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Deflector for XFEL TDS BC1

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Deflector for XFEL TDS BC1

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Abstract. Deflector is the part of the Transverse Deflecting System TDS BC1 of the European X-ray Free Electron Laser (XFEL). TDS BC1 is located on the XFEL beam line at the coordinate z=206 m. This system is designed to monitor the longitudinal phase space and the emittance of the accelerated electron bunch after Bunch Compressor 1 (BC1) , where electron beam energy is 600 MeV. The deflector includes waveguide window, waveguide load, E-bend, ion pump adapters, two antennas, two ion pumps and 1.7 m long disk-loaded EH-hybrid mode deflecting structure. Operating frequency is 2997.2 MHz. Input RF power is up to 24 MW. The deflector has been manufactured, and all designed RF parameters have been obtained experimentally at low RF power level.

1. Introduction Design of TDS System BC1

The XFEL TDS BC1 is one of three deflecting systems in the European XFEL to monitor the longitudinal phase space and the emittance of the accelerated electron beam.

XFEL TDS BC1 is located in the XFEL accelerator tunnel, after the Bunch Compressor 1, at the coordinate z=206 m, where electron beam reaches energy of 600 MeV.

The TDS System BC1 consists of the deflector and High Power RF system (HPRF). The deflector includes all units, connected to the ultra-high vacuum volume of the XFEL accelerator: waveguide RF window, waveguide RF load, E-bend, ion pump adapters, two antennas, two ion pumps and the deflecting structure.

HPRF includes modulator, pulse transformer, klystron, solenoid, waveguide system, water cooling system, power supply distribution block, control and power supply cabinet.

Design of the TDS System BC1 (except control and power supply cabinet, which is located beside) is shown in Figure 1.

The deflector is assembled on the steel alignment girder in the clean room. The structure is installed on the girder via precise supporting units. After assembling the girder is transported from the clean room to the accelerator tunnel. The girder is installed on two concrete pillars via alignment units, allowing precise alignment of the structure to the beam axis.

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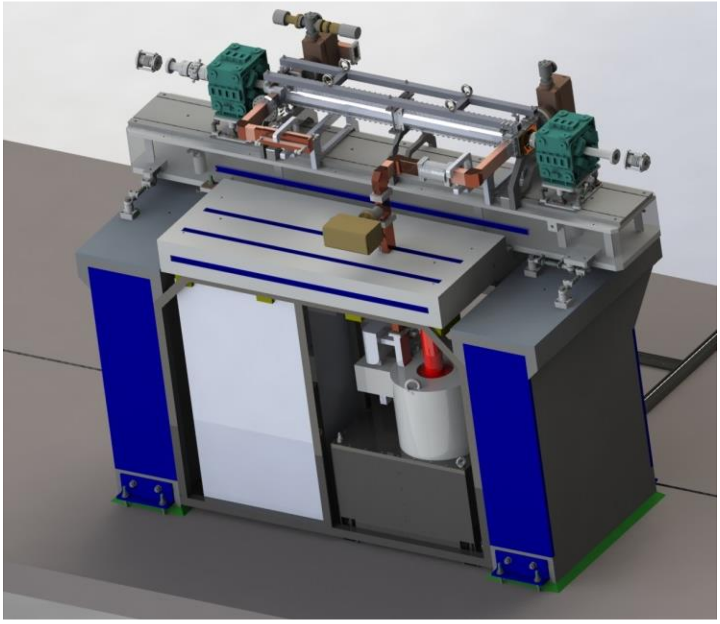


Figure 1. Design of the TDS System BC1.

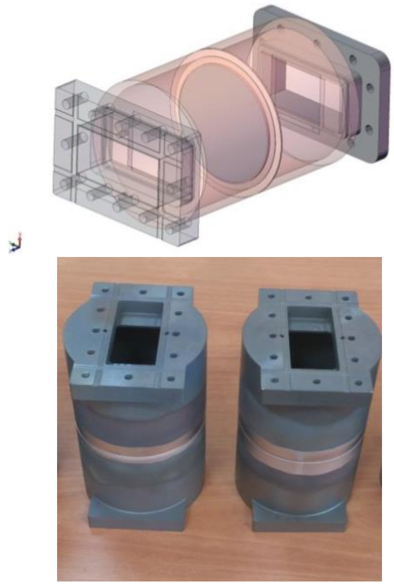
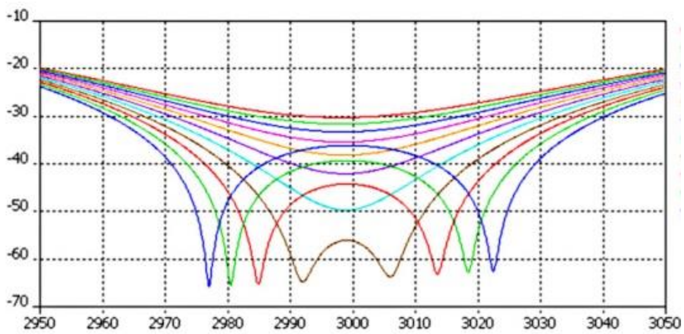


Figure 2. Waveguide window.

2. RF window

Special waveguide ceramic window has been designed for the TDS systems. This is double-mode window. 3D design and the picture of the window are shown in Figure 2. Designed and measured parameters of the window are shown in Figure 3.



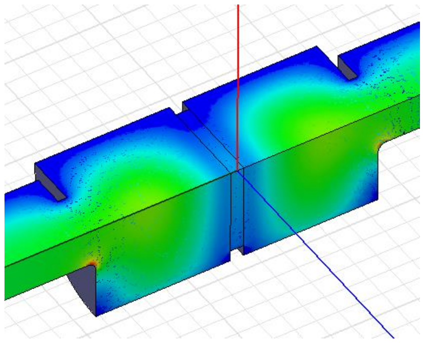


Figure 3. Window: reflection S11(f) for simulated tuning process (operating curve is brown), distribution of the complex amplitude of the electric field and reflection S11(f) measured in the built window. S11=-45 dB at operating frequency.

Advantages of the double-mode window are: low electric field at the ceramic surface (4 times less than in regular waveguide), i.e. low multipacting probability and wide bandwidth (70MHz@30dB and 40MHz@40dB).

3. E-bend

Waveguide E-bend is to be matched and to have low overvoltage on the inner surface. Designed variant is shown in Figure 4. Max electric field on the surface is just 1.5 times higher than in regular waveguide. The bandwidth is 150MHz@40dB. Reflection measured at the produced sample is S11=-47 dB.

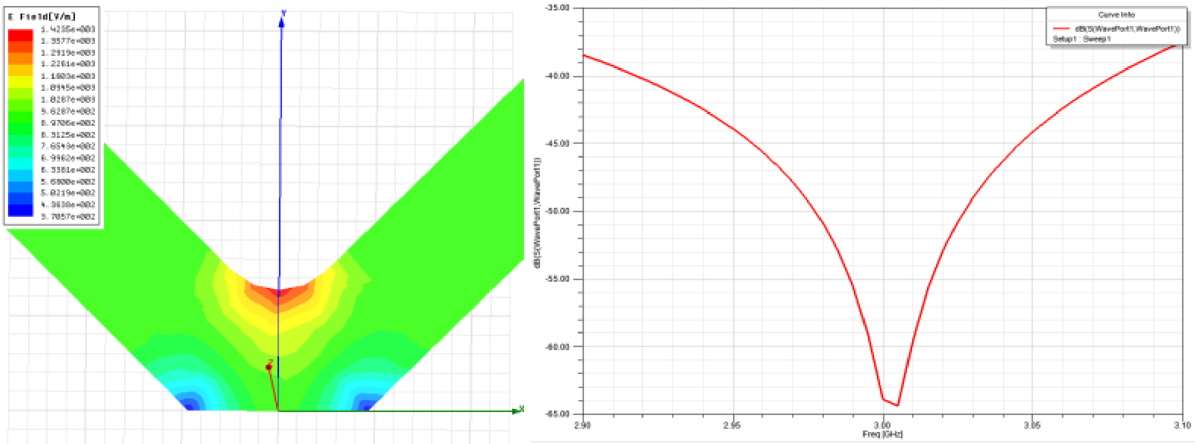


Figure 4. E-bend: distribution of the complex amplitude of electric field in calculation model and reflection S11(f).

4. RF load

The waveguide RF load has been developed specially for the XFEL TDS Systems. Main requirements for the load are a) the good matching in wide bandwidth, b) materials and connections in use to be acceptable for ultra-high vacuum volume of the XFEL accelerator, c) separation of the inner volume and water cooling volume via brazing, welding, ceramics and glass is not acceptable. It means that RF absorbing material is to be located inside the load and it has to be acceptable for ultra-high vacuum volume of the XFEL accelerator.

Sendust has been chosen for the load as an absorbing material. It is a ferromagnetic alloy, consisting of 85% Fe, 5.2-5.6 % Al, 9.4-9.8% Si, with conductivity of 0.6 μOhm·m. Special model of Sendust layer baked on the copper plate has been produced and tested in DESY vacuum group. DESY conclusion is: Sendust is acceptable for ultra-high vacuum volume of the XFEL accelerator.

0.3 mm thick Sendust layer is baked on the inner copper wall of the load. Outside surface of this copper wall is cooled with water flow.

The load is the waveguide with decreasing height on special function. Figure 5 shows calculation model with distribution of the complex amplitude of electric field and photo of load @ E-bend assembly. Measured reflection from the built load is S11=-47 dB. Prototype of the load has been built. It is tested at DESY PITZ TDS stand now [1].

5. Deflecting structure

S-band TW operation constant gradient disk loaded structure with 2π/3 mode of hybrid EH11 wave has been chosen for XFEL TDS. Main parameters are f=2997.2 MHz, length L=1.7 m, aperture radius Ra =21.71 mm, group velocity β_g =-0.01587, attenuation α =0.168 1/m, $\frac{E_d\lambda}{\sqrt{P}}$ =242 Ohm$^{1/2}$.

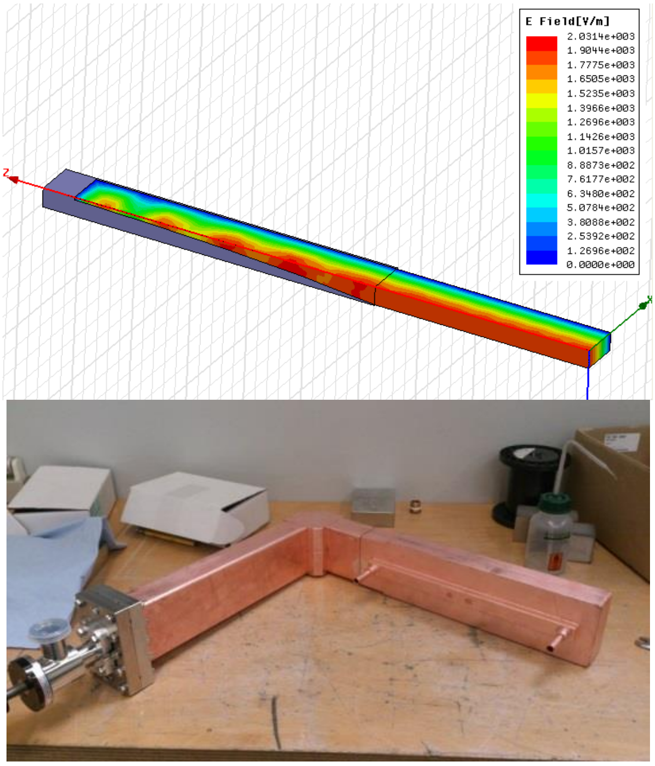


Figure 5. The load: distribution of the complex amplitude of electric field in calculation model and photo of load @ E-bend assembly.

The structure is analogous to the structure for XFEL TDS INJ [2]. Prototype of the structure has been built [1] and it is tested at PITZ facility now. The design model of the structure is shown in Figure 6.

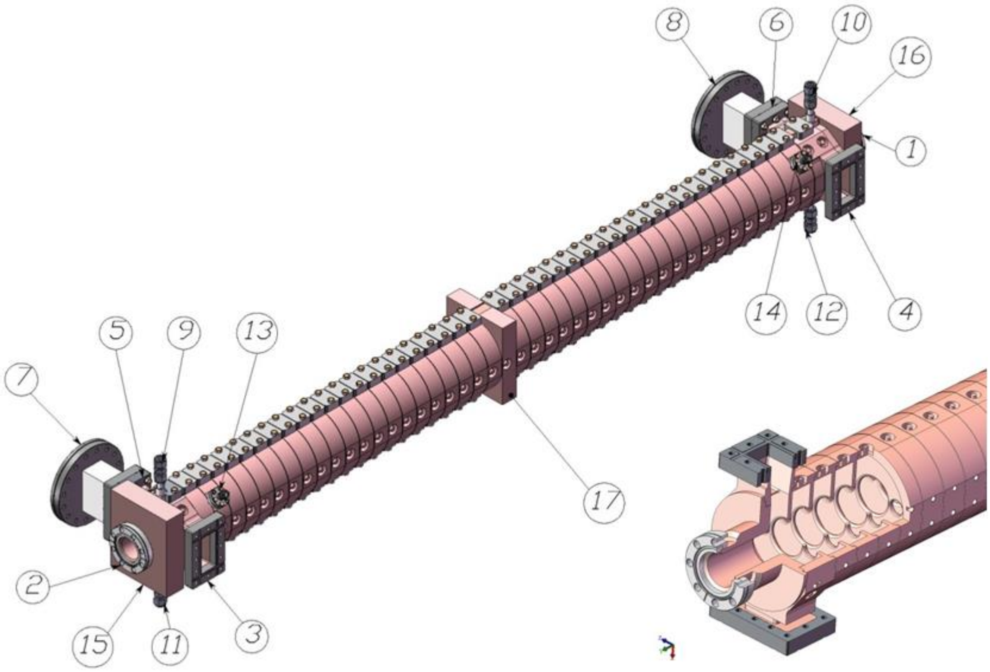


Figure 6. Design model of the structure.

The deflector has been manufactured and tuned. It is shown in Figure 6. The manufactured structure and measured distribution of the electric field are presented in Figure 7

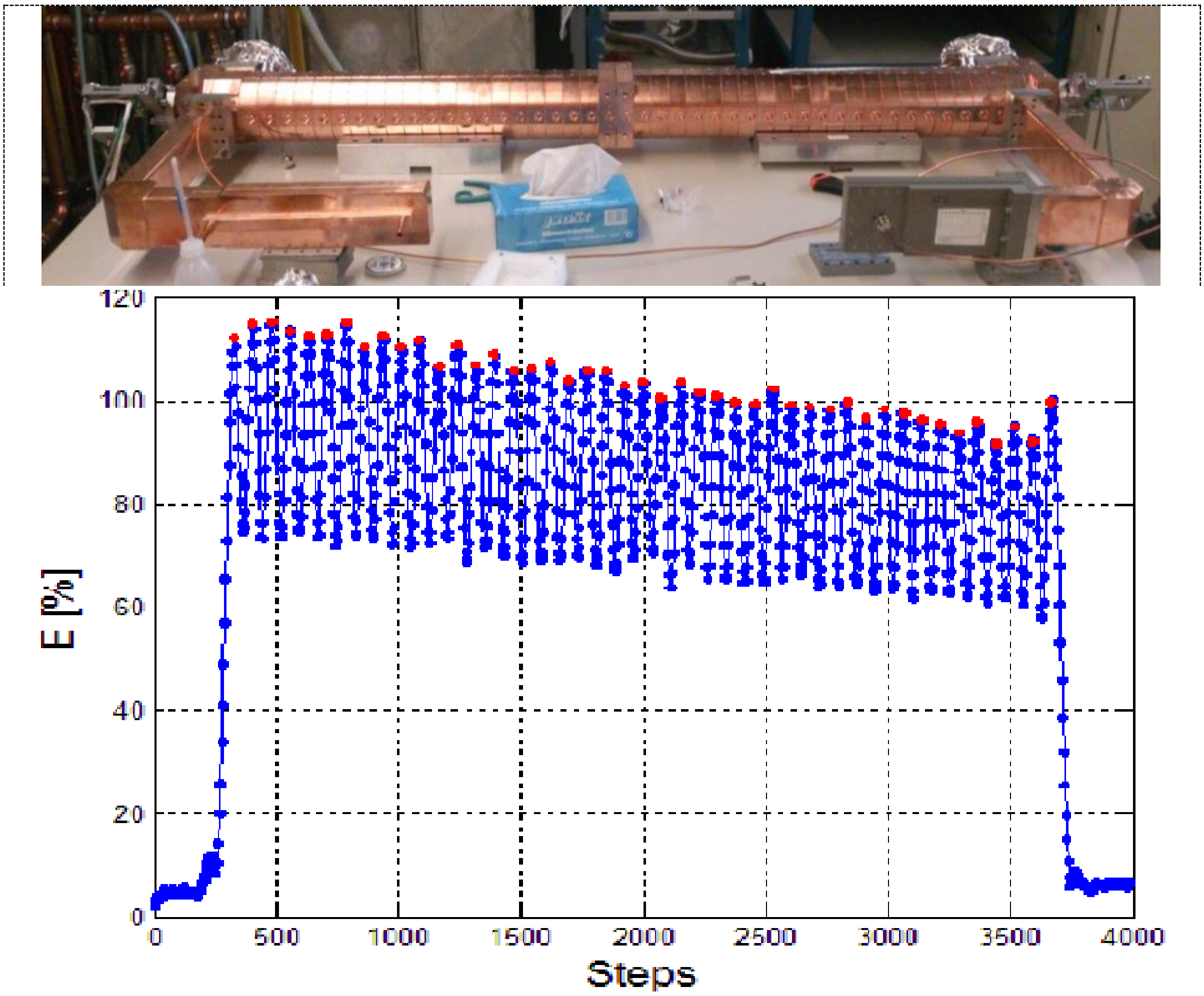


Figure 7. Manufactured deflector structure and measured distribution of the amplitude of the deflecting electric field.

References

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