Development of RF cavity for MuSEUM experiment in a zero magnetic field

K. S. Tanaka[*1,*2] on behalf of J-PARC MuSEUM Collaboration

The MuSEUM (Muonium Spectroscopy Experiment Using Microwave) group is planning to measure the energy of the ground state hyperfine structure (HFS) of muonium at J-PARC/MLF[1)]. Muonium is a hydrogen-like bound state that consists only of leptons, and its HFS is a good probe for testing the QED theory. The latest experiment at LAMPF obtained the following value:[2)]

$$\Delta_{\mathrm{Mu}}^{\mathrm{ex}} = 4.463302765(53)\ \mathrm{GHz}\ (12\ \mathrm{ppb})\ . \tag{1}$$

The total precision was limited by the statistical uncertainty. We will achieve a precision more than 10 times better than that of the latest experiment by using the high intensity muon beam provided at J-PARC/MLF. We plan to measure muonium HFS in a zero magnetic field at D Line[3)] and in a high magnetic field at H Line.

The measurement procedure of the experiment is as follows:

- Muons with their spins polarized to the upstream direction are provided from J-PARC/MLF muon beam line.
- RF cavity located in the center of the magnet containing pure Krypton gas. Muons stop by collisions in the gas and polarized muonium are formed by electron capture process with Krypton.
- High momentum decay positrons are emitted preferentially in the direction of the muon spin. By driving the transitions with an applied microwave magnetic field, the muon spin can be flipped and the angular distribution of high momentum positrons is changed from predominantly upstream to downstream with respect to the beam direction.

In this paper, the development of the RF cavity for the zero field experiment is described.

Figure 1 shows the cavity for zero field experiment. The inner diameter of the cylindrical cavity for the zero field experiment is tuned so that the resonance frequency of the TM110 mode matches the transition frequency of muonium HFS of 4.463 GHz. Frequency sweep is enabled in the range of 20 MHz by the insertion system of a tuning bar made of conductive material.

A microwave is delivered by a coaxial cable and coupled into the cavity by the input loop. The microwave power in the cavity is picked up by a loop coil and measured by the thermal power sensor (R&S NRP-Z51). The measured power is feedback to the signal generator to stabilize the input microwave power at a level of 0.02 % which brings no systematic uncertainty.

Figure 2 shows the dependence of resonance frequency on the displacement of the tuning bar. The red line shows the transition frequency of the hyperfine splitting and the red band shows the sweep range of the measurement. As shown in this figure, tunability of the cavity is enough for the measurement.

Thus, the RF system for the zero field experiment is ready. We will start the first measurement of muonium HFS in a zero field in 2016.

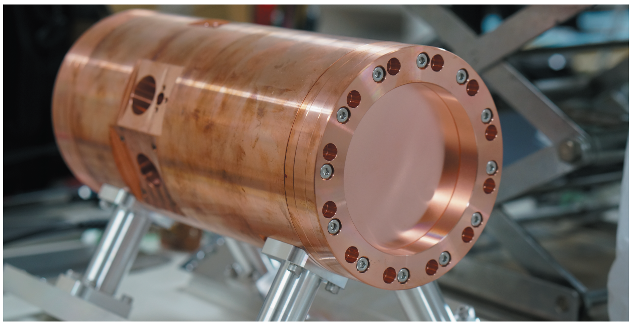

Fig. 1. Photo of the cavity for zero field experiment. The inner radius is 41 mm and the axial length is 230 mm.

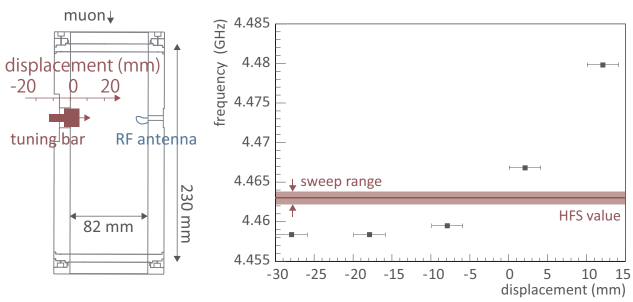

Fig. 2. The left figure shows the cross-sectional view of the cavity. The tuning bar is inserted from the side surface to tune the resonance frequency of the cavity. Right figure shows the relation between the resonance frequency and the displacement of the tuning bar. The red line shows a transition frequency of HFS and the red band is a sweep range to observe the resonance line shape.

References
1) K. S. Tanaka on behalf of MuSEUM Collaboration.: RIKEN Accel. Proog. Rep. **47**, 277 (2014).
2) W. Liu *et al.*, Phys. Rev. Lett. **82**, 711 (1999).
3) S. Kanda on behalf of MuSEUM Collaboration.: in this report.

*1 RIKEN Nishina Center
*2 Graduate School of Arts and Sciences, University of Tokyo