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RF DEFLECTOR FOR PITZ

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Abstract

A detailed characterization of the longitudinal and transverse phase space of the electron beam provided by the Photo Injector Test Facility at DESY in Zeuthen (PITZ) is required to optimize the electron beam for Free-Electron Laser (FEL) applications. By means of a RF deflector the transverse slice emittance and the longitudinal phase space can be analysed. The proposed structure is a travelling wave RF deflector working on the TM_{11}-like mode at 1.3 GHz.

RF DEFLECTOR DESIGN

A travelling wave (TW) structure was chosen for the RF deflector (RFD) for PITZ because it has a short filling time which permits to analyse single bunches in a bunch train [1]. A detailed analysis of the PITZ diagnostics with RF deflector and its influence on the longitudinal beam phase space is reported in [1]. The analysis shows the possibility to achieve a time resolution of about 0.5 ps, and a longitudinal momentum resolution of 10^{-4}.

The main RF deflector design parameters are reported in Table I. In Fig. 1 the complete HFSS [2] simulated structure is shown. The two input/output coupler cells have two pumping ports symmetric with respect to the coupling windows in order to reduce the non uniformity of the field distribution in the coupler regions. As we will see in the following it's possible to minimize the integral of the unwanted longitudinal electric component on axis by turning one of the two coupler 180° around the z axis.

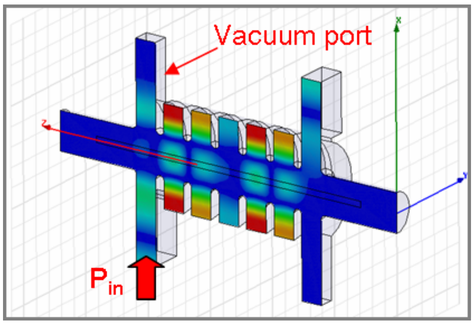

Fig. 1: HFSS simulated structure.

The single cell with the E and H electromagnetic field profiles are reported in Fig.2, while in Table II we have reported the cell dimensions. Two options for the iris aperture have been investigated: the option with large iris allows having a better uniformity of the deflecting field has a function of the transverse position of the particles in the beam while the option with small iris is more efficient. The single cell main parameters are reported in Table III. The transverse shunt impedance is defined as follows:

$$Z_T = \frac{\overline{E}_T^2}{P_{in}}$$

where P_{in} is the input power and:

$$\overline{E}_T = \frac{|V_T|}{L_{cell}} = \frac{\left|\int_0^{L_{cell}} \left(\tilde{E}_x - c\tilde{B}_y\right) \cdot e^{i2\pi f_{RF}\frac{z}{c}} dz\right|}{L_{cell}}$$

Table I: RF deflector design parameters

	Value	Unit
Frequency (f_{RF})	1.300	GHz
Filling time	≈ 0.2	μs
$P_{in\ MAX}$	9.1	MW
$V_{T\ MAX}$ @ $P_{in\ MAX}$	1.8	MV
Available length	≈1	m

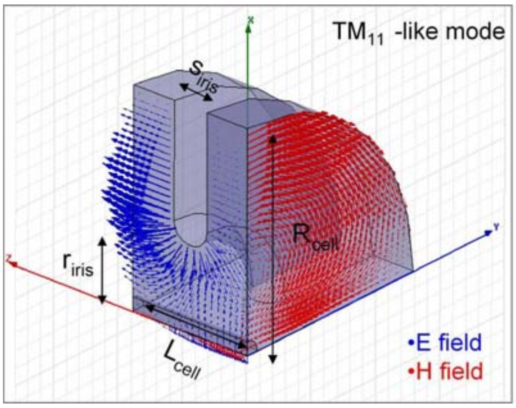

Fig. 2: single cell of the RFD.

The plot of the transverse E and B fields (in magnitude and phase) and the total transverse deflecting force as a function of the longitudinal coordinate are reported in Fig. 3.

Table II: single cell dimensions (in mm)

Dimensions	Large iris	Small iris
r_{iris}	50	32
R_{cell}	129	135.5
s_{iris}	22	22
L_{cell}	76.87	76.87

Table III: single cell main parameters.

	Large iris	Small iris
Z_T [kΩ/m^2]	~ 7.65*10^2	~ 1.30*10^3
Quality factor Q	18100	19900
Group velocity v_g/c	~ -0.022 (backward)	~ -0.020 (backward)
Attenuation constant α [1/m]	~ 0.034	~ 0.035
Mode operation	$2\pi/3$	$2\pi/3$
Max surface E field (E_s/E_T)	3.5342	2.0546

The input/output couplers have been designed following the technique illustrated in [3] and the final reflection coefficient is below 0.02. The magnitude of the transverse electric and magnetic fields in the 13 cells structure, are reported in Fig. 4.

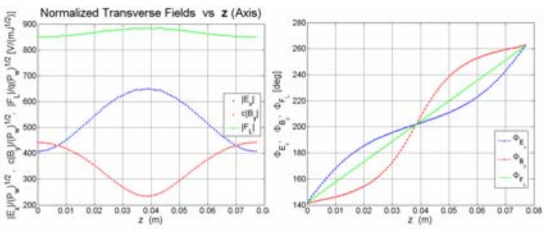

Fig. 3: transverse E and B fields and total transverse force (magnitude and phase).

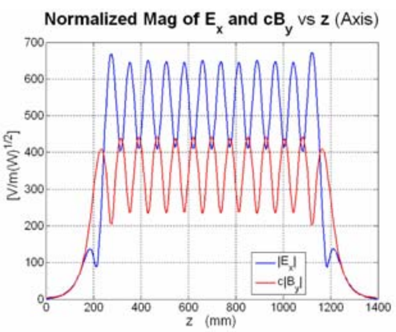

Fig. 4: Magnitude of the electric field in the 13 cell structure (small iris case).

The total voltages experienced by the synchronous particle passing on-axis and off-axis through the deflector and the longitudinal electric field component seen by the synchronous particle along z axis, has been calculated for both large iris and small iris cases. The results in the case of large iris case are reported in Figs. 5-7. Fig. 5 shows the deflecting voltage as a function of the injection phase ($\Phi_{inj}^{\epsilon_{long} meas}$ is the optimum injection phase for longitudinal emittance measurement). The maximum transverse deflecting voltage achievable with 4.38 MW of input power is about 1.8 MV. The integral of the longitudinal electric field on axis (Figs. 6-7) is zero and this is due to the fact that the input/output couplers are 180° rotated. Off-axis the integral is different from zero because of the field configuration of the TM_{11}-like deflecting mode [4].

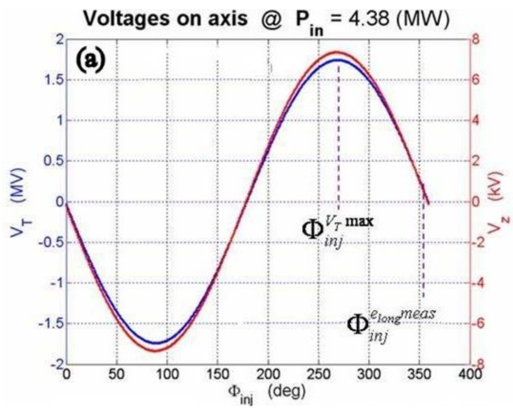

Fig. 5: on-axis transverse (blu curve) and longitudinal (red curve) voltages as a function of the injection phase (13 cells structure with large irises).

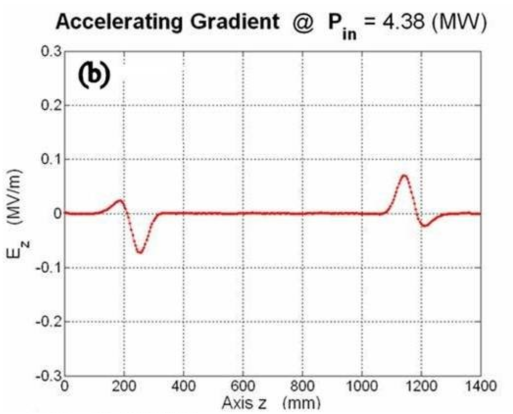

Fig. 6: longitudinal electric field on axis as a function of the longitudinal position (13 cells structure with large irises).

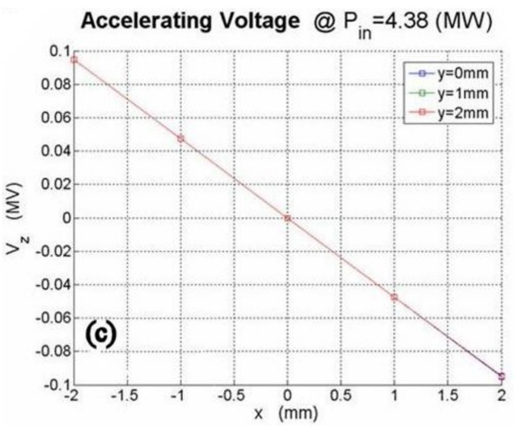

Fig. 7: Accelerating voltages as a function of the horizontal (x) and vertical (y) coordinates (13 cells structure with large irises).

The transverse deflecting voltage is uniform near the axis, as shown in Fig. 8. This implies a uniform beam deflection.

Similar results have been obtained in the small iris case.

To shift in frequency the 90 degree tilted polarity of the TM_{11}-like deflecting mode two metallic rods have been inserted in each cell from iris to iris. The simulated single cells structure is reported in Fig. 9.

In Fig 10 we report the resulting dispersion curves showing that, in frequency, the two modes are separated more that 50 MHz in both large and small iris cases.

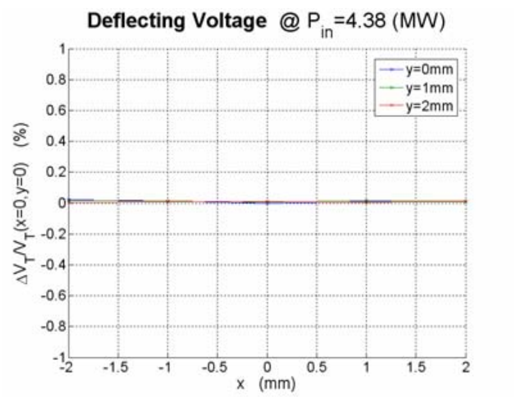

Fig. 8: Beam deflection as a function of the transverse coordinates.

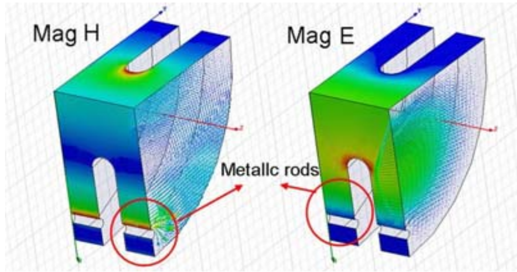

Fig. 9: RFD cell with metallic rods.

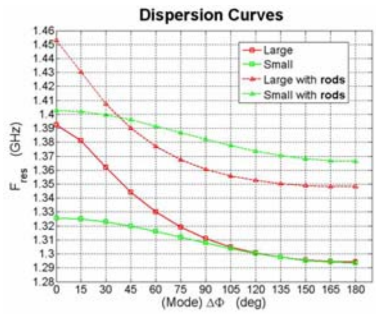

Fig.10: Dispersion curves of the working mode and 90° tilted polarity.

CONCLUSIONS

The PITZ RFD at 1.3 GHz has been designed. Two options with small and large iris aperture have been considered. The option with large irises allows having a better uniformity of the deflecting field has a function of the transverse position of the particles in the beam while the option with small iris is more efficient. The two input/output coupler cells have two pumping ports symmetric with respect to the coupling windows in order to reduce the non uniformity of the field distribution in the coupler region. To shift in frequency the 90 degree tilted polarity of the TM_{11} deflecting mode two metallic rods have been inserted in the cells.

References

[1] S.Korepanov, et al., DIPAC 07.
[2] www. ansoft.com
[3] D. Alesini et al., NIM A, Vol. 580, pp. 1176-1183, 2007.
[4] P. Bernard, et al., CERN 68-30, (1968).