LOW POWER TEST OF RFQ MOCK-UP MODULES AT 175MHz FOR IFMIF PROJECT

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Abstract

The 175MHz RFQ mock-up modules which consist of end-plate modules and central modules, have been designed by MAFIA code, and the mock-up modules have been fabricated for a low power test. By the low power test results and the analysis of higher modes, it was found that the resonant frequency of operation mode (TE_{210}) is not affected by higher modes in the RFQ length of 4.1m. This result showed one of feasibility for the application technique using two coupling plates in the 12m-long IFMIF RFQ.

1 INTRODUCTION

International Fusion Materials Irradiation Facility (IFMIF) is an accelerator-based neutron irradiation facility to develop materials for fusion reactor[1-3]. In the system, 40MeV deuteron beam with a current of 250 mA is injected into liquid lithium flow with a speed of 20 m/s, neutron field similar to the D-T Fusion reactor (2MW/m2, 20 dpa/year for Fe) is produced by the Deuteron-Lithium (D-Li) stripping reaction. The required current of 250 mA is realized by two beam lines of 125 mA, and the output energies at injector, radio-frequency quadrupole (RFQ) linac and drift tube linac (DTL) are designed to be 0.1, 5.0 and 40 MeV, respectively [4].

In the 175 MHz IFMIF RFQ system, the RFQ total length is needed to be 12 m to accelerate ions up to 5 MeV, and hence suppression of higher modes is indispensable. For this purpose, a coupling plates are used, central modules which have a short longitudinal length, are connected through the coupling plates. This coupled cavity technique is developed for 350 MHz RFQ system in APT/LEDA project of LANL[5-8], will be used in IFMIF RFQ system. In order to apply this technique, it is indispensable to verify resonant frequencies of operation mode and higher modes in the short central module. In case that two coupling plates are applied for the IFMIF RFQ, the short central module length is 4 m, operation mode and higher modes in the length were verified by the low power test and the analysis of higher modes.

2 DESIGN OF RFQ MODULES

A four-vane RFQ modules were designed by MAFIA code. The RFQ modules consist of two end-plate modules and central modules, two end-pate modules are connected to both sides of the central modules. A coupling pates are not included in, to evaluate operation mode (TE_{210}) and higher modes (TE_{21n} and TE_{11n}) up to a longitudinal length of 4.1 m. For both modules, the vane tip has no modulation, the cavity shapes have no curved lines excepting for the vane tips. The bore diameter and the vane radius are required by Ion Beam Transport Simulation, the diameter and the radius are ϕ8 mm and 4 mm, respectively. The resonant frequency was analyzed by changing each cavity dimension. For the resonant frequency of 175MHz, mock-up modules were fabricated. The material of aluminum was used. Photograph of central module and end-plate module are shown in Fig.1. The gap between end-plate and undercut vane edge is 40 mm, the longitudinal length and the radial length for the undercut vane is 50 mm and 70mm, respectively. In this dimension, electric field strength at the vane edge which is 1% lower than one at the central module center, is suppressed, electric field uniformity around the tip of vane for a longitudinal length is kept.

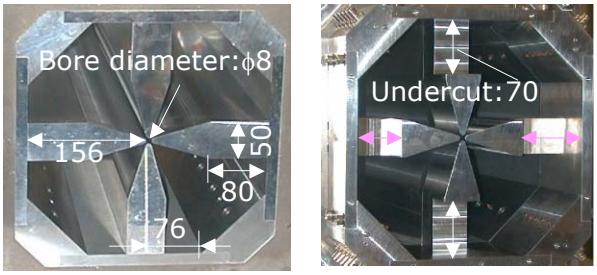

Fig.1 Photograph of Central and End-pate module

3 LOW POWER TEST

In Fig.2, photograph of the 4.1m-Long RFQ module is indicated. The RFQ module consist of four central modules and two end plate modules, each central module length is 1m. In the end-plate modules, the central module length of 50mm is including. In this system, the resonant frequency and the mode number for operation mode and higher modes were measured Network Analyzer. The two loop coils of ϕ60mm and ϕ25mm were used for an RF input coupler and a pick-up coil, respectively. For the resonant frequency, a peak values of a transmission coefficient factor (S_{21}) were measured, the mode number was evaluated by phase difference in each cavity and the calculation results by MAFIA code.

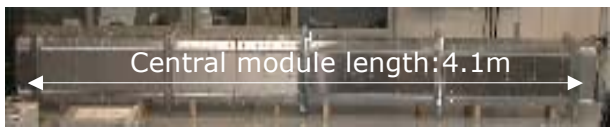

Fig.2 Photograph of the 4.1m-Long RF module

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The measured result is shown in Fig.3. Six peaks are observed, it was found that TE_{110}, TE_{210}, TE_{111}, TE_{211}, TE_{112} and TE_{212} mode from a low frequency side are excited. The resonant frequency of 187 MHz for the operation mode (TE_{210}) was measured, but the designed value was 175 MHz. The order of mode number and the number of higher modes, however, are in agreement with calculation results. The frequency difference between TE_{210} and TE_{110}, and between TE_{210} and TE_{111} are more than 1.6 MHz, the operation mode of TE_{210} was not affected by these higher modes. It was found that the operation mode is not affected by higher modes if the frequency of operation mode is far from higher modes more than 1MHz.

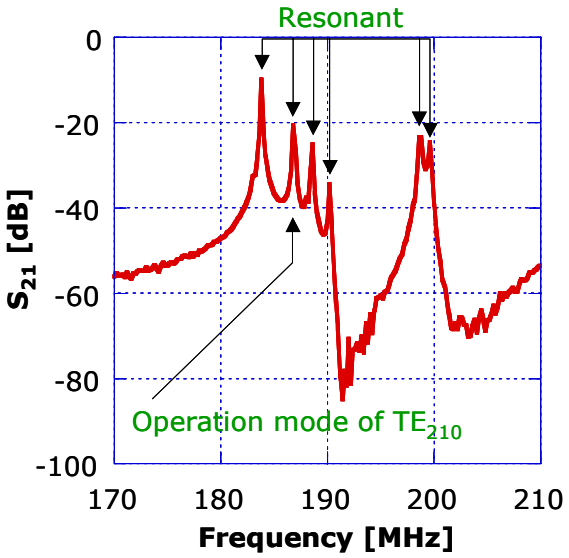

Fig.3 Measured resonant frequency

In order to agree with these measured resonant frequencies, mesh sizes of MAFIA code were optimized. In this result, it was found that the mesh size not in excess of 5mm/mesh is needed at the end-plate module part in z-axial direction, but the mesh size of 27.5mm/mesh or less is needed at central module part. The difference between measured values and calculated values was caused by the roughness of mesh sizes. Because the boundary condition are complicated configuration by undercut vane parts and the gap between the end-plate and undercut vane edge, the mesh size has to be cut fine at the end-plate parts. The measured resonant frequencies were in agreement with the calculated values using the optimized mesh sizes, within 200kHz ~1.13MHz. For the frequency difference between each modes, it were in agreement within -0.18 ~ +0.471 MHz.

4 IMPROVEMENT OF RFQ MODULE

The central module and the end-pate modes were redesigned by the optimized mesh sizes so as to obtain the resonant frequency of 174 MHz in the RFQ module length of 4.1m. The improved cavity dimensions are shown in Fig.4. The values with arrow are indicated for the improved dimension, blue and red values are previous and improved dimension, respectively.

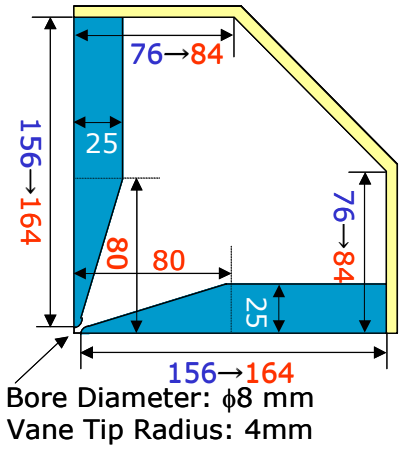

Fig.4 Improved cavity dimension

One central module and two end-plate modules were improved, the resonant frequency in the RFQ module length of 1.1m was measured. The measured result is shown in Fig.5. The resonant frequency of 175.65 MHz for operation mode was obtained, the frequency was in a good agreement with the calculated one of 174.36 MHz. The difference was less than 1% of operation frequency. This difference is supposed to be caused by misalignment at the connection between central module and end-plate module, but the analysis in details has not been done yet.

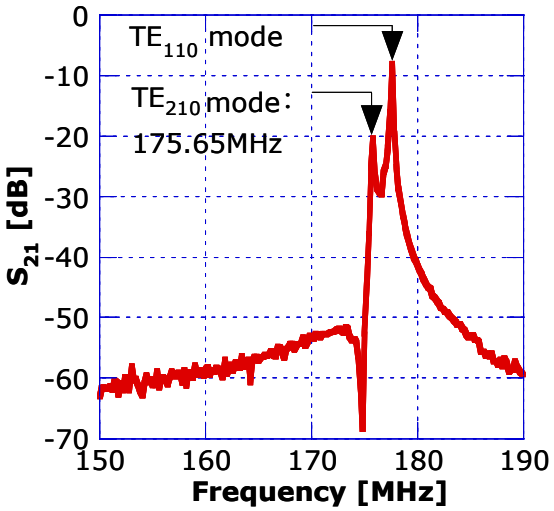

Fig.5 Measured resonant frequency of Improved RFQ

5 HIGHER MODES ANALYSIS

Higher modes analysis as a function of a longitudinal length up to 4.1 has been done by MAFIA code using the optimized mesh sizes. The result is shown in Fig.6. In the case of RFQ length of 4.1 m, the resonant frequencies of TE_{210} and TE_{111} modes are 173.91 MHz and 176.18 MHz,

respectively. The difference is 2.27 MHz, it is assessed that the operation mode is not affected by TE_{110} mode. It is also found that the difference of more than 1.54 MHz is obtained by the RFQ length of more than 2.1m, operation mode is not affected. But the RFQ system design using 2, 3 and 5 coupling plates is considerable in this result, the RFQ design using two coupling plates will a good candidate from a low cost-effectiveness point of views.

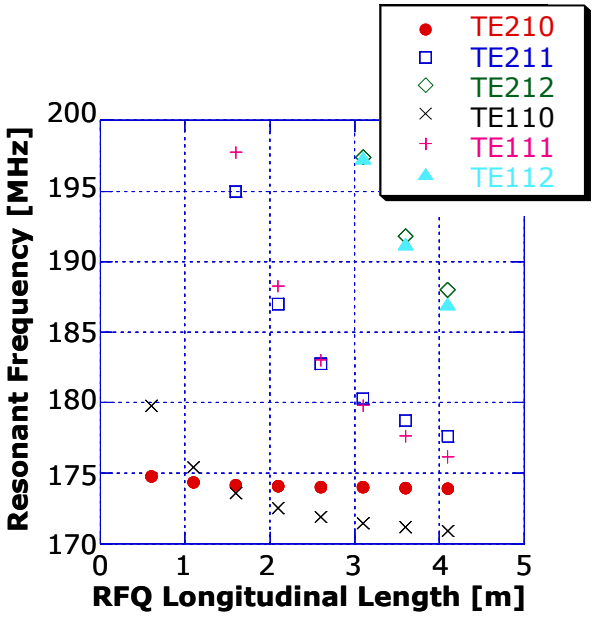

Fig.6 Higher modes analysis

5 FUTURE PLANS

In this works, the cavity's dimension for 175 MHz RFQ is obtained, the ridged coaxial waveguide of 1 5/8' is suitable for RF Power lead. From the withstanding voltage points of view, water cooling for the inner conductor is indispensable, R&D of multi RF input couplers are needed to lead the RF power of 700kW level per one RFQ module length of 4.1 m. In the nest step, a high power RF input couplers using this ridged coaxial waveguide are installed into RFQ modules, the evaluation for the resonant frequency and the power balance in each cavity by a low power test is planning.

6 SUMARY

The RFQ modules which consist of end-plate modules and central module, were designed by MAFIA code, the modules were fabricated for a low power test. In the tests, the resonant frequencies of operation mode and higher modes were measured in the RFQ length of 4.1m, it was found that the operation mode will not be affected by TE_{111} mode. The mesh sizes of MAFIA code, moreover, were optimized so as to agree with the measured resonant frequency, it was found that the mesh size of 5mm/mesh in a longitudinal direction is needed for end-plate parts. The RFQ modules were redesigned by the optimized mesh sizes, and the RFQ modules were improved. The resonant frequency of 175.65 MHz in the RFQ length was obtained by the improved RFQ modules, the measured frequency was in a good agreement with the calculated one of 174.39 MHz. By this result, MAFIA code has made it possible to analyze accurately for 175 MHz RFQ. In the higher mode analysis by this MAFIA code, it was found that the operation mode is not be affected by TE_{111} mode in the RFQ length of 4.1 m, it was indicated that one of feasibility for the application technique using two coupling plates in the 12m-Long IFMIF RFQ.

REFFERENCE

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