NEW DESIGN OF HOM COUPLER USING COAXIAL-LIKE ROUNDED WAVEGUIDE

M. Sawamura#, R. Hajima, R. Nagai, N. Nishimori, JAEA, Tokai, Ibaraki 319-1195, Japan

Abstract

It is important to damp higher-order modes (HOMs) of superconducting accelerators especially for energy-recovery linacs (ERLs) of high current operation. Though various types of antenna/loop HOM couplers, beam-line HOM dampers, and waveguide HOM couplers have been developed, there are some problems such as inner conductor heating of an output connector for HOM couplers and low packing factor for beam-line HOM dampers. We propose new design of HOM couplers. These HOM couplers consist of a coaxial line coupled with a cavity or a beam pipe, and a rounded waveguide which cuts off the accelerating mode. The rounded waveguide is similar to a coaxial line and the inner conductor and outer conductor are connected with a plate which corresponds to waveguide side wall. This enables the inner connector cooled down efficiently through the outer conductor. The calculation results of MW-STUDIO will be presented.

INTRODUCTION

HOM damping is important for superconducting cavities, especially for high current CW machines such as ERLs. The lower Q-values of HOMs lead to the smaller capacity of a refrigeration system and the higher threshold current against the beam breakup (BBU).

Many types of HOM damping for elliptical cavities have been developed such as an antenna/loop HOM coupler, a beam-line HOM damper, and a waveguide HOM coupler.

Though the beam-line HOM damper has the advantages of high power-handling capability and radial symmetry to avoid beam kick, it has no filter to exclude the accelerating mode and must be installed far from the cavity enough not to influence the accelerating mode. This results in low packing factor and lowering efficient accelerating field.

The antenna/loop HOM coupler can be attached to the beam pipe close to the cavity with no extra beam pipe length. Attaching close to the cavity requires a filter to exclude the accelerating mode and the filter cannot be adjusted after cooling. Furthermore the HOM power must be transmitted out of the HOM coupler though a connector. The connector tends to be heated due to poor thermal conductance between the inner and outer conductors [1-3]. Though high heat transfer materials such as sapphire are used to increase the heat transmission between the inner and outer conductors, it is uncertain if high HOM power required for high current ERL can be transferred through the connector.

Though a waveguide has in principal cutoff frequency, the size of waveguide is larger than that of antenna/loop HOM coupler.

These types of HOM damping can be used for elliptical cavities according to the requirements.

The spoke cavity is about half the size of the elliptical cavity for the same frequency. The size of HOM damping equipment becomes relatively large as compared with the cavity size. Since the bore diameter is relatively small and the wavelength of the lowest HOM is almost comparable to the spoke cavity diameter, the beam-line HOM damper is impractical for the spoke cavity. The size of waveguide HOM coupler is too large to be attached to the spoke cavity side wall or end wall practically. Though the antenna/loop HOM coupler seems to be practical for the spoke cavity, the heat problem must be settled.

We propose two new types of HOM couplers to be attached to both elliptical and spoke cavities. One is the combination of coaxial line and waveguide. The other is rounded waveguide.

The present paper describes the calculated results of RF property of two types of HOM couplers.

DESIGN OF COAXIAL-WAVEGUIDE HOM COUPLER

The waveguide HOM coupler requires no filter since it has cutoff frequency. It requires much space to connect to the beam pipe or the cavity regardless of handling power so that the numbers of couplers is limited. To reduce the connecting space, the coaxial line is preferable because it can transmit all the modes regardless of its size. One of our proposing HOM coupler uses the coaxial line to connect to the beam pipe or the cavity, and the waveguide to exclude the accelerating mode and to propagate HOMs as shown in Fig. 1. We call this a coaxial-waveguide HOM coupler.

The RF property was calculated with electromagnetic simulation code of Microwave Studio. The calculation model consists of the coaxial-waveguide HOM coupler and a coaxial line where RF power mainly propagates as shown in Fig. 2 (top). There are three ports. One side of coaxial line is defined as port No.1, the other side as port No.3, and the waveguide output as port No.2. It is supposed that the accelerating frequency is 1300 MHz and cutoff frequency is 1500 MHz The size of the model was determined according to these frequencies.

#sawamura.masaru@jaea.go.jp

ISBN 978-3-95450-143-4

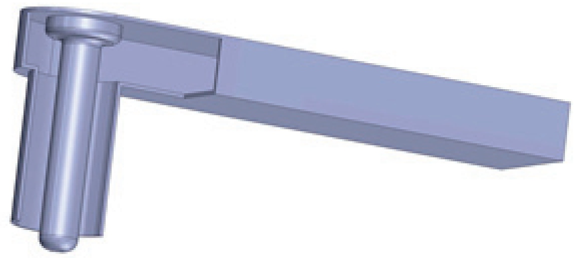

Figure 1: Layout of coaxial-waveguide HOM coupler.

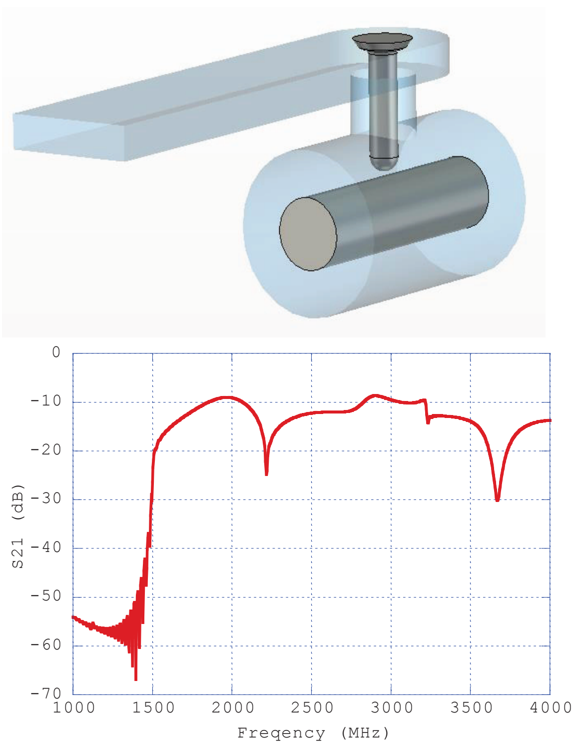

Figure 2: The calculation model of coaxial-waveguide HOM coupler (top) and calculated S-parameter of this model (bottom).

The S-parameter of S21 was calculated as shown in Fig. 2 (bottom). This result indicates the good RF properties of excluding the accelerating mode and of highpass filter above the cutoff frequency.

Fig. 3 shows the electric field propagating through the coaxial-waveguide HOM coupler. The electric field of the accelerating frequency of 1300MHz propagates through coaxial line and the near connecting port of the HOM coupler (Fig. 3 top). On the contrary the electric field of 2000MHz above the cutoff frequency the electric field propagates through both the coaxial line and waveguide (Fig. 3 bottom).

DESIGN OF C-SHAPE WAVEGUIDE HOM COUPLER

The HOM power propagating through the waveguide of the coaxial-waveguide HOM coupler must be absorbed or extracted to outside. When the power is absorbed within the waveguide, the RF absorber is installed at the end of the waveguide and the heat must be transferred not to increase the cavity temperature. When the power is extracted to outside, the waveguide is connected to outside of a cryomodule. This case causes the heat invasion to the cavity. Converting to the coaxial line connecting with a cable is another method to extract the HOM power. This case causes the inner conductor heating in case of high HOM power.

We propose another type of HOM coupler deforming the coaxial-waveguide HOM coupler. When the waveguide is rounded gradually as shown in Fig. 4, one long side wall of the waveguide, which is opposite to the coaxial line port, becomes an inner conductor and the other long side wall becomes an outer conductor. Two short side walls become partition plate connecting the inner and outer conductors as shown in Fig. 5 (top). Since the shape of deformed waveguide resembles alphabetical character of C, we call this waveguide a C-shape waveguide (CWG).

The coaxial line intersecting at a right angle to the CWG in Fig. 5 (top) can be moved in a straight line with the CWG. Another coaxial line can be connected to the output side as shown in Fig. 5 (bottom).

The CWG has advantages as the follow,

(1) As with the rectangle waveguide, the CWG has cutoff frequency according to its size.
(2) The CWG can be connected with coaxial lines easily since it has inner and outer conductors.
(3) The inner conductor of the CWG is easily cooled from the outer conductor since the inner and outer conductors are connected with the partition plate.

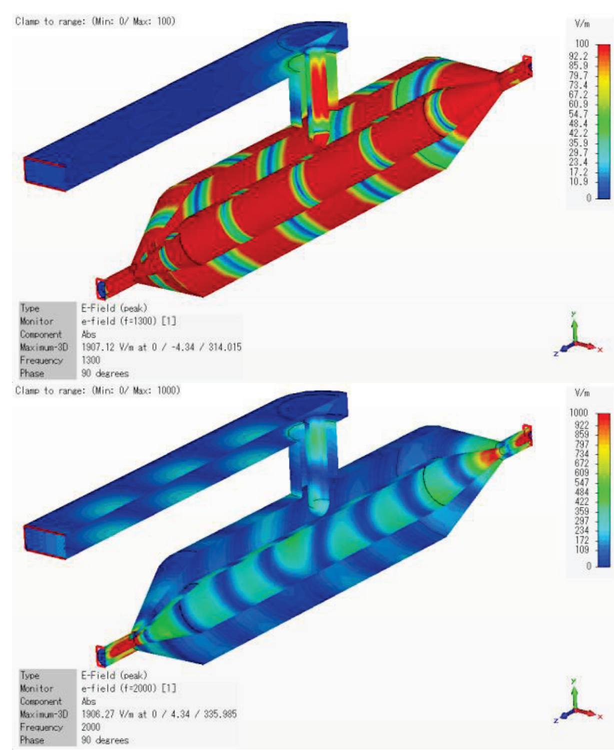

Figure 3: The propagating electric field of 1300MHz (top) and of 2000MHz (bottom).

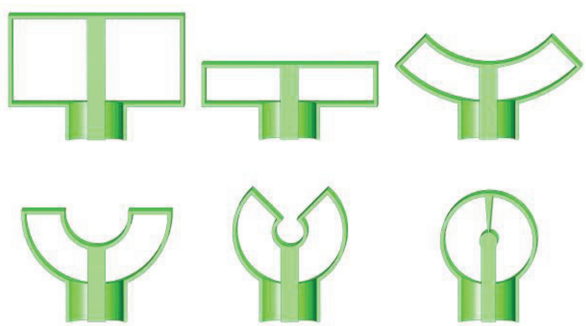

Figure 4: The coaxial-waveguide HOM coupler is deformed to C-shape waveguide by rounding the waveguide from top left to right.

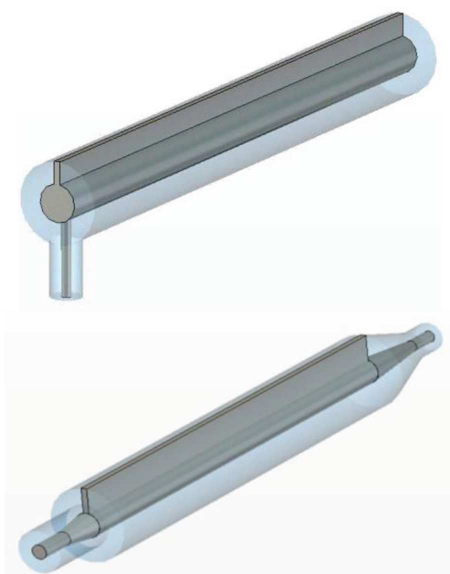

Figure 5: C-shape waveguide of rectangle type (top) and straight type (bottom).

The RF property of the model of Fig. 5 (bottom) is calculated and the S-parameters are shown in Fig. 6 (top). This indicates that the CWG has cutoff frequency and that it acts as a highpass filter. The propagating electric fields of the accelerating mode of 1300MHz and that above the cutoff frequency are shown in Fig. 6 (middle and bottom). Under the cutoff frequency the RF propagates only near the input coaxial line. Above the cutoff frequency the RF field propagates though the CWG to the output port of coaxial line.

Fig. 7 shows the dependence of the outer radius of the CWG. The inner radius varies to keep the same ration of inner radius to outer radius. This indicates that increase of the radius of the CWG decreases the cutoff frequency. The cutoff frequency of CWG is approximately determined by the average arc length.

Fig. 8 shows the dependence of the length of CWG. This indicates that the transmission of the accelerating mode decreases with the length of CWG. Since the CWG uses the cutoff property of waveguide, it requires the certain length of twice or more its wavelength to restrict the transmission of the accelerating mode.

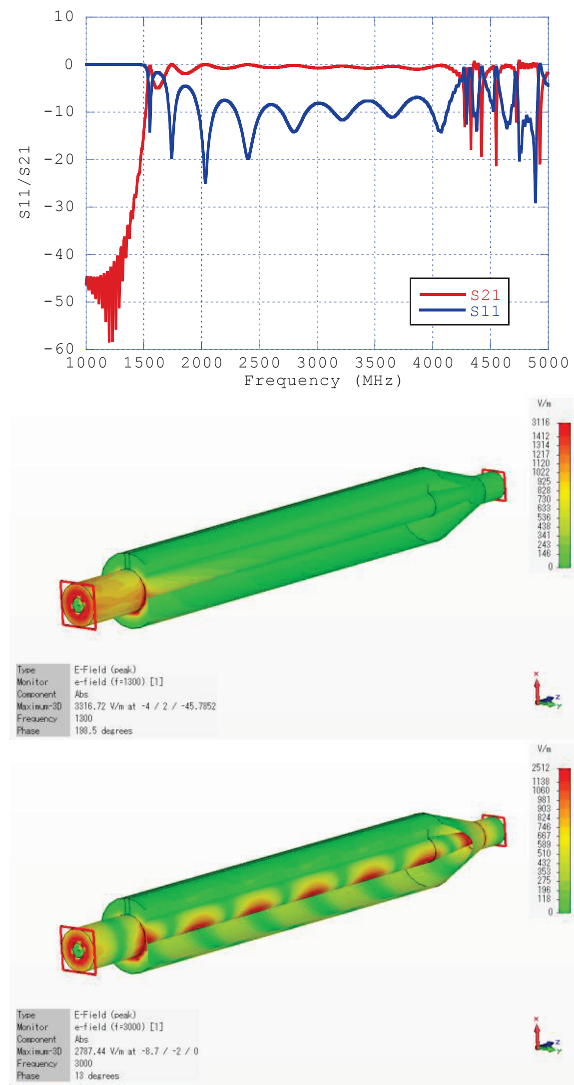

Figure 6: S-parameters of C-shape waveguide (top) and propagating electric field under cutoff frequency (middle) and that above the cutoff frequency (bottom).

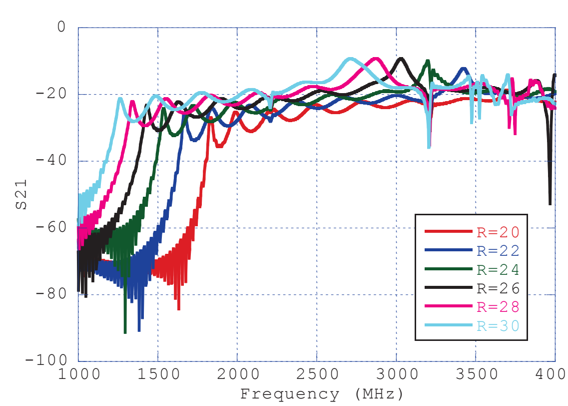

Figure 7: Cutoff frequency dependence according to the outer radius of C-shape waveguide.

ISBN 978-3-95450-143-4

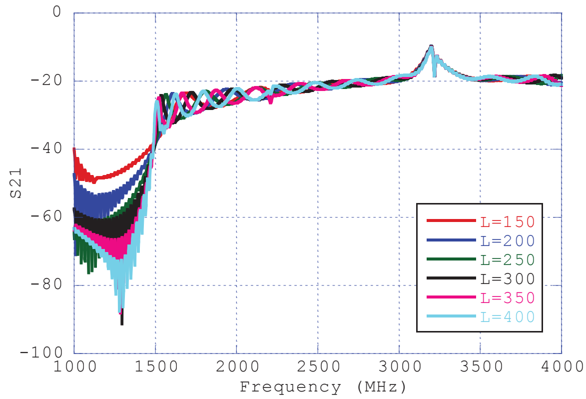

Figure 8: Transmission dependence of C-shape waveguide according to the length.

This makes the total length long. In order to compact the CWG, it is possible to round the CWG along the beam pipe or the cavity as shown in Fig. 9 (top). The CWG can be also folded to shorten the total length as shown in Fig. 10 (top). Each case shows good transmission property as shown in Fig. 9 (bottom) and Fig. 10 (bottom).

CONCLUSION

Two new types of the HOM coupler models were proposed and calculated. These HOM couplers are combined with the coaxial line and waveguide. Both HOM couplers have cutoff frequency in principal and show good RF property of the highpass filter. Since the CWG brings easy heat transfer from the inner conductor to the outer conductor, the heat problem of the output connector can be solved with the CWG.

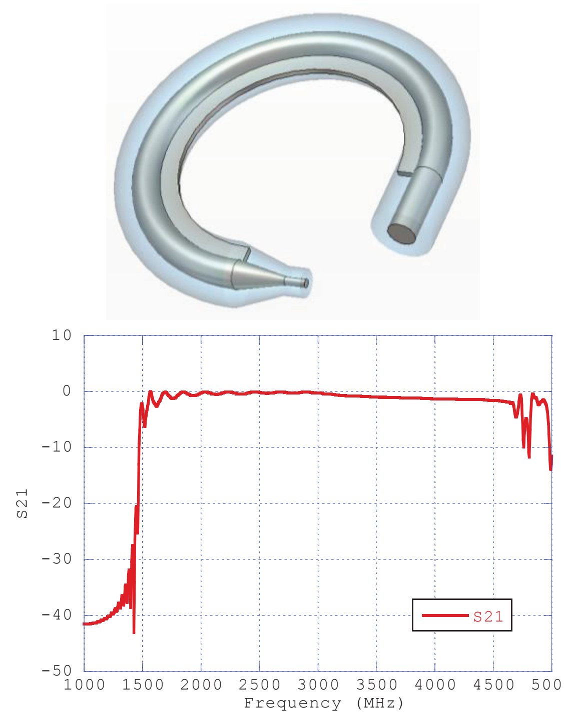

Figure 9: Rounded CWG (top) and transmission property (bottom).

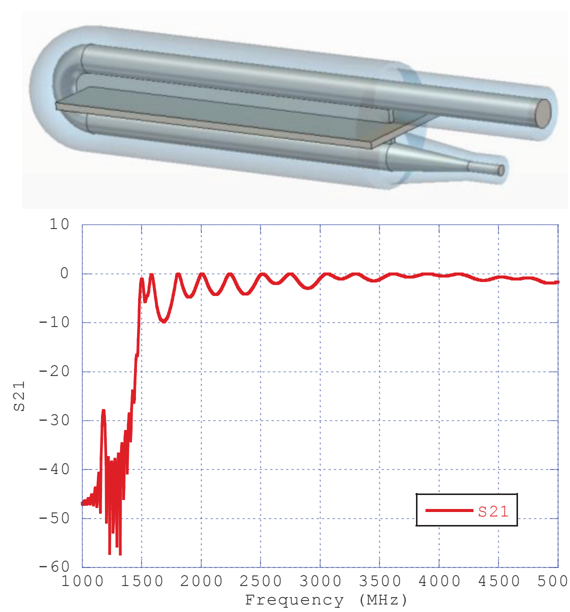

Figure 10: Folded CWG (top) and transmission property (bottom).

REFERENCES

[1] P. Kneisel et al., "Testing of HOM Coupler Designs on a Single Cell Niobium Cavity", Proc. of PAC2005, 4012-4014 (2005).

[2] G. Wu et al., "Electromagnetic Simulations of Coaxial Type HOM Coupler", Proc. of 12th SRF (SRF2005), 600-603 (2005).

[3] J. Sekutowicz, "Improved Heat Conduction Feedthroughs for HOM Couplers at DESY", Proc. of ERL2011, 102-104 (2011).