RF measurements of Prototype Cavities for ATF2 Q-BPM

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Abstract

Prototype cavity BPMs for ATF2 Q-magnets were fabricated. We describe the results of the port measurement. f, Q_L, Q_0, Q_{ext} and β were checked. Q_{ext} was a little higher than the design, but it seems to be acceptable. A fine tuning of the cavity diameter is needed to adjust the frequency to be 6.426 GHz. It was found that the frequency changes a little and x-y isolation becomes worse, after brazing. Effectiveness of the frequency splitting dents was not clear, especially after brazing.

1 Prototype models

The following is the cavities we have tested.

- KEK without dents model.
- KEK with dents model.
- PAL without dents model. We measured before/after brazing condition.
- PAL with dents model. We measured before/after brazing condition.
- PAL with dents model (already brazed).

2 Measurement

Figure1 shows the definition of the port number.

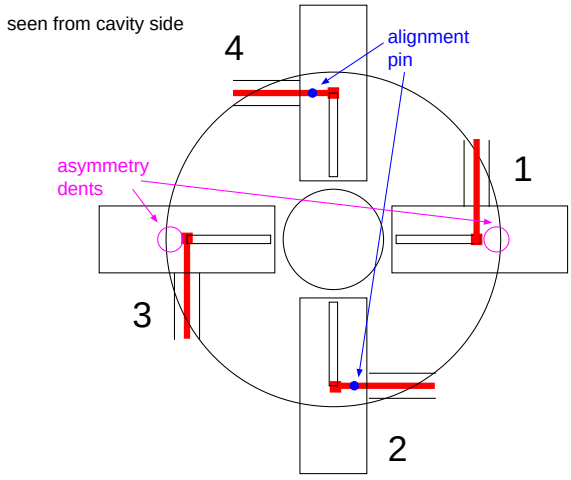

Figure 1: Definition of the port numbers.

We did S_{11} or S_{21} measurement using a network analyzer. From the frequency depencence curve obrained, we extracted frequency (f), band width (Δf) and S-parameter at resonance. The definition of Δf is explained in Figure 2 and Figure 3. It is a full-width of half-resonance.

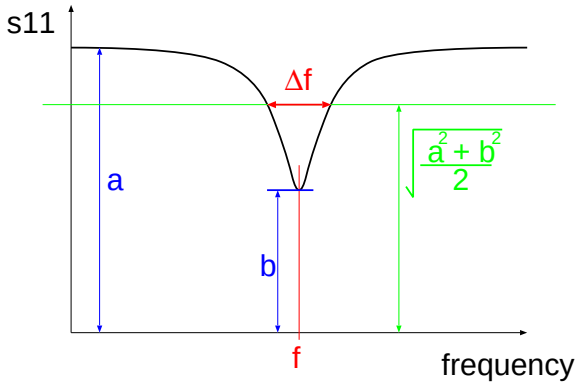

Figure 2: 1-port measurement case.

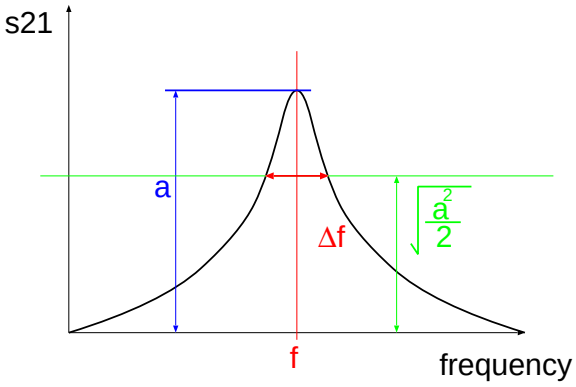

Figure 3: 2-port measurement case.

When we did the measurement, ports which were not used were terminated by 50 Ω loads. We extracted those values as;

- β was calculated from 1-port measurement by $\beta = \frac{1-S_{11}}{S_{11}}$. It could be calculated from 2-port measurement of opposite ports by $\beta = \frac{S_{21}}{1-S_{21}}$.
- Q_L was calculated by $Q_L = \frac{f}{\Delta f}$.
- Q_0 was calculated by $Q_0 = (1+\beta)Q_L$.
- Q_{ext} was calculated by $Q_{ext} = \frac{Q_0}{\beta}$.

The definition of x-y isolation is explained in Figure 4. From the ratio of S_{21} of opposite and transverse ports, the x-y isolation is defined to be

$$\text{isolation} = 20 \log \frac{S_{21}(\text{transverse})}{S_{21}(\text{opposite})} \quad . \tag{1}$$

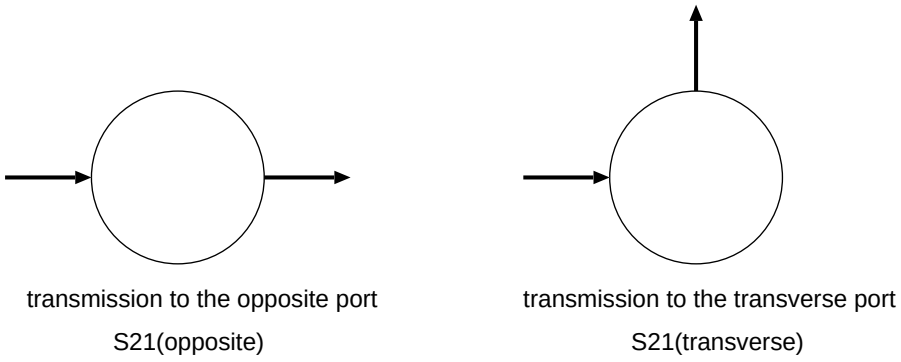

Figure 4: Definition of x-y isolation.

3 Result

3.1 Results of KEK test model (Without dents)

This measurement was done at KEK. The environment was 23 degee temperature and 40 % humidity. We tightened the compression than the previous report.

Table 1: KEK Without dents model

port	f (GHz)	Δf (MHz)	S	Q_L	β	Q_0	Q_{ext}
1	6.41834	1.60	0.842	4011	0.188	4765	25346
2	6.41828	1.55	0.827	4140	0.209	5005	23947
3	6.41834	1.55	0.842	4162	0.188	4944	26298
4	6.41828	1.57	0.819	4088	0.221	4991	22584
1-3	6.41834	1.78	0.160	3606	0.190	4291	22584
2-4	6.41828	1.78	0.167	3606	0.200	4327	21635
1-2	6.41828	1.16	0.0137				
2-3	6.41834	1.10	0.0129				
3-4	6.41828	1.15	0.0142				
4-1	6.41828	1.13	0.0139				

We loosened the compression of the cavity cover on purpose. Then, Q_0 decreased a little and x-y isolation was improved a little.

Table 2: KEK Without dents model (compression loosened)

port	f (GHz)	Δf (MHz)	S	Q_L	β	Q_0	Q_{ext}
1	6.41858	1.82	0.869	3526	0.150	4055	27035
1-3	6.41858	2.02	0.139	3178	0.161	3691	22925
1-2	6.41858	1.38	0.0055				

3.2 Results of KEK test model (With dents)

This measurement was also done at KEK. The environment was 24 degee temperature and 42 % humidity. We tightened the compression than the previous report. It improved Q_0 value a little. The roughness of the contact surface was improved by re-machining. It improved Q_0 value to the same level as the without dents case.

Table 3: KEK With dents model

port	f (GHz)	Δf (MHz)	S	Q_L	β	Q_0	Q_{ext}
1	6.41732	1.66	0.840	3860	0.190	4593	24173
2	6.41654	1.61	0.843	3985	0.186	4726	25409
3	6.41732	1.63	0.845	3937	0.183	4657	25448
4	6.41654	1.61	0.835	3985	0.198	4774	24111
1-3	6.41732	1.81	0.162	3545	0.193	4229	21912
2-4	6.41654	1.75	0.162	3667	0.193	4374	22663
1-2	6.41684	1.34	0.0074				
2-3	6.41690	1.42	0.0065				
3-4	6.41696	1.40	0.0074				
4-1	6.41690	1.46	0.0074				

We loosened the compression of the cavity cover on purpose. Then, Q_0 decreased a little and x-y isolation became worse.

Table 4: KEK With dents model (compression loosened)

port	f (GHz)	Δf (MHz)	S	Q_L	β	Q_0	Q_{ext}
1	6.41792	1.94	0.868	3308	0.152	3811	25071
2	6.41702	1.78	0.868	3605	0.152	4152	27322
2-4	6.41702	1.99	0.139	3225	0.161	3744	23256
2-3	6.41732	1.59	0.0075				

3.3 Results of PAL prototype model (Without dents)

This measurement was done at PAL. The environment was 25.1 degee temperature and 48 % humidity. We prepared a special jig to compress the cavity for the before brazing measurement.

Table 5: PAL Without dents model (serial no. 4), Before brazing

port	f (GHz)	Δf (MHz)	S	Q_L	β	Q_0	Q_{ext}
1	6.41764	1.20	0.741	5348	0.350	7222	20611
2	6.41759	1.07	0.744	6005	0.345	8074	23432
3	6.41764	1.11	0.739	5801	0.354	7855	22185
4	6.41763	1.13	0.752	5673	0.330	7543	22880
1-3	6.41771	1.12	0.242	5705	0.319	7526	23573
2-4	6.41766	1.10	0.233	5834	0.304	7607	25040
1-2	6.41769	0.72	0.0267				
2-3	6.41770	0.73	0.0273				
3-4	6.41725	0.71	0.0263				
4-1	6.41771	0.73	0.0267				

Table 6: PAL Without dents model (serial no. 4), Before brazing (compression loosened)

port	f (GHz)	Δf (MHz)	S	Q_L	β	Q_0	Q_{ext}
3	6.41896	1.70	0.824	3776	0.213	4580	21503
3-1	6.41887	1.87	0.147	3433	0.172	4023	23392
3-2	6.41880	1.26	0.0170				

After brazing test was done in the environment of 25.4 degee temperature and 47 % humidity.

Table 7: PAL Without dents model (serial no. 4), After brazing

port	f (GHz)	Δf (MHz)	S	Q_L	β	Q_0	Q_{ext}
1	6.42082	1.09	0.776	5864	0.289	7556	26177
2	6.42084	1.10	0.761	5824	0.314	7653	24371
3	6.42089	1.10	0.750	5864	0.333	7815	23487
4	6.42077	1.10	0.762	5864	0.313	7699	24599
1-3	6.42078	1.10	0.218	5824	0.279	7446	26731
2-4	6.42066	1.10	0.224	5864	0.288	7554	26206
1-2	6.42069	0.71	0.0080				
2-3	6.42065	0.69	0.0084				
3-4	6.42064	0.72	0.0085				
4-1	6.42061	0.71	0.0076				

3.4 Results of PAL prototype model (With dents)

This measurement was also done at PAL. The environment was 25.3 degee temperature and 50 % humidity.

Table 8: PAL With dents model (serial no. 1), Before brazing

port	f (GHz)	Δf (MHz)	S	Q_L	β	Q_0	Q_{ext}
1	6.41778	1.05	0.729	6117	0.371	8387	22591
2	6.41705	1.04	0.705	6148	0.419	8722	20835
3	6.41777	1.06	0.725	6076	0.379	8380	22099
4	6.41709	1.04	0.735	6185	0.361	8416	23332
1-3	6.41774	1.05	0.250	6112	0.334	8151	24434
2-4	6.41706	1.05	0.215	6111	0.273	7782	28473
1-2	6.41755	0.91	0.0016				
2-3	6.41736	1.14	0.0012				
3-4	6.41732	1.15	0.0008				
4-1	6.41728	1.01	0.0010				

Table 9: PAL With dents model (serial no. 1), Before brazing (compression loosened)

port	f (GHz)	Δf (MHz)	S	Q_L	β	Q_0	Q_{ext}
1	6.41848	1.85	0.853	3469	0.172	4066	23637
1-3	6.41844	1.78	0.148	3616	0.174	4246	24359
2-4	6.41753	1.65	0.165	3889	0.197	4655	23645
2-3	6.41818	1.73	0.0181				
4-1	6.41796	1.43	0.0152				

After brazing test was done in the environment of 24.9 degee temperature and 48 % humidity.

Table 10: PAL With dents model (serial no. 1), After brazing

port	f (GHz)	Δf (MHz)	S	Q_L	β	Q_0	Q_{ext}
1	6.42024	1.16	0.769	5559	0.301	7229	24058
2	6.41952	1.20	0.749	5350	0.336	7145	21294
3	6.42024	1.17	0.769	5487	0.301	7138	23729
4	6.41952	1.19	0.769	5383	0.300	6997	23345
1-3	6.42019	1.16	0.216	5523	0.275	7040	25626
2-4	6.41946	1.18	0.221	5452	0.284	7001	24635
1-2	6.41983	1.13	0.0177				
2-3	6.41982	1.07	0.0189				
3-4	6.41978	1.11	0.0171				
4-1	6.41983	1.09	0.0176				

3.5 Results of PAL prototype model (With dents), already brazed one

This measurement was also done at PAL. The environment was 23.8 degee temperature and 52 % humidity. The measurement was done before brazing also, however the procedure and difinition of the values were different. It was not easy to compare before/after brazing results. Here, we only note the result of after brazing.

Table 11: PAL With dents model (serial no. 3), After brazing

port	f (GHz)	Δf (MHz)	S	Q_L	β	Q_0	Q_{ext}
1	6.42051	1.16	0.771	5523	0.297	7163	24123
2	6.41978	1.16	0.766	5558	0.305	7256	23756
3	6.42051	1.17	0.744	5488	0.344	7374	21455
4	6.41977	1.16	0.762	5558	0.313	7297	23326
1-3	6.42049	1.15	0.227	5598	0.294	7242	24650
2-4	6.41973	1.13	0.220	5666	0.281	7259	25819
1-2	6.42006	1.12	0.0225				
2-3	6.42008	1.11	0.0236				
3-4	6.42004	1.15	0.0237				
4-1	6.42015	1.11	0.0226				

In order to check the amount of frequency shift due to air, we measured it again after it was pumped down to 10^{-3} torr. The frequency was found to be increased by 2 MHz in vacuum condition. The environment was 25.1 degee temperature and 48 % humidity.

Table 12: PAL With dents model (serial no. 3), After brazing, Vacuum

port	f (GHz)	Δf (MHz)	S	Q_L	β	Q_0	Q_{ext}
1	6.42241	1.17	0.769	5489	0.301	7139	23755
4	6.42165	1.15	0.763	5596	0.311	7334	23613
1-3	6.42240	1.16	0.229	5561	0.297	7214	24262
2-4	6.42165	1.14	0.210	5633	0.266	7132	26807
1-2	6.42196	1.12	0.0209				

4 Summary

The results were summarized in Table 13.

The compression tightness of KEK model is not as good as PAL models which have a special jig to compress. It limits Q_0 value of KEK models.

The inner diameter of the cavities were 53.822 mm in all the model. The frequency was found to be 6.417 GHz. It increased after brazing to be 6.420 GHz. Considering the frequency shift in vacuum (2 MHz), there still is 4 MHz disagreement with the target frequency. In order to adjust the frequency to be 6.426 GHz, the inner diameter should be modified to 53.788 mm.

The frequency difference of two dipole mode was about 700 kHz in the cases of with dents model.

It was found that the x-y isolation was degraded to around -20 dB even if it had been -40 dB before brazing.

Table 13: Summary

			Before brazing			After brazing		
model	dents	compression	Q_0	f (GHz)	isolation	Q_0	f (GHz)	isolation
KEK	without	tight	4926	6.41831	-21.6 dB			
KEK	without	loose	4055	6.41858	-28.1 dB			
KEK	with	tight	4688	6.41732, 6.41654	-27.1 dB			
KEK	with	loose	3982	6.41792, 6.41702	-25.4 dB			
PAL	without	tight	7674	6.41763	-19.0 dB	7681	6.42083	-28.7 dB
PAL	without	loose	4580	6.41896	-18.7 dB			
PAL	with	tight	8476	6.41778, 6.41707	-46.1 dB	7127	6.42024, 6.41952	-21.3 dB
PAL	with	loose	4066	6.41844, 6.41753	-19.5 dB			
PAL	with	tight	7800	6.417,	-23 dB	7273	6.42051, 6.41978	-19.7 dB