HIGH POWER TEST OF SINAP X-BAND DEFLECTOR AT KEK

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Abstract

A crucial RF structure used for bunch length measurement for Shanghai X-ray Free Electron Lasers (SXFEL) at the Shanghai Institute of Applied Physics (SINAP), Chinese Academy of Science [1]. The design, fabrication, measurement and tuning have been completed at SINAP [2], and the high power test was carried out at Nextef of KEK with international collaboration. This paper presents the RF conditioning process and test results.

INTRODUCTION

For ultra-short bunch length measurement, it has proved that, x-band deflecting structure is an important RF unit with high gradient and resolution [3,4]. An X-band deflecting structure has been designed, fabricated, and tuned at SINAP [5], and tested with high power at least 45 MW at Nextef. This paper presented the test platform, RF conditioning process and the test results.

LAYOUT OF TEST PLATFORM

The X-band deflecting structure tested in the Nextef Shield-A at KEK based on the international collaboration among CERN, KEK and SINAP, and the operating frequency of KEK is 11.424GHz, the same as SINAP deflector. After oversea shipping to KEK, the preparing work before install, such as measuring of reflection coefficient, leak checking, and waveguide components check, as shown in Fig. 1

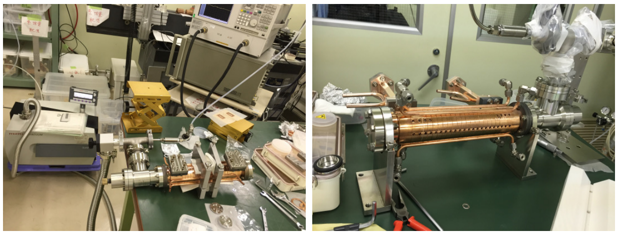

Figure 1: Preparing work before installation (a) leak checking, (b) waveguide components check.

After all the preparing work completed, the installment of SINAP deflector carried out. It is well known that the test platform of Nextef is used for X-band accelerating structures, such as the series of TD24, as shown in Fig. 2 (a). Therefore, the layout of deflector test standing almost as the same as TD24, but the waveguide changed a little because of the dimension difference between two structures, the layout of deflector as shown in Fig. 2 (b).

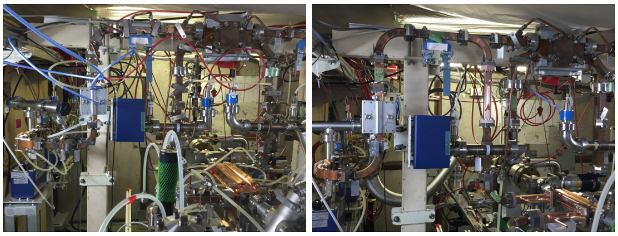

Figure 2: Layout of Nextef Shield-A, (a) TD24, (b) SINAP deflector.

To measure the power feed into and reflect, directional couplers used in the upstream of input coupler, and two faraday cups are installed in the upstream and downstream of deflector to measure dark current.

RF CONDITIONING PROCESS

Evacuation of gas carried out after installment of deflector and waveguide components, and RF conditioning process begin when the vacuum condition satisfied the requirement. The whole conditioning process shown in Figure 3, pulse width from 51 nanoseconds to 173 nanoseconds.

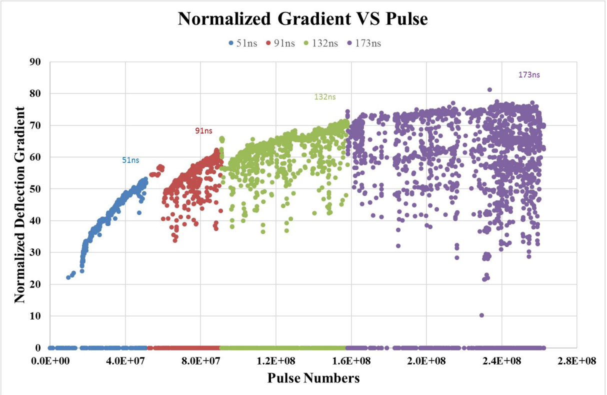

Figure 3: RF conditioning process of deflector

See from the conditioning process, totally 260 million pulses feed into and final deflection gradient exceed 75 MV/m which correspond to about 45 MW input power. As the conditioning time or pulses continue raising, the power of input is increasing slowly and even more breakdowns happen as the process running at 173 nanoseconds. An example of such data is shown in Fig. 4, the yellow curve is the input power feed into the deflector, and the blue curve is the reflection from the output coupler when no breakdown happens (a), or reflection from the cavity which breakdown happens (b). The green and violet curve are the transmission and dark current on the downstream of deflector. As

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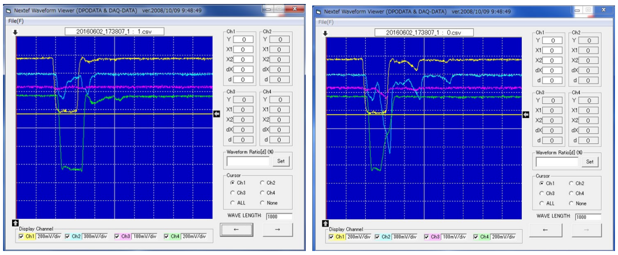
the results shown in Fig. 4, no visible dark current observed in the case of normal operation, whereas a weak dark current flash when breakdown happens.



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Display Channel ☑ Ch1 200mV/div ☑ Ch2 300mV/div ☑ Ch3 100mV/div ☑ Ch4 200mV/div

Figure 4: Different signals from X-band deflector high power test. (a) normal waveform and (b) waveform of breakdown (Yellow: input, green: transmission, blue: reflection, violet: downstream dark current).

BREAKDOWN POSITION ANALYSIS

Considering the limitation of power keeping raising, the analysis of breakdown position has carried out, and the breakdown position analysis as shown in Fig. 5.

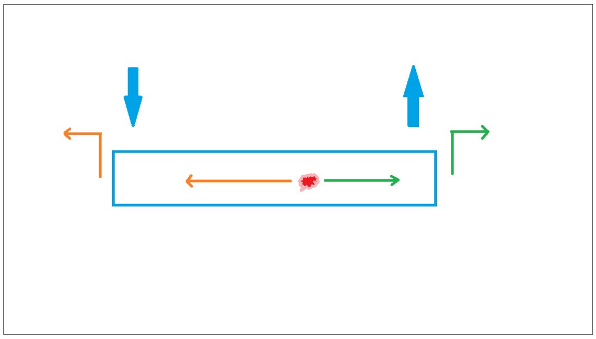

Figure 5: Diagram of breakdown event (Yellow: reflection wave, Green: transmission wave)

Assume the absolute time of breakdown is T and the position is z, therefore the time (T_R_s) of the reflection wave back to the input port could be described as,

$$T\_R_s = T + \int_0^z \frac{1}{vg}\,dz \tag{1}$$

And the time (T_T_r) of transmission wave to output port is,

$$T\_T_r = T + \int_z^L \frac{1}{vg}\,dz \tag{2}$$

Then, the time difference of reflection wave and transmission wave are,

$$\Delta T\_R_s = T + \int_0^z \frac{1}{vg}\,dz \tag{3}$$

$$\Delta T\_T_r = T + \int_z^L \frac{1}{vg}\,dz - T\_fill \tag{4}$$

Where T_fill is the filling time of the deflector. Hence the difference between reflection and transmission wave is,

$$\Delta T\_R_s - \Delta T\_T_r = \int_0^z \frac{1}{vg}\,dz - \int_z^L \frac{1}{vg}\,dz + T\_fill \tag{5}$$

Here define function $F(z)$ as the integration differential, then we have,

$$F(z) = \Delta T\_R_s - \Delta T\_T_r - T\_fill \tag{6}$$

F_((z)) is a quadratic polynomial usually, expressed as,

$$F(z) = A * z^2 + B * z + C \tag{7}$$

For SINAP deflector, which is constant impedance structure, the function can be write as,

$$\begin{aligned} F(z) &= \int_0^z \frac{1}{vg}\,dz - \int_z^L \frac{1}{vg}\,dz \\ &= \frac{2z}{vg} - \frac{L}{vg} - T\_fill \end{aligned} \tag{8}$$

Instead of the parameters of deflector, F_((z)) plotted in Fig. 6.

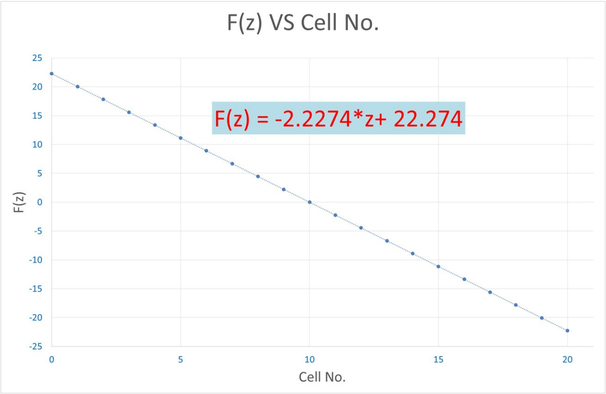

Figure 6: Function of position analysis vs cell number

and the results are shown in Fig. 7, most of the breakdowns concentrated on the upstream and downstream close to the couplers from the breakdown events distribution, and a small amount of breakdowns from the analysis program exceed the length of the deflector which need more analysis from the post processing.

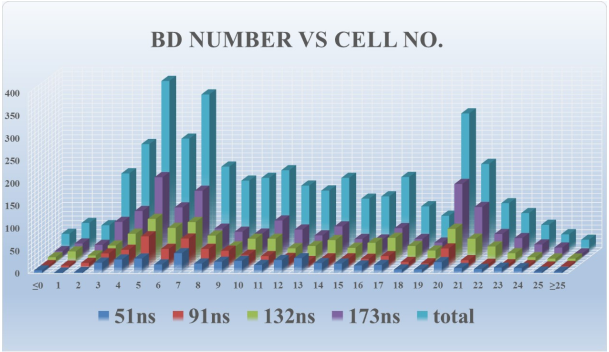

Figure 7: Breakdown events number vs cells

After the first brazing of the deflector between cells and couplers, found that there exists the problem of gas leakage, therefore a second brazing is required and solved the leakage problem finally. It is well known that, the electric field discharge is the main reason of breakdown events, and the leakage of silver-copper alloy flow into cells in the first brazing procedure, as described before, which directly increase the probability of breakdown greatly, thats why here is a hot cell in the downstream of the deflector, where the electric field is lower that the upstream. To determine the places of these hot cells, observation of hot cells by optical microscope and scanning electron microscope were developed. The cut view of SINAP deflector as shown in Fig. 8.

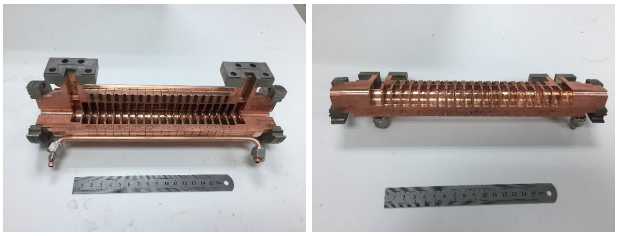

Figure 8: Cut view of deflector

CONCLUSION

The RF conditioning of SINAP X-band deflector has completed at KEK, and the results meet the requirement of bunch length measurement. Furthermore, the results of breakdown position analysis also done, which show that there are several cells breakdown frequently in the upstream and downstream of the deflector. Thus, more analysis of breakdown position will carry out, including observation of inner surface and position analysis program.

ACKNOWLEDGMENT

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