

Figure 1: Assembled XiPAF RFQ.

Field distribution is obtained by measuring the phase change of the S12 signal. Figure 2 shows the linear relationship between the S12 phase and frequency. It can be seen that there is a good linearity in the range of  $\pm 5$  kHz near the centre frequency. The disturbance slightly exceeds  $\pm 5$  kHz near the last tuner in Fig. 2(b). However, the data near tuners are not actually used in the tuning program. Therefore, the method for such measurement is reasonable.

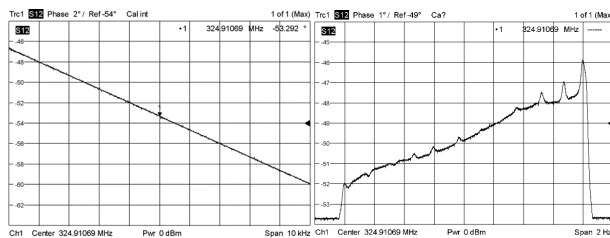


Figure 2: Assessment of the linear relationship between the S12 phase and frequency (a) and phase shift of signal S12 with the bead position (b) in one measurement.

## PRE-BRAZE TUNING

Before the pre-braze tuning, the four vanes of the XiPAF RFQ are assembled, but not brazed together. The dipole-mode stabilizer rods are not brazed on the flanges and the lengths can still be adjusted. A dummy coupler is mounted on the cavity to imitate a real coupler. The main objectives for the pre-braze tuning are: 1) verify that both the field distribution and resonance frequency can be tuned to meet requirements; 2) determine the length of dipole-mode stabilizer rods to ensure a large frequency separation between the operating quadrupole mode and the nearest dipole modes.

The pre-braze tuning begins with all the aluminium tuners flush with the inner surface of the cavity wall. Before pre-braze tuning, the relative error of the operating quadrupole mode field is within  $\pm 25.0\%$ , and the dipole mode component is within  $\pm 12.8\%$  of the quadrupole mode. With the field distribution measured, the tuning program THURT [5] can calculate new insertion depth of tuners.

After several iterations, the relative error of the operating quadrupole mode field drops below  $\pm 2.0\%$  while the dipole mode component is about  $\pm 16\%$ . The dipole component is rather large, because we finally find that a wrong normalization method for the dipole field has been adopted during the pre-braze tuning. Figure 3 shows the corrected normalized field distribution of the quadrupole and dipole modes after pre-braze tuning.

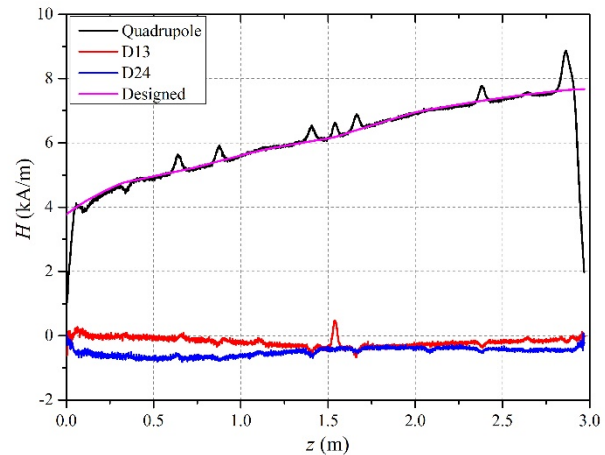


Figure 3: Normalized field distribution of the quadrupole and dipole modes after pre-braze tuning (22 °C, and 42% humidity).

After the field distribution and frequency are tuned, the frequency separation of the operating mode and adjacent dipole modes is adjusted by adjusting the length of the dipole-mode stabilizer rods. Figure 4 shows Measured frequency of operating mode and adjacent modes with the rod length. As the length increases, the frequency separation of the operating mode and adjacent dipole modes first increases and then decreases. The length of the dipole mode stabilizer rod is finally set to 150 mm, and the frequencies of the nearest dipole mode are separated from the operating mode by at least 5.25 MHz.

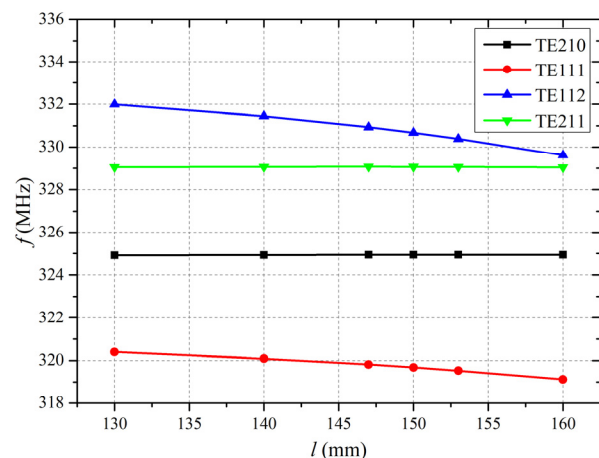


Figure 4: Measured frequency of operating mode and adjacent modes with the rod length.

## FINAL TUNING

The final tuning is carried out after the vanes of the RFQ are brazed together. Main objectives of the final tuning are: 1) determine the length of the copper tuners so that both field distribution and resonance frequency meet requirements; 2) determine the size and angle of the coupling loop in order to adjust the coupling coefficient to the target value.

The final field distribution is shown in Fig. 5. It can be seen that after the final tuning, the relative error of the operating quadrupole mode field is within  $\pm 2.7\%$ , and the dipole mode component is within  $\pm 1.9\%$  of the quadrupole mode. Quadrupole field error exceeds  $\pm 2\%$  only in a small part of the bunching section.

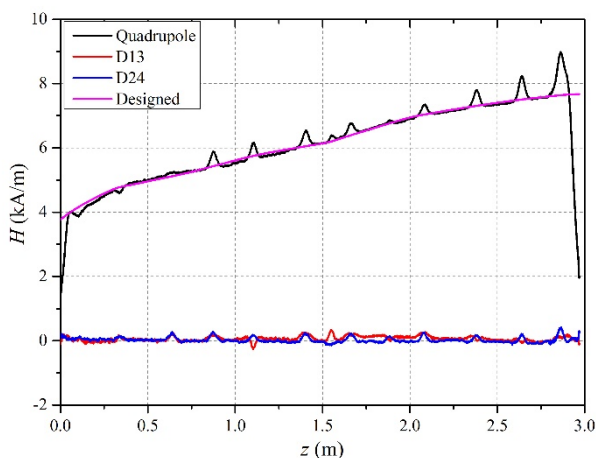


Figure 5: Normalized field distribution of the quadrupole and dipole modes after final tuning (23.7°C, with nitrogen fed into the cavity).

The resonance frequency of the operating mode is 324.89 MHz in the environment of 22°C and 10% humidity. The frequency spectrum is shown in Fig. 6. It can be seen that the frequency difference between the operating quadrupole mode and the nearest dipole mode is 4.85 MHz. And we have measured the resonance frequency of operating mode in the environment of 23°C and 0.25 Pa inside the cavity later. It shows that the frequency rises to 325.02 MHz, and the frequency becomes 325.01 MHz when the environment is converted to 25°C, vacuum. The difference between the frequency converted and target value is only 10 kHz.

The final coupling coefficient measured is 1.03 while the quality factor  $Q_0$  is 7300. Peak cavity power with this  $Q_0$  should be 457 kW and peak beam power is 18 kW. The desired coupling coefficient should be  $\beta = 1 + P_{\text{beam}}/P_{\text{cavity}} = 1.04$ . The attenuation of all pickups falls in -59.5 dB~ -60.5 dB area after adjusting.

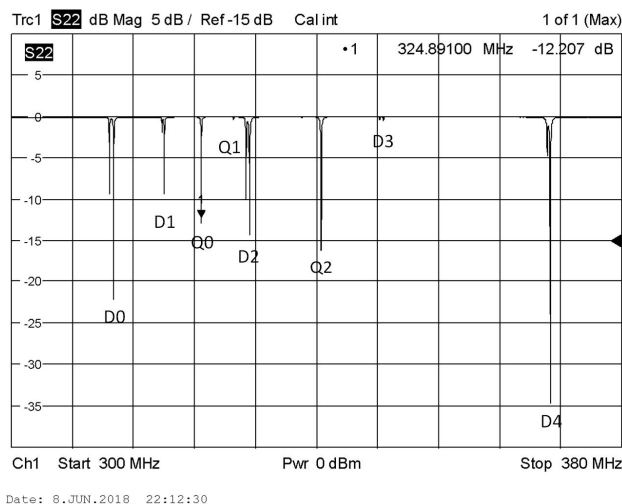


Figure 6: Frequency spectrum of XiPAF RFQ after final tuning (22 °C, 10% humidity).

## CONCLUSIONS

One 325 MHz four-vane RFQ accelerator with ramped inter-vane voltage has been manufactured for the 7 MeV linac injector of the XiPAF project. The machining, assembly, and RF tuning of the RFQ cavity has been completed successfully. The magnetic field distribution near the outer wall is obtained by the bead-pull method. The RFQ is tuned twice to meet the requirements, pre-braze tuning and final tuning. The relative error of the operating quadrupole mode field is within  $\pm 2.7\%$ , and the dipole mode component is within  $\pm 1.9\%$  of the quadrupole mode. The final measured coupling coefficient of the RF power coupler equals 1.03, with the desired value of 1.04.

## REFERENCES

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