PETRA CAVITY VACUUM RF CONDITION WITH FIELD BALANCE MECHANISM FOR TPS STORAGE RING IN NSRRC *

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Abstract

In the first stage commissioning of TPS (Taiwan Photon source) storage ring in NSRRC, two room temperature Petra cavities will be used. At this commission stage, 100mA with 950keV beam loss is estimated to have 47.5kW beam loss for each cavity. In the meanwhile, the cavity loss at the specified 1.2MV of each cavity will be about 50kW. Therefore, coupling coefficient of 2.2 is required. Hence, the modification of the input coupler is done with the enhancement of its coupling coefficient of beta from 1.7 to 2.2 as well as added water cooling channels for two plungers' neck. Besides, due to the two-tuner system of Petra cavity, field-balance tuner control system is also developed in house. In RF vacuum processing up to 1.4MV, some modification of the tuner mechanical structure is also done to reach very high vacuum condition (lower than 5 nTorr) for storage ring requirement.

TPS STORAGE RING COMMISSION STAGE I: PETRA CAVITIES

Taiwan Photon Source (TPS) is a 3 GeV synchrotron radiation facility for advanced science research. For the RF systems in the storage ring, 2 sets of 300kW transmitter for two KEKB type SRF modules provide total 3.2MV RF accelerating voltage. However, the SRF module with such high accelerating voltage needs to avoid the particle pollution during initial beam commission of TPS system. Since the accumulated particles on the cold surface of niobium cavity will require several thermal cycling to diminish them and such thermal cycling will degrade the reliability and lifetime of indium sealing with the increasing risk of vacuum leak [1]. Hence, in the first stage of machine commission, the vacuum system with beam processing will make use of two sets of room temperature 5-cell Petra cavity providing total of 2.4-2.8 MV accelerating voltage for 100mA beam current. The required operating parameters for Petra cavities during stage I system commission is listed in Table 1.

ACCESSORIES SETUP

In order to insert particle accelerating cavities into system with less effort, the necessary accessories shall be integrated together with the cavity on a mechanical support. The layout of the Petra cavity is shown in Fig. 1. In order to maintain the pressure within very high vacuum level (<5nTorr), two 500-liter and two 300-liter sputtering ionization pumps are connected with cavity during baking. 500-liter ion pump are added with a T-tube at both ends of it while two 300-liter ion pumps are connected at pumping ports at cell #1 and #5. For frequency tuning, two plungers are also added at the plunger ports at cell #2 and #4. The input coupling port is connected with the doorknob and input coupler at the back side. The water cooling system is not shown in Fig. 1 to prevent the view to be too complex. The relative electronics are located at the bottom side of the support including plunger controller, temperature meters, water flow meters, ion-pump controller and interlock circuits.

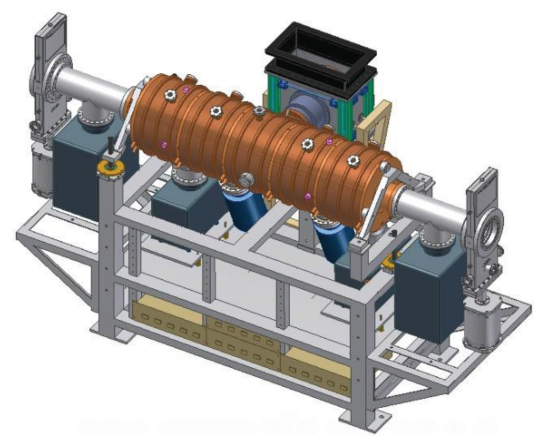

Figure 1: Layout of 5-cell Petra Cavity with All it's accessories.

Table 1: The Operating Parameters for 1st Stage TPS Machine Commission

Parameters	Value	Units
Frequency	499.65	MHz
Coupling coefficient	2.2	
Power	150	kW
RF gap voltage	1.4	MV
Beam current	100	mA
Vacuum	< 5	nTorr

Two Plungers and Field Balance

The main object of the plungers is to tuning the resonant frequency of cavities to match with the master clock of synchrotron system. For multi-cell cavities, the plungers' position also determines the field distribution at each cell of the cavity. The unbalanced field distribution between each cell within the cavity may cause the thermal problem while one side of cells have much stronger field strength than the other side.

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Field Balance Calibration Procedure

In addition to control resonant frequency, the dual plunger position controller for field balance shall also be applied for multi-cell cavity. Before applying the field balance mechanism, field distribution shall be measured by bead pull method [2] before integrating cavity with vacuum system. The first step is to adjust the position of plungers and verify that the field distribution within the multi-cell cavity is symmetrical to centre. To do this, we have added a ruler on the plunger's vertical side and align the copper stick used for touch upper/down limit switch as shown in Fig. 2. The position of copper stick for limit switch detection shall be adjusted carefully on the gear wheel of the plunger to let both of the plungers have identical position indicators. When manually adjusting the plungers' position, the resonant frequency is also controlled at 499.65 MHz. As the position of both plungers are identical and resonant at 499.65MHz, bead pull methods is thus applied by pulling a metal bead with diameter of 10mm through the cavity and sample the position and the corresponding resonant frequency. The square of the frequency drift caused by the metal bead at certain position indicates the relative E-field strength at that point [2]. As the mechanical position of the both plunger are identical, the E-field distribution shall be symmetrical to the centre of the cavity as shown in Fig. 3. The unbalance field is also applied with 10mm physical position difference of two plungers.

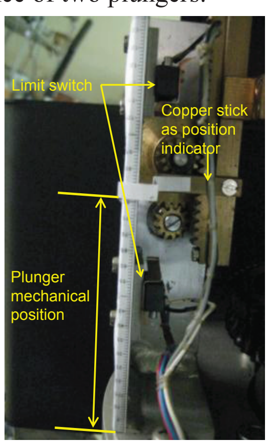

Figure 2: The ruler for plunger position monitor.

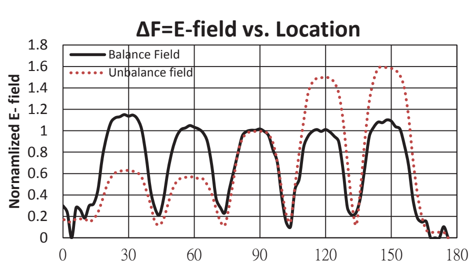

Figure 3: The balance and unbalance field distribution by control the position of two plungers.

In-situ Balance Measurement by Frequency Drift

The theory for bead pull method for E-field strength measurement can also be applied on indicating that if the plungers have the same protrude depth inside the cavity. If the positions of the both plungers are close to be identical, the movement perturbation for resonant frequency drift shall also be close. First, we adjust the position of the plungers to let the field distribution in Petra cavity to be unsymmetrical but still have resonant frequency of 499.65MHz as Fig. 3. Let the present positions of plungers as reference zero. Then we change the position of two plungers separately with up/down distance of 2mm and record the frequency drift caused by each plunger. The unbalance field distribution will make the frequency drift caused by two plungers to be different as Fig. 4. Later, the mechanical positions of both plungers are adjusted to be the same with field distribution as the balanced one in Fig. 3. The frequency drift caused by both plungers would be close as Fig. 5. In such way, the in-situ field balance is thus successful verified by just moving the plungers' mechanical position and taking the corresponding frequency drift.

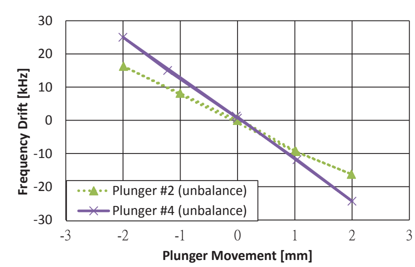

Figure 4: The frequency drift caused by the same movement of plungers in unbalance field distribution.

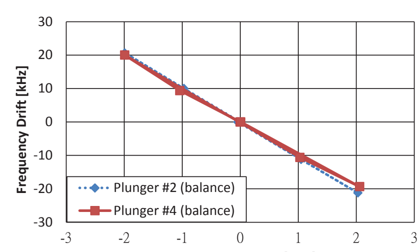

Figure 5: The frequency drift caused by the same movement of plungers in balance field distribution.

In-situ Balance Measurement by Field Strength

There are small coupling ports on each cell for monitoring the field strength within. The coupled power at such small coupling ports is called Pt here. However, the coupling coefficient needs to be carefully calibrated by S21 measurement from doorknob coupler to those small coupling ports. To have meaningful Pt value, the coupling coefficient shall be adjusted at field balance condition. When the in-situ balance is done by the mechanical position of both plungers, the coupling coefficients (S21) at cell #2 and #4 are calibrated to be identical. Just like the method described above by frequency drift, the movement of one plunger would cause the equal amplitude variation but in opposite directions of Pt at the small coupler #2 and #4. This way was originally applied by DESY [2] and used here for field balance verification as Fig. 6. At this stage, the coupling power at small coupling ports for Pt measurement can directly proportion to the actual field strength of each cell within the cavity.

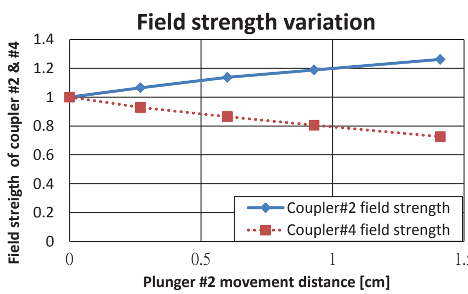

Figure 6: At balance field situation, the coupled field strength power would have the same amplitude variation but opposite direction at cell #2 and #4 by moving just one plunger at cell #2.

Plunger Neck Modification with Added Water Cooling Channel for Better Vacuum

During RF processing, the poor vacuum is found when certain RF power or above is fed into the Petra cavity. Some reasons are investigated such as the missing clean of the exquisite structure of the plunger, the missing clean of certain portion within the cavity as well as the thermal distribution during RF processing. The thermal spot was found at the necks connecting cavity and the plungers. High temperature would cause gas releasing phenomenon just like baking the cavity. However, in such baking-like situation, very high vacuum would be difficult to reach.

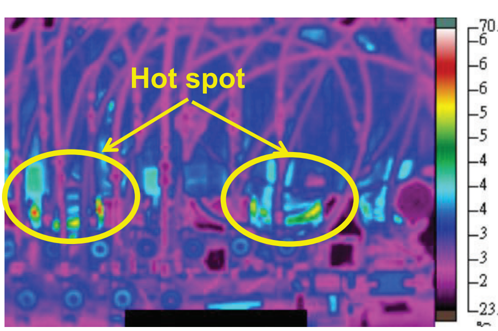

Figure 7: The thermal spot happened during high power RF vacuum condition.

Therefore, the modification of the plungers for better cooling is done by adding water cooling channel as shown in Fig. 8. By the way, the input coupler length is extended by 10mm as shown in Fig. 9 for improving the coupling coefficient from 1.7 to 2.2 for beam loading of 100mA.

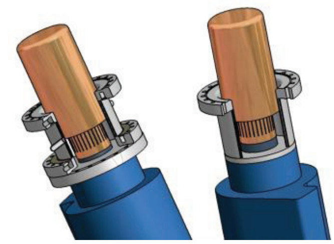

Figure 8: The plunger modification with cooling water channel added for better vacuum during RF processing (left figure) and original design (right figure).

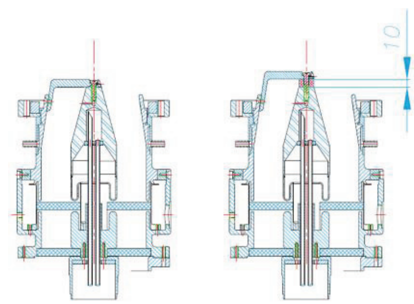

Figure 9: The coupling coefficient changing from 1.7 to 2.2 by extending the coupling length by 10mm.

In-situ Controller for Field Balance

During high power operation, the field balance shall be done automatically since the synchronization of both motors of the plungers as well as the potential meter for exact plunger position is not applicable. A field strength detection circuit for field balance compensation is added for automatically field balance control with the frequency locking Servo amplifier by monitoring Pt at cell #2 to #4.

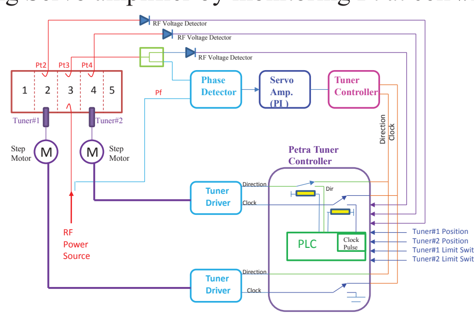

Figure 10: The automatic in-situ balance controller for real time separately control two plungers for balance field distribution with calibrated couplers on each cell.

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