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DEVELOPMENT OF HOM ABSORBERS FOR CW SUPERCONDUCTING CAVITIES IN ENERGY RECOVERY LINAC

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Abstract

Higher Order Modes (HOM) absorbers for superconducting cavities in energy recovery linac (ERL) have been developing at TOSHIBA in collaboration with High Energy Accelerator Research Organization (KEK) since 2015. A prototype HOM absorber for 1.3 GHz 9-cell superconducting cavity was fabricated in 2017. An aluminium nitride based lossy dielectrics (AlN) cylinder was brazed in a copper cylinder which has lattice-like slots on the inner surface. RF performance measurements of this prototype HOM absorber at room temperature and low temperature were carried out at KEK. As the results, it was found that some HOMs were absorbed by the prototype HOM absorber. However, many cracks occurred in the AlN cylinder before these measurements. R&D of brazing between AlN cylinder and copper has started and a new prototype HOM absorber was fabricated based on the R&D results. The heat removal test of the new prototype HOM absorber was carried out. RF measurement results of the previous prototype HOM absorber and fabrication process and the heat removal test results of the new prototype HOM absorber will be presented in this paper.

INTRODUCTION

KEK has been designing the 10 mA class ERL-FEL light source accelerator. The main linac uses 9-cell cavities with beam line type HOM absorbers. The target accelerating gradient is 12.5 MV/m. The 9-cell cavity is designed from experience of the KEK compact ERL (cERL) main linac [1]. HOM absorbers are one of the key components to determine the ERL cavity performance to reduce the HOM problem for the high current operation. The absorption heat of HOM absorber is estimated to about 10 W and shape of the HOM absorber has been designed [2]. A prototype HOM absorber for 1.3 GHz 9-cell cavity was fabricated in 2017 [3]. An AlN cylinder was brazed in a copper cylinder which has lattice-like slots on the inner surface. Stainless steel flanges were joined on either end of the copper cylinder by electron beam welding to fabricate a whole prototype HOM absorber.

RF PERFORMANCE MEASUREMENTS

RF performance measurements of the prototype HOM absorber were carried out at KEK. Main specification of the prototype HOM absorber is shown in Table 1. The prototype HOM absorber is shown in Fig. 1. The prototype HOM absorber was connected with the 1.3 GHz single-cell superconducting cavity for ERL (see Fig. 2) and Q values of the cavity were measured at room temperature. Instead of the prototype HOM absorber, the copper pipe without the AlN cylinder was connected with the single-cell cavity and Q values of the cavity were measured at room temperature. Fig. 3 shows the measurement results of Q values of the cavity with the prototype HOM absorber and the copper pipe. It found that some HOMs were absorbed by the prototype HOM absorber. The cavity with the prototype HOM absorber was installed in the horizontal cryostat and cooled down with nitrogen gas. Q values of the cavity were measured before cooling and at 136 K. Measurement results were added to Fig. 3. Q values at 136 K were almost same as Q values at room temperature, so it was found that some HOMs were absorbed by the prototype HOM absorber at low temperature.

Table 1: Prototype HOM Absorber Specifications

Type	Beam line type
Inner diameter	100 mm
Heat absorption	10 W
Working temperature	80 K
RF absorbing material	AlN (Sienna tec., STL-150D)
Flanges material	Stainless steel (SUS316L)

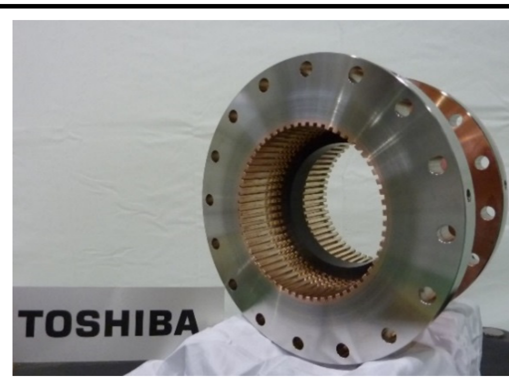

Figure 1: Prototype HOM absorber.

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Figure 2: Prototype HOM absorber was connected with the single-cell cavity for RF measurements at room temperature.

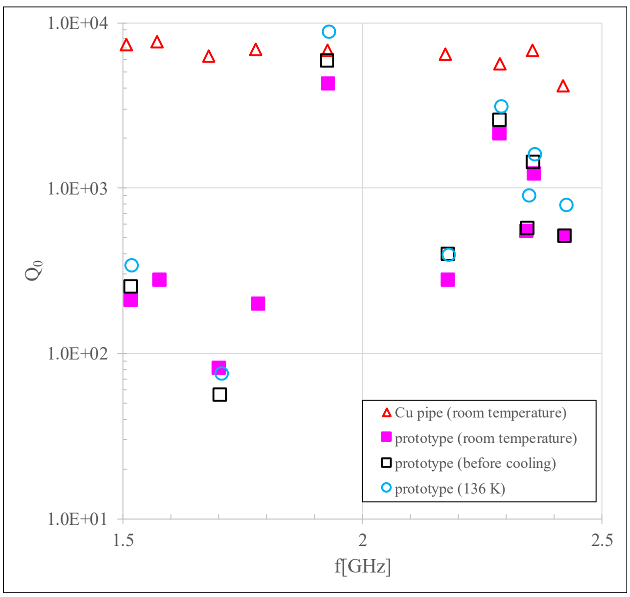

Figure 3: Measurement results of Q values. Red triangles show Q values of the cavity with the copper pipe, squares filled in pink show Q values of the cavity with the prototype HOM absorber at room temperature, black squares show Q values of the cavity with the prototype HOM absorber before cooling in the cryostat, blue circles show Q values of the cavity with the prototype HOM absorber at 136 K.

FABRICATION OF A NEW PROTOTYPE HOM ABSORBER

Brazing Tests

Many cracks occurred in the AlN cylinder of the prototype HOM absorber before RF measurements. R&D of brazing between AlN cylinder and copper has started to find the brazing method that would not crack in the AlN cylinder. A thin board of copper was brazed on the outer periphery of an AlN cylinder. In order to relieve the stress due to thermal expansion, the copper board was formed into strips. Brazing conditions are shown in Table 2. Fig. 4 shows the test pieces which brazed an AlN cylinder and thin copper strips. The width of a copper strip is 3 mm for test piece (A) and 10 mm for test piece (B). Fig. 5 shows enlarged photograph of outer surface of test piece (A). It was found that the copper strips were perfectly touched the AlN cylinder.

Both end faces of the brazed test pieces were observed with the optical microscope. It was found that many cracks occurred in the AlN cylinder near the brazed parts with copper strips in two test pieces. Test piece (B) was cut to measure the depth of a crack. As the results, the depth of a crack was about 4.4 mm.

Table 2: Brazing Conditions

Brazing material	Silver
Process temperature	750 °C
Furnace atmosphere	Vacuum

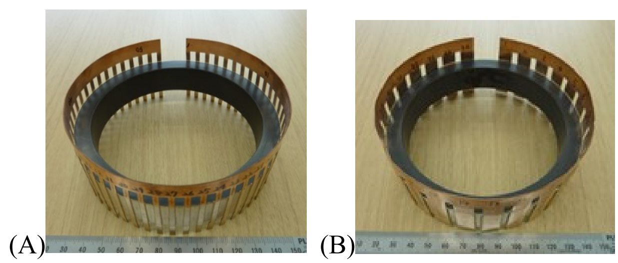

Figure 4: Test pieces which brazed an AlN cylinder and thin copper strips. The width of a copper strip is 3 mm for test piece (A) and 10 mm for test piece (B).

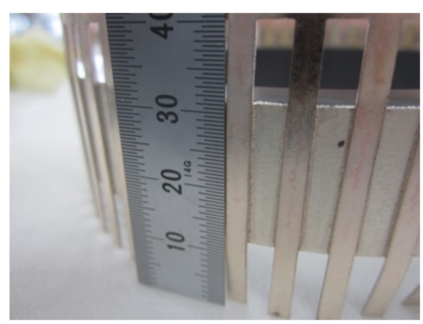

Figure 5: Outer surface of test piece (A).

Fabrication Process

A new prototype HOM absorber was fabricated using the brazed test piece (A). Main specifications of a new prototype HOM absorber is the same as the previous one as shown in Table 1. The copper board of the brazed test piece was electron beam welded to the inside of the copper cylinder and stainless steel flanges were electron beam welded to both ends of the copper cylinder. The new prototype HOM absorber is shown in Fig. 6.

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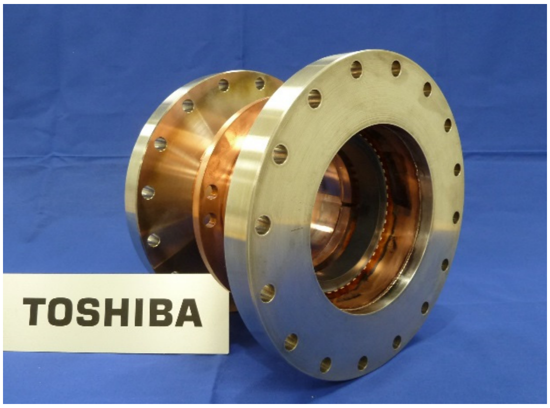

Figure 6: New prototype HOM absorber.

HEAT REMOVAL TEST OF THE NEW PROTOTYPE HOM ABSORBER

The heat removal test of the new prototype HOM absorber was carried out at KEK. Four ceramic heaters were attached on the AlN cylinder. Some thermocouples were attached on the copper cylinder and the AlN cylinder. The prototype HOM absorber was installed in the horizontal cryostat and cooled down with nitrogen gas (see Fig. 7). After the temperature of the prototype HOM absorber stabilized at about 90 K, the heaters outputted 10 W. The temperature of the AlN cylinder and the copper cylinder were measured. The temperature differences of the copper cylinder and the AlN cylinder were plotted in Fig. 8. It was found that the temperature of the copper cylinder was lower about 4 K than the temperature of the AlN cylinder. It was consistent with 3 K that estimated from thermal conductivity. It was confirmed that the new prototype HOM absorber was able to absorb heat of 10 W.

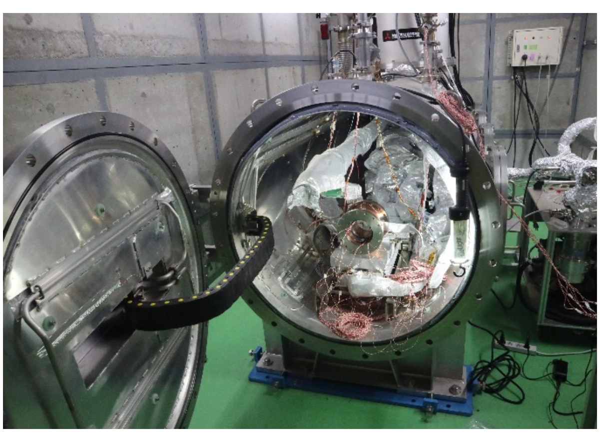
Figure 7: The prototype HOM absorber was installed in the horizontal cryostat.

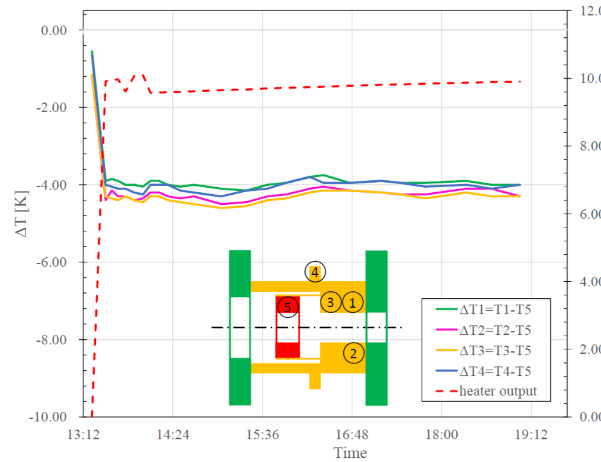

Figure 8: Heat removal test results of the new prototype HOM absorber.

CONCLUSION

RF performance measurements of the prototype HOM absorber fabricated in 2017 were carried out at room temperature and low temperature at KEK. As the results, it was found that some HOMs were absorbed by the prototype HOM absorber. R&D of brazing between AlN cylinder and copper has started to find the brazing method that would not crack in the AlN cylinder. The new prototype HOM absorber was fabricated based on the R&D results and the heat removal test was carried out. As the results, it was found that the temperature difference of the copper cylinder and the AlN cylinder was about 4 K and the measurement results were consistent with calculated value. It was confirmed that the new prototype HOM absorber was able to absorb heat of 10 W.

Measurement of emitted gases and particles of the new prototype HOM absorber in vacuum will be carried out at KEK. R&D of brazing between AlN cylinder and copper will be continued.

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