows Q_0 for increasing rf field at 1.5°K for the typical Type A cavity.

Several observations can be made from the present results:

Multipactoring breakdown was observed for a few cases of Type A cavities. The electrons were observed by a biased voltage collector.

The effects of various cavity shapes are not clear in this frequency band but surface preparation effects are more dominant.

No x-ray radiation was observed.

In recent experiments, heat pulses were observed at the bottom wall of the cavities at the breakdown field level.

Electron Acceleration by a Nine-cell Structure

A C-band, π-mode, nine-cell structure as shown in Fig. 4 was fabricated by a method of preparation similar to that of the single cavity. Phase velocity was 0.85c for the injection electron energy of about 80 keV. End cavities have slightly different diameters to obtain the flat field distribution on the axis. Dimensions were determined by calculation and also from the experimental results of the three-cell structure. The irregularity of the axial field distribution measured by the bead measurements has not yet been compensated by squeezing the cavity wall.

A schematic drawing of the arrangement for the acceleration test is shown in Fig. 5. Electrons were injected from a 100-kV gun through an inner conductor pipe of a coaxial rf line, into a niobium structure.

The preliminary test showed that Q_0 for the π-mode was 5×10^8. The effective accelerating field was 3 MeV/m and accelerated electrons reached an energy of 0.64 MeV with injected energy of 70 keV. Beam intensity was a few μA and FWHM of the energy spectrum was 0.1 MeV.

Acknowledgements

We wish to express our thanks to Director T. Nishikawa for continuous encouragement, to Dr. K. Mittag for many helpful suggestions, and to the people of KEK machine shop for the design and construction of the equipment.

References

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2. C.M. Lyneis, H.A. Schwettman, J.P. Turneaure, Appl. Phys. Lett. 31, 541 (1977).
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Discussion

R.H. Miller, SLAC: Is the 500-MHz cavity intended for use in a storage ring or a linac?

Kojima: We are now considering the feasibility of using superconducting rf cavities for the TRISTAN electron ring.

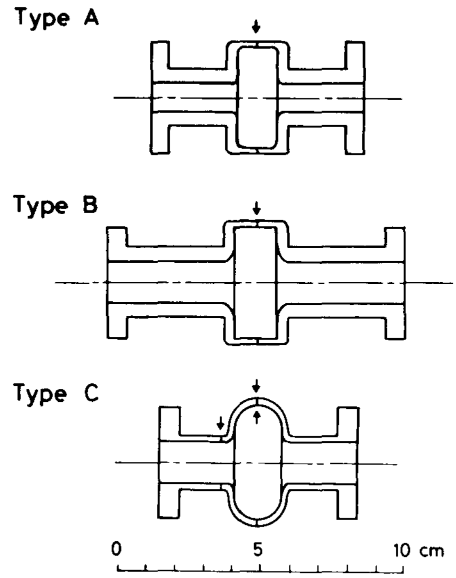


Fig. 1 Various geometry of C-band cavities, arrows indicate the welding points.

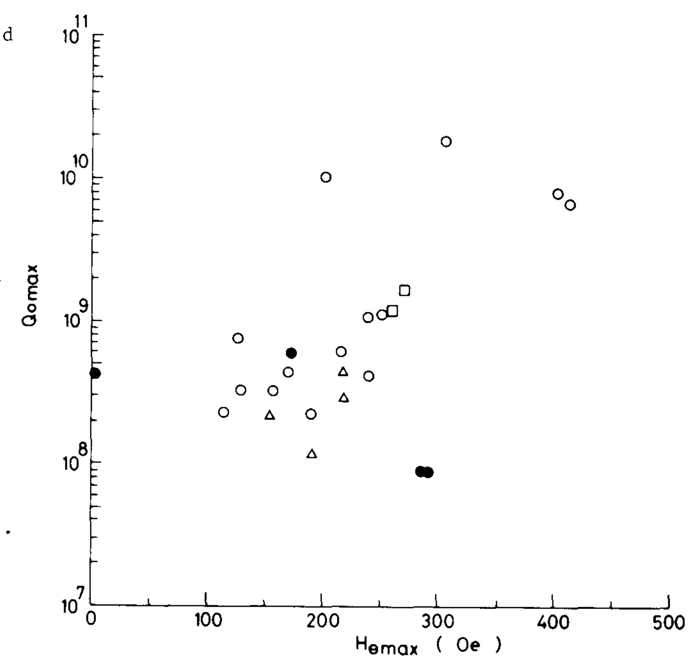


Fig. 2 Results for C-band cavities, circles are for Type A in Fig. 1, triangles are for Type B and squares are for Type C.

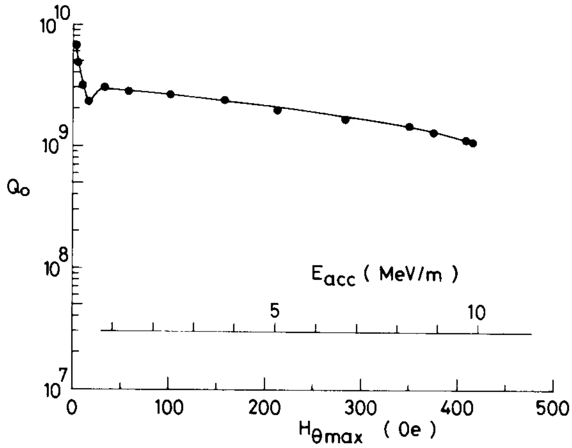


Fig. 3 Typical results for Q_0 vs rf field.

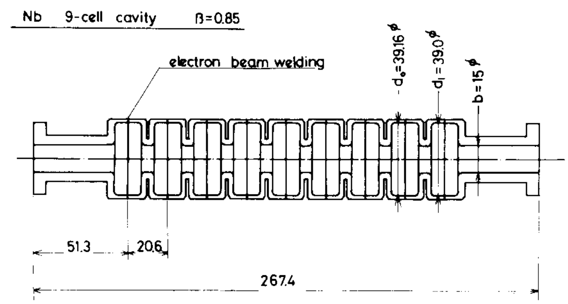
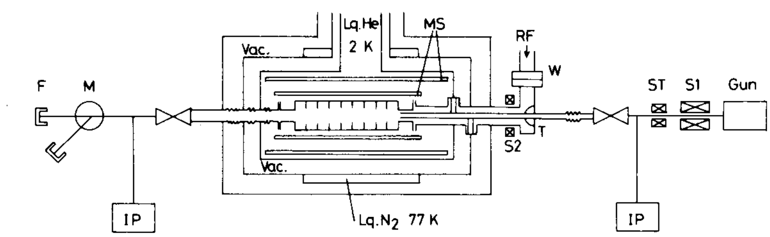


Fig. 4 A nine-cell structure.



S1 S2	Solenoid coil
ST	Steering coil
W	Ceramic window
T	Transition from waveguide to coaxial line
MS	Magnetic shield
M	Analyzer magnet
F	Faraday cup

Fig. 5 Schematic drawing for the arrangement of electron acceleration.