LAYOUT OF THE PITZ TRANSVERSE DEFLECTING SYSTEM FOR LONGITUDINAL PHASE SPACE AND SLICE EMITTANCE MEASUREMENTS

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Abstract

Transverse Deflecting Systems are designated for longitudinal beam diagnostics of ultra-short electron bunches in modern FEL projects. At the European XFEL, Transverse Deflecting Systems are foreseen at three locations. A prototype of the TDS in the injector of the European XFEL will be installed at PITZ, which is identical in terms of deflecting structure, low-level RF system and powerful RF hardware. This PITZ TDS has the aim to prove the required performance for all TDS subsystems as well as serve as a diagnostics tool for PITZ. Results of the test cells measurements of a S-band traveling wave structure are presented, showing very good agreement with calculated parameters. RF power supply system, including a 3 MW klystron and other RF hardware, is described. Solid state 130 kV Marx modulator has been developed for the klystron feeding. 10 kV module of the modulator has been built and tested. The modulator allows for high voltage shutdown within pulse.

INTRODUCTION

To achieve and maintain stable operation of the European X-Ray Free-Electron Laser (XFEL), three dedicated diagnostic sections are foreseen for the characterization and stabilization of the electron beam. The diagnostic sections will be located in the injector and downstream of the two bunch compressor sections BC1 and BC2.

The slice emittance measurement will be accomplished by using transverse deflecting systems (TDS) in combination with fast kickers that deflect individual bunches onto 4 off-axis viewing screens for beam size measurements [1]. The temporal resolution is determined by the deflecting voltage of the TDS and electron beam size at the location of the TDS. The aim is to achieve a temporal resolution of 200 fs in the injector, 20 fs in BC1, and 15 fs in BC2.

DEFLECTING STRUCTURE

The relatively short TDS sections are designed based on constant impedance disc-loaded waveguide (DLW), traveling wave structures, operating in 2π/3 mode. To decrease design and construction costs, all TDS have the same cell dimensions (see Fig. 1). Several DLW based structures [2,3], differing in the solution of stabilization for the plane of deflection [4,5,6], have been considered based on:

- fulfillment of XFEL TDS requirements with well balanced parameters combination;
- level of development for the structure itself and for all steps in the TDS construction and tuning;
- proven experience, including high RF power operation.

The type of structure with two stabilizing holes (LOLA [2] structure) has been chosen for XFEL TDS.

Calculated RF parameters for 16 cells (including an RF input and output cell) of PITZ TDS are f=2997.2 MHz, β_{gr}=-0.01587, $r_{sh\perp}$=16.85 MOhm/m, Q=11780, α=0.168 1/m, $E_{0\perp}\lambda/\sqrt{P}$=242 Ohm$^{1/2}$, deflecting voltage V=1.7 MV at input RF power P=2.5 MW.

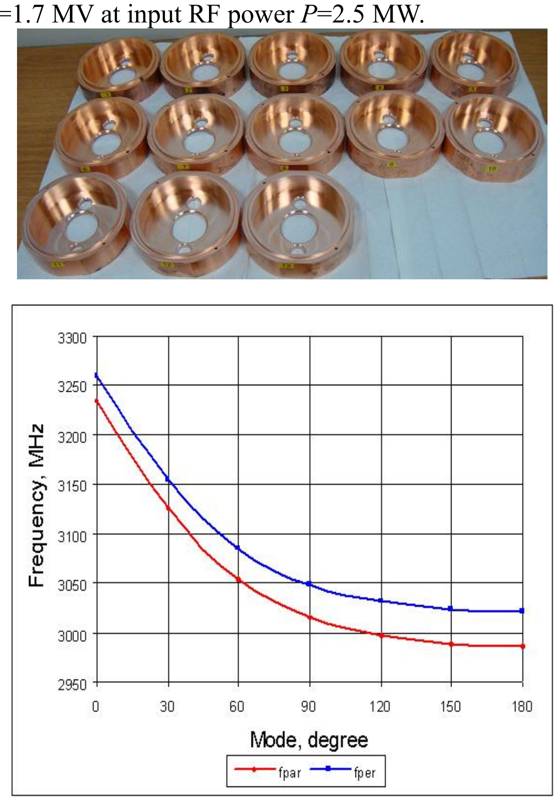


Figure 1: Cups of PITZ TDS and calculated dispersion curves of operation (f_o) and non-operation (f_{no}) polarization.

TECHNICAL DESIGN OF THE PITZ DEFLECTOR

The technical design of the PITZ deflector is shown in Fig. 2. The input and output coupler of the TDS are identical.

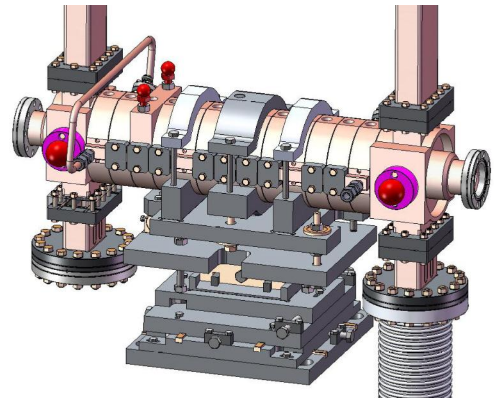


Figure 2: Technical design of deflector.

RF COUPLERS

The coupler includes the waveguide and vacuum pumping ports. It provides symmetrical distribution of electric field in the RF coupler cell with respect to the beam axis (Fig. 3).

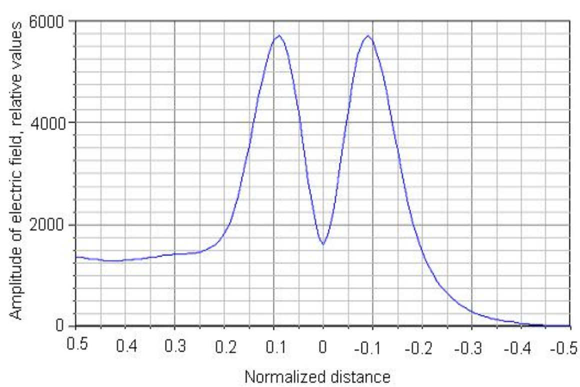


Figure 3: Radial distribution of electric field in the RF coupler cell (along input waveguide axis).

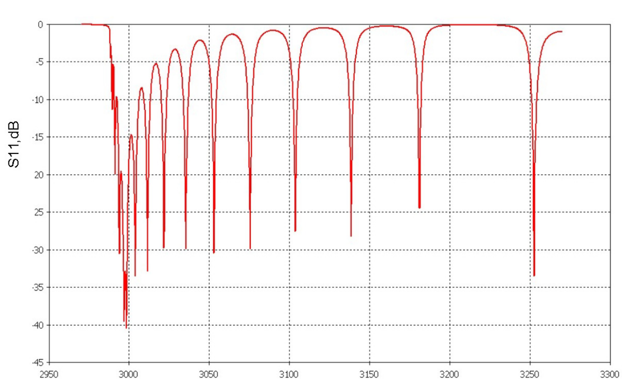


Figure 4: Reflection S_{11} in the input port in frequency band.

Simulated dependence of reflection from input RF port is plotted in Fig. 4 and S_{11} value at operating frequency is about –40 dB.

Calculated deflecting field distribution along the deflector axis *z* is shown in Fig. 5. The field drop is very smooth, which means that the couplers are matched. The drop corresponds to designed attenuation of α=0.168 1/m in the structure.

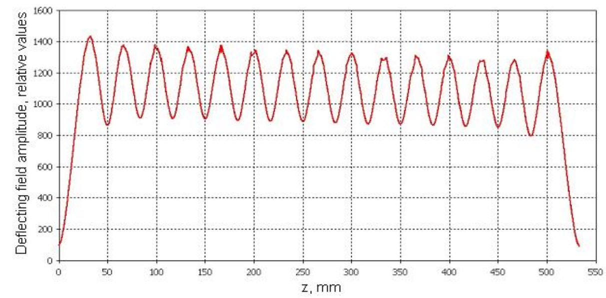


Figure 5: Calculated amplitude of deflecting field along the deflector axis *z*.

Calculated phase shift per cell in the deflector is shown in Fig. 6. The phase shift in *N* cell is equal to the phase in *N* cell minus the phase in (*N*-1) cell. The difference both in field amplitude and in phase shift for first and last cells from regular structure is natural, because RF coupler cells differ from the cells of regular structure.

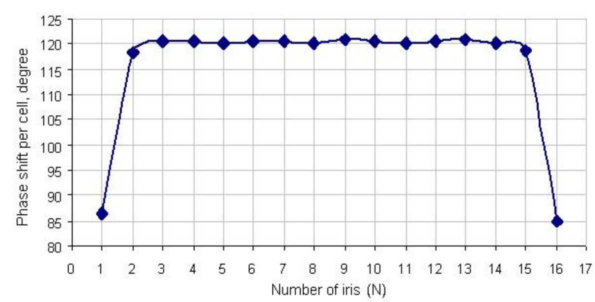


Figure 6: Calculated phase shift per cell in the deflector.

RF MEASUREMENTS OF THE CELLS

The frequencies of the manufactured cups have been checked using the 3-cell copper test model. The frequency deviation is –0.159…+0.117 MHz (peak to peak). It is equivalent peak to peak deviations in the cell radius +2.4 ….-3.2 µm.

The resonance frequency, measured in the 12-cell structure including 11 regular TDS cups and two half-cells of the test model (Fig. 7) at $2\pi/3$ mode is *f* =2997.078 MHz at t=26^{0}C, *H*=70%, *p*=990 mbar. Required frequency is 2997.077 MHz at the same environmental conditions.

Measured unloaded Q-factor is *Q*=11044, which is 94% of calculated value.

The deflector tuning after brazing is foreseen in the range ±2 MHz by using thin wall bending.

Figure 7: The stand for the structure test.

SOLID STATE MODULATOR

Design of RF generator with modulator, klystron and cabinet is shown in Fig. 8.

The 130 kV, 100 A, 4 μs solid state Marx modulator has been developed to feed the klystron. It consists of 14 modules. The output voltage is a sum of the module voltages.

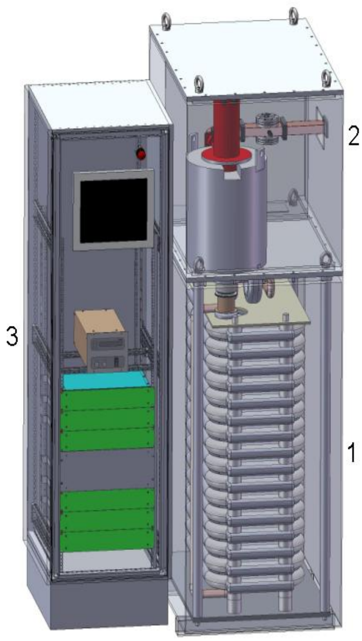
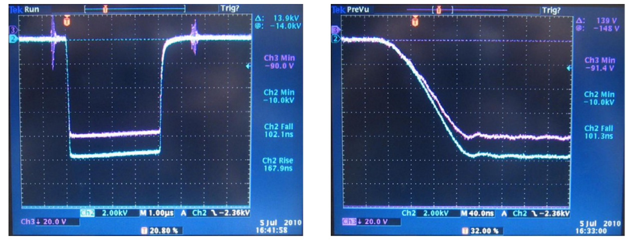


Figure 8: Design of RF generator including modulator (1), klystron (2) and cabinet (3).

The rise time can be controlled in the range 100-200 ns.

The modulator interlock allows high voltage shutdown within pulse in case of the breakdown in the klystron for the protection of the klystron and the modulator.

The oscillogram at module test is shown in Fig. 9.



a (1 μs/div) b (40 ns/div)

Figure 9: Pulse shape (a) and pulse rise shape (b). Pink is the current (20 A/div). Blue is the voltage (2 kV/div).

PITZ TDS LAYOUT

General sketch of the PITZ TDS is shown in Fig. 10. RF power supply system includes 3 MW CPI klystron VKS 8262HS, RF amplifier, LLRF, 40 m long waveguide system.

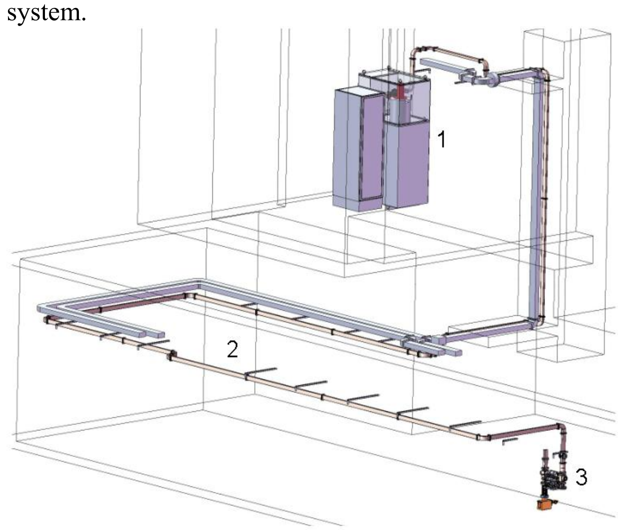


Figure 10: Design of PITZ TDS. 1 is RF generator, 2 is waveguide line, 3 is deflector.

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