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# DESIGN, FABRICATE, AND TUNING OF X-BAND DEFLECTING STRUCTURE FOR CERN*

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*Abstract*

The first prototype of 20-cell x-band deflecting structure have finished the high power test at Nextef of KEK in 2016. Although the imperfection of coupler slots design, which prevent higher power feed into structure, most of the crucial performance parameters were measured and proved to have been met. The coupler slots of input and output coupler are 1mm thickness, that led to seriously pulse heating in these region. Hence, a new 20-cell x-band deflecting structure will optimize to check the performance under high power. Between the international collaboration of CERN, KEK and SINAP on high gradient technique, the optimized x-band deflecting structure will use the European frequency, and will tested in X-box of CERN. In this paper, the optimization, fabrication and tuning process will be described, then the RF conditioning will carry out in the recently.

## INDUCTION

X-band transverse deflecting structure will be used on shanghai Soft X-ray Free Electron Lasers (SXFEL) facility [1], and the first prototype have finished the high power test at KEK on the collaboration between CERN, KEK and SINAP. The test and analysis results proved the bad performance under high power test caused by too thin iris slots of couplers where lead pulse heating seriously. Under the background of international collaboration between CERN, KEK and SINAP on high gradient technique, a new X-band deflecting structure operate at European frequency (11.994GHz) is designed for CERN. The design, fabrication and tuning are introduced in this paper.

## DESIGN AND OPTIMIZATION OF DEFLECTOR

The first prototype of X-band deflector designed for SXFEL have finished high power test, which indicated that the modified poynting vector Sc on the irises and pulse heating on the slots between coupler cavity and waveguide need further optimize to improve the performance [2]. The optimization of the iris diameter and thickness can improve the power flow in the structure, which are the main parameters of this optimization. The simulation model as shown in Figure 1.

The iris diameter and thickness influence the Sc obvious, hence the optimize process is totally focus on these two parameters. Table 1 listed the simulation results of modified poynting vector, surface electric and magnetic fields varied by iris diameter and thickness.

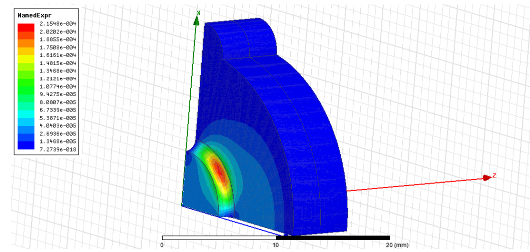

Figure 1: Simulation model of regular cell.

Table 1: Modified Poynting Vector, Surface Electric and Magnetic Field Results (50MW Input)

| Param-eters | Sc (W/mm$^2$) | E (MV/m) | H (KA/m) |
|---|---|---|---|
| a=5, t=2 | 6.60 | 169 | 576 |
| a=4, t=2 | 4.98 | 164 | 549 |
| a=4, t=2.6 | 4.46 | 153 | 489 |

In Table 1, *a* and *t* are iris radius and thickness, respectively. The results give an obvious conclusion of this deflecting structure, that the smaller diameter and bigger thickness decrease the modified poynting vector and the surface electric and magnetic fields. The final parameters of regular cell are listed in Table 2.

Table 2: Parameters of Regular Cell

| Parameters | Value |
|---|---|
| Operating frequency | 11.994 GHz |
| Phase advance per cell | 2Pi/3 |
| Length of cell | 8.3317 mm |
| Structure length | 230 mm |
| Iris aperture 2a | 8 mm |
| Iris thickness | 2.6 mm |
| Quality factor Q | 6222 |
| Group velocity Vg/c | -2.69% |
| Filling time | 21 ns |
| Attenuation factor | 0.751 |
| Input power | 50 MW |
| Peak surface electric field | 153 MV/m |
| Peak surface magnetic field | 489 KA/m |
| Peak modified Poynting vector | 4.5 MW/mm$^2$ |

The regular cells have been optimized and provide an outstanding performance on Sc and surface fields. Another important part is the couplers, which have two considerations to improve pulse heating. Firstly, the diameter of slots between coupler and waveguide instead by 3mm, that

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could reduce the surface magnetic field on the slots. Another way is reducing the power on the slots by dual feed coupler. The model as shown in Figure 2.

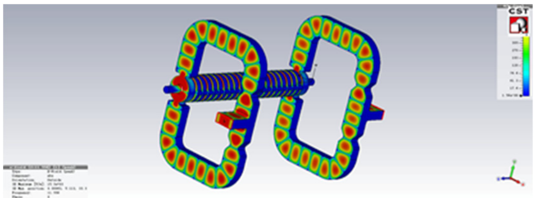

Figure 2: Dual feed coupler for CERN deflector.

## MECHANICAL DESIGN AND FABRICATION

The solid model as shown in Figure 3. The deflector has six water pipes in the cavity wall, and integrated two loop in and out in the end. The couplers are consisted with a box and cover, and each coupler contains two pins for pulling or pushing to tune frequency.

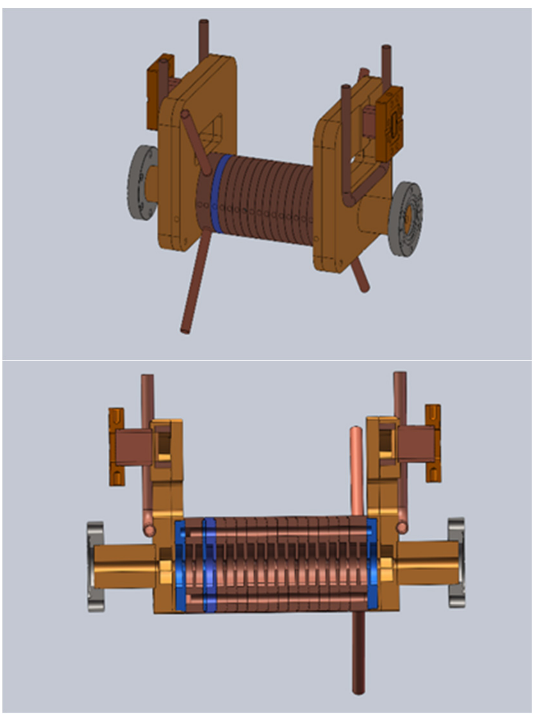

Figure 3: Solid model of 20-cell deflector, up: view at isoplane and down, cutting view).

Each coupler is consisted of three parts, box, cover and waveguide, and the box as shown in Figure 4.

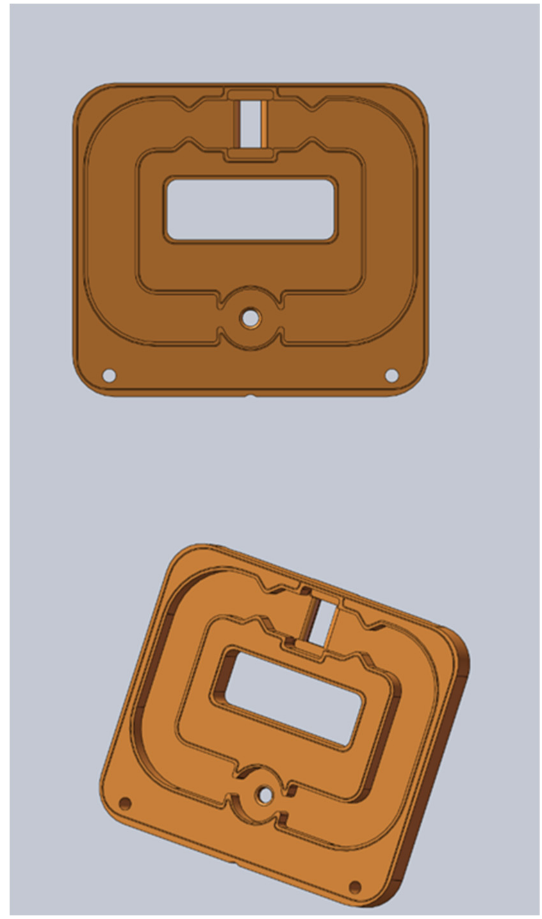

Figure 4: Part view of box of coupler.

Two tuning pins inserted into the wall from angle of 45 degrees direction to tune the frequency and coupling of coupler.

All the cells and couplers are fabricated on the lathe and milling machine, which has 5mm mechanical error.

## MEASUREMENT AND TUNING OF DEFLECTOR

Before high power test of the deflector, the cells and couplers should tune to working state. The improved non-resonant perturbing method, with "cage" type perturbing object, has been proved to be a good scheme for deflecting structure [3]. The first field distribution measured as shown in Figure 5.

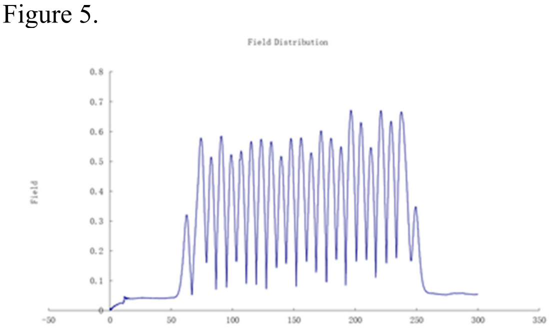


Figure 5: Field distribution measurement before tuning.

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The result is measured by "cage" through from output side to input side. The peak of electric field amplitude (Ey) located at the iris center, where phase varies slowly, but tuning of the cells is on the cell center with tuning pins inserted into the cavity wall. Hence, a simulation of the calculation procedure for tuning has carried out. The simulation model is based on the matched result of 20-cell deflector, and set any one or two or more cells under detuning state. Figure 6 (a) gives a simulation result of electric field distribution when the radius of 8# cell smaller than other cells, and Figure 6 (b) gives the calculation result.

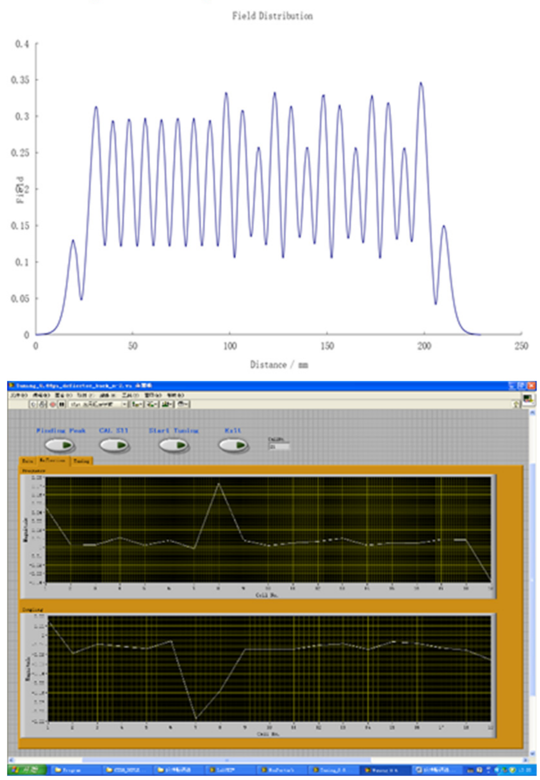


Figure 6: Simulation of field distribution and calculation results under 8# cell detuning.

Figure 7 gives a simulation of field distribution and analysis results under four cells detuning (8#, 9#, 11#, 13#), where 8# and 13# is higher than operating frequency, and 9# and 11# lower.

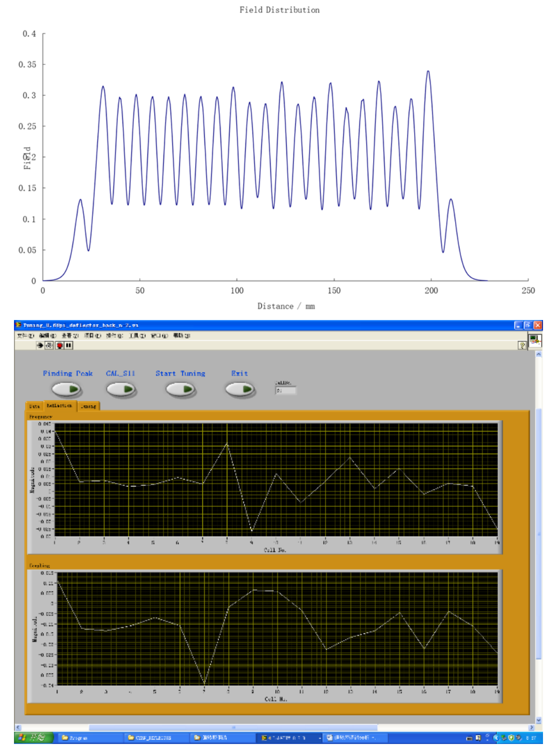


Figure 7: simulation and calculation results under four cells detuning

The results from the calculation software give the correct direction of cavity tuning procedure. Therefore, the measurement and tuning of deflector are solved.

## SUMMARY

The research on design, fabrication, tuning and High power test of first prototype have done in 2018, and several x-band deflecting structures will be used on shanghai soft X-ray free electron lasers. A new 20 cells x-band deflecting structure has been finished the design, fabricate and pre-tuning, also the simulation and analysis of tuning for deflector have discussed and proved to be useful. The final tuning will complete in recent days and then will be installed at X-box of CERN for high power test.

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