Transverse deflecting structure XFEL TDS INJ

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Abstract. The Transverse Deflecting System XFEL TDS System INJ has been built as the part of the European X-ray Free Electron Laser for longitudinal bunch profile and slice emittance measurements. The 0.7 long Transverse Deflecting Structure (TDS), as the part of the system, has been built on base of the disk-loaded structure with hybrid EH-wave, operating frequency 2997.2 MHz and pulse input RF power up to 3 MW. The structure has been built, tuned and installed in the XFEL Injector beam line. All design parameters have been got at low RF power level. Electron beam has been passed through the whole Injector including TDS.

1. Structure development

For the measurement of the longitudinal bunch profile, the slice energy spread and the slice emittance three TDS Systems are foreseen in the European XFEL, located in Injector, after Bunch Compressor 1 (BC1), and after Bunch Compressor 2 (BC2), with the beam energies 130 MeV, 600 MeV and 2.5 GeV in TDS Systems correspondently.

1.1. TDS type and parameter definition

TDS type and parameters are defined after detailed consideration of different conflicting demands. To allow single bunch operation, during short RF pulse (up to 3.1μs) the TDS should be filled with RF power quickly. It should provide required deflecting voltage during flat top operation and should be quickly released from RF power between RF pulses. TDS impact on regular beam due to both long range and short range wakefields should be minimized. The TDS length should be small to provide the minimal lattice perturbations. The S-band Travelling Wave (TW) constant gradient TDS, based on the disk loaded structure with $2\pi/3$ mode of hybrid EH11 wave is the most well balanced, reasonable and realistic choice for XFEL TDS.

Considering both RF parameters and particularities of technology in structure construction for the following TDS:

- disk-loaded TW structure with two stabilizing holes [1],
- disk-loaded TW structure with two peripheral recesses [2],
- two options of disk-loaded TW structures with oval aperture [2],

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- disk-loaded TW structure with resonant slot,
- standing wave deflecting structure [3],

and basing on:

- practically similar RF parameters for considered TW structures,
- fulfillment of TDS requirements with well-balanced parameters combination,
- level of development both for the structure itself and for all steps in the TDS construction and tuning,
- proven experience, including high RF power operation,

the TW structure with two stabilizing holes, shown in figure 1, with backward hybrid EH11-wave has been selected for realization in XFEL TDS. This structure is well known LOLA TDS, [1], with the RF parameters optimized to meet XFEL requirements. To reduce cost of construction, parameters of cells are selected to fulfill simultaneously requirements for all three XFEL TDS and for chosen option disk inner radius is Ra =21.71 mm, relative group velocity is β_g =-0.01587, attenuation constant is α =0.168 1/m, and normalized field is $\frac{E_d\lambda}{\sqrt{P}}$ =242 Ohm$^{1/2}$.

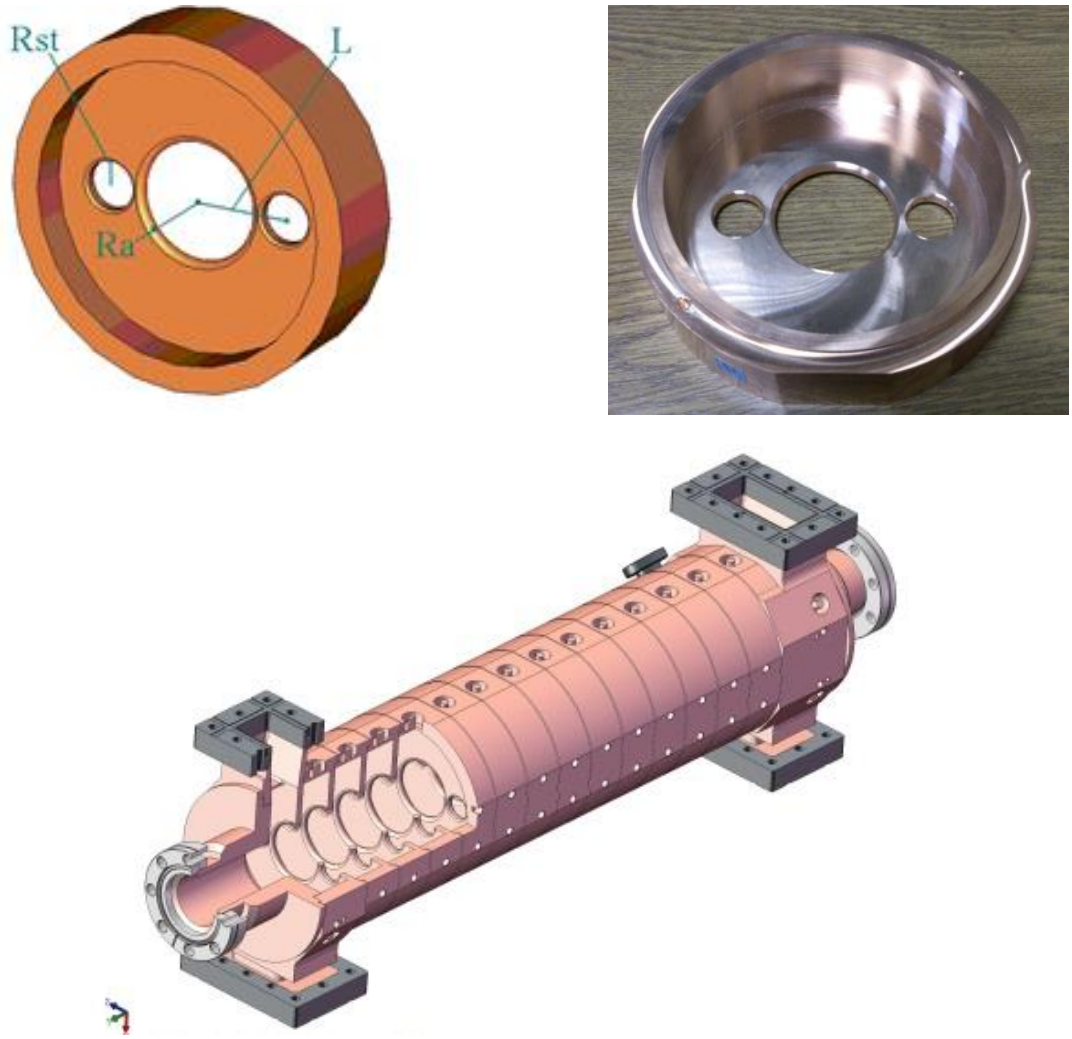


Figure 1. Deflecting structure. Artistic view of TDS cell, TDS cell for technical test, CAD model of TDS INJ structure.

2. TDS production.

The TDS parts were produced with NC machine tool, figure 2. The regular cells were tested in the 6-cells resonant model and, if required, were tuned by removing some material from inner surface of the cell. Finally the narrow spread in cell frequencies was achieved, equivalent to ~ 3 μ deviations in the outer cell radius. The RF coupler cells have been tuned in the whole structure assembled with the press. The tuned structure has been brazed in vacuum furnace by using 72%Ag-28%Cu alloy.



Figure 2. The cells in the production: machine tool, produced cells and the total structure brazed in furnace.

3. Tuning after brazing

The final RF tuning of the structure has been performed after brazing on the low RF level stand. Results are shown in figure 3. The structure is shown at the test stand in figure 4.

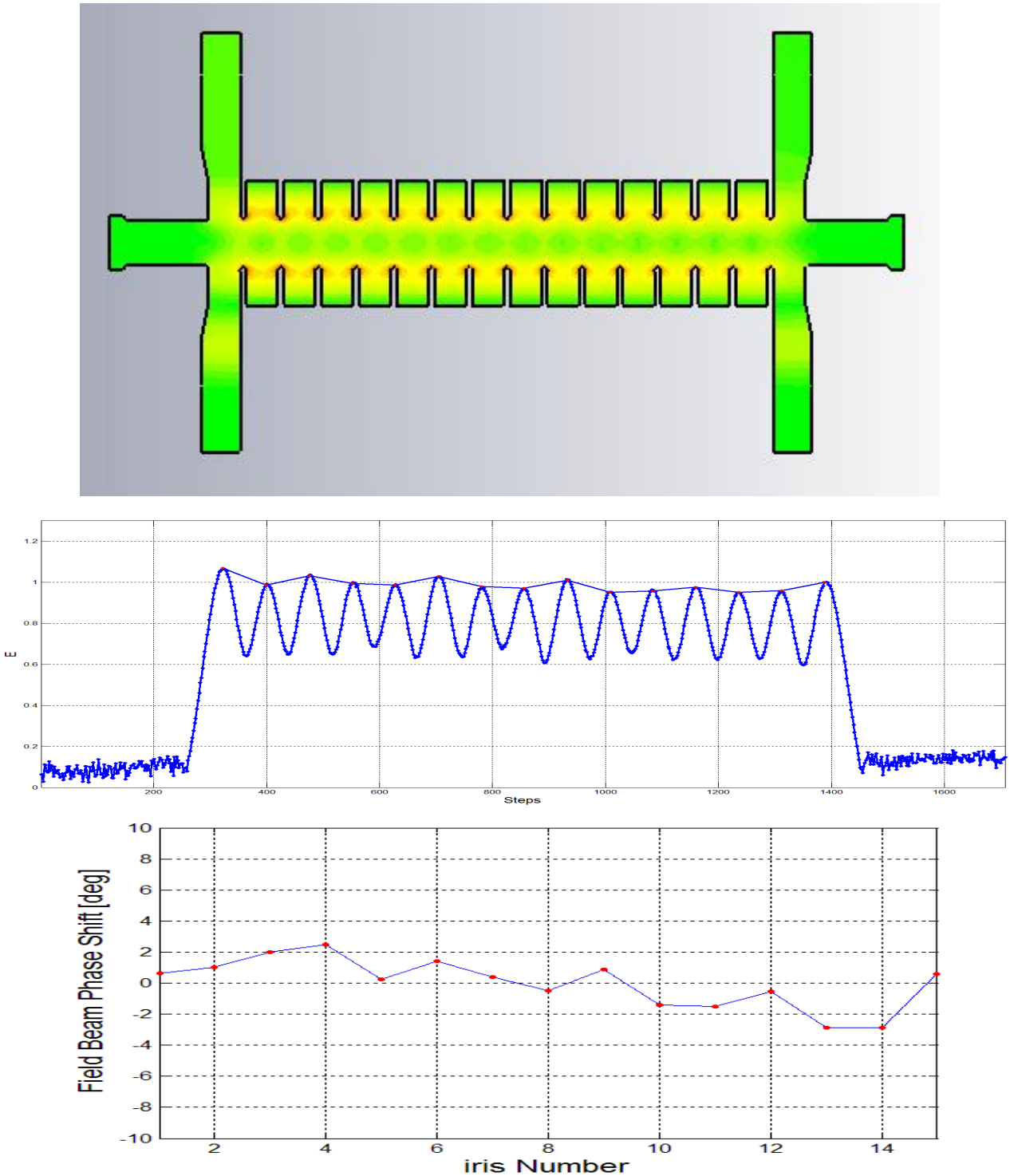


Figure 3. Low level RF test: complex amplitude, amplitude and phase of the electric deflecting field on the beam axis.

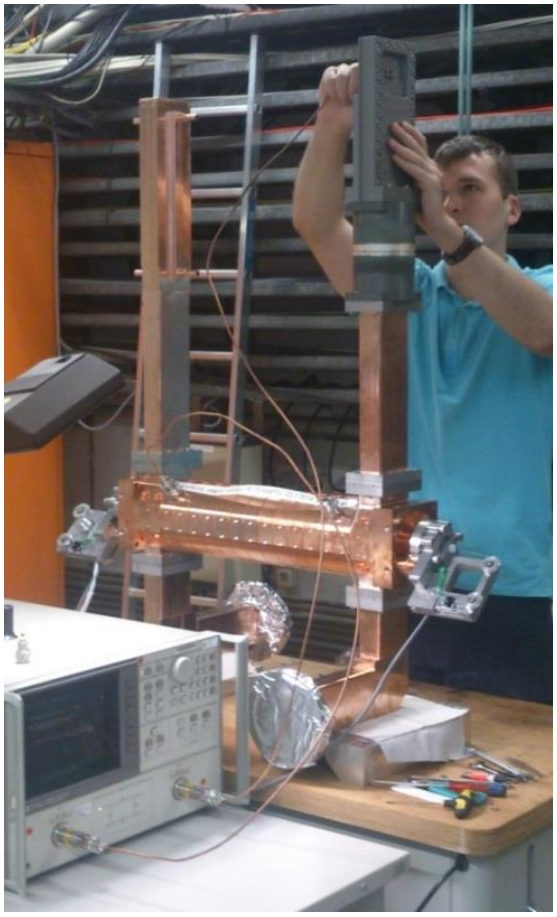


Figure 4. TDS structure at the test stand.



Figure 5. TDS structure installed in the XFEL injector tunnel.

Each TDS cell is equipped with two special hollows with the thread rod in center. This hollow has wall 2 mm thick, which can be bent either inside or outside the cell using special tools. This procedure allows us either increase or decrease cells frequency for the required structure tuning. Results, obtained in tuning of deflecting field distribution, are shown in figure 3. The measured reflection from the TDS in the frequency band is shown in figure 6.

In the TDS INJ structure RF probes for phase measurements are located in the cells #3 and #14. The measured transmissions to the antennas from input RF coupler are -66.0 dB and -66.8 dB respectively. Measured reflection from the structure with the waveguide window is S11=-41 dB at operating frequency.

4. Assembling of the deflector

The TDS INJ deflector includes all components connected to the ultra-high vacuum volume of the XFEL accelerator: TDS itself, waveguide RF window, two RF probes, RF load, part of straight waveguide, two ion pumps with adapters. The deflector was assembled on the steel girder. The structure is installed on the girder via two precise support units and there are special supports for the ion pumps.

After assembling in a clean room the whole deflector was tested for vacuum leaks. For transport to the injector tunnel, two aperture holes were closed with CFF blank-flanges. At the XFEL beam line, figure 5, the girder with deflector installed on two concrete pillars via special alignment units. Working with these alignment units allows us to align the structure on the beam axis.

Prototype of this structure has been built before [4] and it is tested at DESY PITZ facility now.

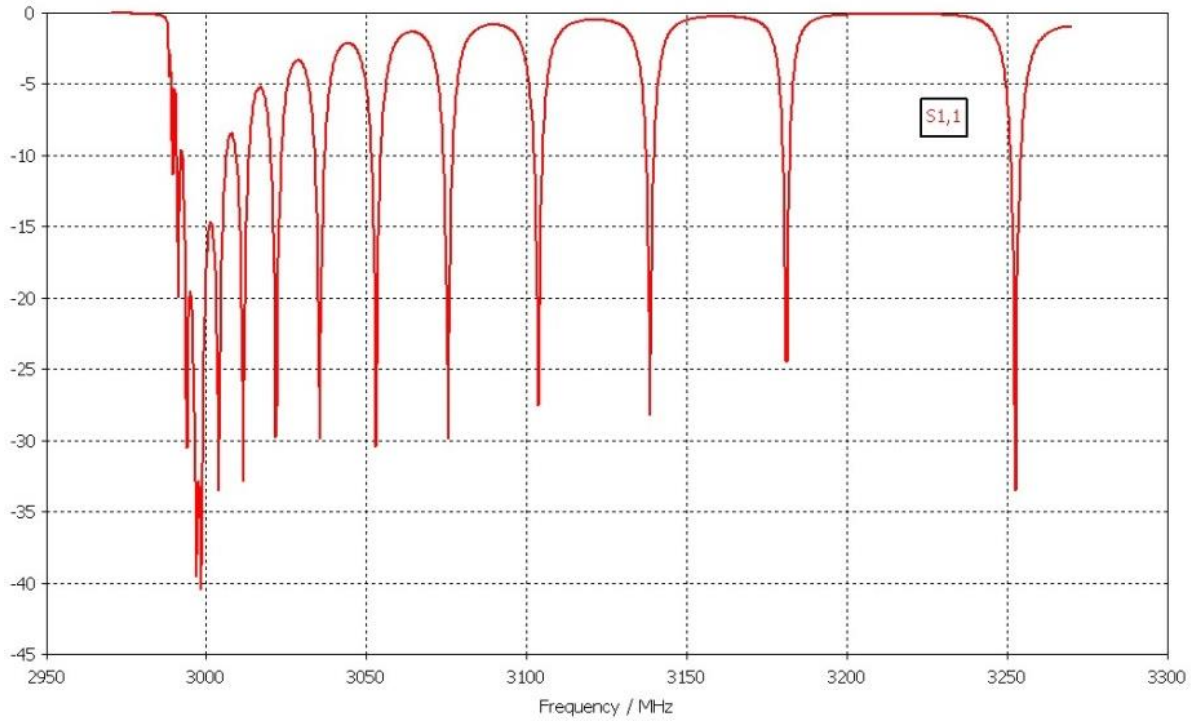


Figure 6. TDS structure at the test stand.

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