ISBN: 978-3-95450-168-7 doi:10.18429/JACoW-IPAC2015-MOPHA024

A NOVEL TRANSVERSE DEFLECTING CAVITY FOR SLICE DIAGNOSTICS AT BERLINPRO*

A. Ferrarotto, B. Riemann, T. Weis, DELTA Dortmund Germany,
T. Kamps, H.-W. Glock, J. Völker, HZB Berlin Germany

Abstract

BERLinPro [1], [2] is an energy-recovery linac project to be realized at the Helmholtz-Zentrum Berlin (HZB) for an electron beam with 1 mm mrad normalized emittance and 100 mA average current. The initial beam parameters are determined by the performance of the electron source, an SRF photo-electron injector. The development of this SRF photon-electron injector is a main task of BERLinPro. Especially the beam emittance is basically defined by the SRF photogun. For beam diagnostics time dependent effects from the RF curvature and space charge must be taken into account and a sophisticated slice diagnostics is required [3]. To perform this type of diagnostics a transverse deflecting cavity has been designed, characterized and is presently under construction. This single cell cavity operates in a TM_{110}-like mode at 1.3 GHz optimized for high transverse shuntimpedance of appr. 3.2 MΩ by a concentration of fields near the beam axis. The cavity has a novel geometry that allows for an operation with both polarizations of the TM_{110}-mode. The layout of the deflecting cavity will be presented together with the results of the low RF characterization.

INTRODUCTION

The Energy Recovery Linac (ERL) project BERLinPro should provide an electron beam with an average current of 100 mA and a normalized emittance of 1 mmmrad. The electron beam should be produced in a SRF photogun operating at 1.3 GHz repetition rate in CW mode. The beam emittance is basically defined by the SRF photogun.
A SRF gun with 100 mA average current and an emittance of 1 mm mrad has never been demonstrated. As part of the development process of such a SRF gun GunLab was designed as a test facility to characterize beam parameters of SRF photoinjectors. The main challenge of GunLab is to characterize the full six-dimensional phase space as a function of drive laser and RF parameters [4]. For usage in GunLab a novel type of transversal deflecting cavity (TCAV) for slice emittance measurements [5] in horizontal and vertical direction was designed. The development process of this novel TCAV is described in this paper.

TRANSVERSE DEFLECTING CAVITIES

Typically deflecting cavities make use of a TM_{110}-like mode in a modified cylinder geometry to apply transverse momentum to particle beams. This transverse momentum

$$\Delta p_\perp = e\left|\int_{-\infty}^{\infty} B_\perp(z)\, e^{i\frac{k}{\beta}z}dz - \frac{i}{\beta c}E_\perp(z)\, e^{i\frac{k}{\beta}z}dz\right| \quad (1)$$

$$= e\left|\frac{1}{\omega}\int_{-\infty}^{\infty} \vec{\nabla}_\perp E_z(z)\, e^{ikz}dz\right| \quad (2)$$

depends on the transverse components of the electric and magnetic fields on the cavity axis acting on the particle beam. z represents the coordinate along the cylinder axis, $k = \omega/c$ represents the wave number, e the electric charge of the particles, c the speed of light and ω represents the RF angular frequency. The transverse momentum is related to the transverse deflection voltage

$$V_\perp = \frac{\Delta p_\perp c}{e} \quad (3)$$

and to the transverse shunt impedance

$$Z_\perp = \frac{V_\perp^2}{2P} = \frac{V_\perp^2 Q}{2\omega U} \quad (4)$$

with the quality factor Q of the transverse deflecting mode and the electromagnetic energy U stored in this mode.

TWO POLARIZATIONS

The theory of cylinder resonators shows that the TM_{110}-mode has two polarizations, rotated by 90 degrees. In a perfectly symmetric resonator, there are both polarizations degenerated with arbitrary spatial orientation. Usually the symmetry of the resonator is broken by inserting protrusions. This asymmetry splits the resonance frequencies and fixes the orientation of the two polarizations. The orientation of the polarization determinates the plane of transverse deflection. Depending on their actual shape, the protrusions also increase the electric and magnetic fields on the cavity axis. For use in GunLab we need a transversal deflection in both transversal planes to reconstruct the full six dimensional phase space as a function of drive laser and RF parameters. Thus we designed a novel type of transverse deflecting cavity which is able to make use of both polarizations of the TM_{110}-Mode at the same resonance frequency. To select the actual polarization we use two plungers as shown in Figure 1. The plunger which protrudes deeper inside the resonator determines the polarizations and by that the planes of transverse deflection.

* Work supported by BMBF under contract no. 05K10PEA

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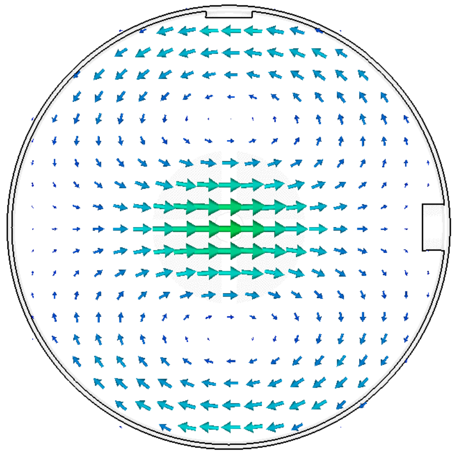

Figure 1: Magnetic field of a TM110-like mode in the center of a cylindrical cavity. The plunger which protrudes deeper inside the resonator determines the polarization and by that the plane of transverse deflection.

FIRST CAVITY DESIGN FOR LOW LEVEL RF-TESTS

As a first approach for such a kind of cavity we designed the one shown in Figure 2. To increase the transverse electrical and magnetic field strength on the beam axis we used (simple) conical protrusions on both sides of a cylinder resonator. To make use of both polarizations at the same resonance frequency we have to preserve their discrete rotation symmetry. For this reason we split the cones in four parts

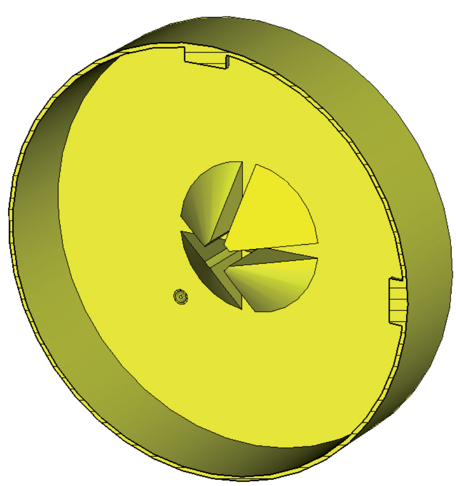

Figure 2: CAD design of our first TCAV prototype. Cylindrical shape with protrusions based on cones, two plungers and capacitive inputcoupler.

with a small gap between these parts and place the plungers parallel to these gaps. Based on the CAD design shown in Figure 2, we build the prototype shown in Figure 3 for low level RF tests. This first prototype operates in a TM_{110}-like mode at 1.314 GHz, has a quality factor of approximately 15000 and a transverse shunt impedance of 1.55 MΩ.

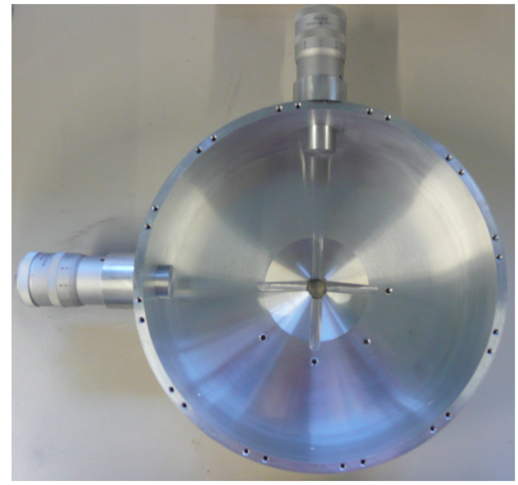

Figure 3: First aluminum prototype for low level RF-Tests based on the CAD design shown before.

SECOND CAVITY DESIGN FOR LOW LEVEL RF-TESTS

After the first prototype has shown that it is in principle possible to build and operate such a kind of TCAV with low level RF, we ran set of simulations to find a more advanced and optimized geometry for our TCAV. We used an elliptical instead of a cylindrical shape und replaced the simple cones by protrusions based on sine functions. These smoother surfaces reduce power loss and the new protrusions increase the electric and magnetic field strengths on the beam axis. Based on the CAD design shown in Figure 4 we build another aluminium prototype for low level RF-Tests. This second prototype operates at in a TM_{110}-like Mode at 1.3 GHz has a quality factor of approximately 16000 and a transverse shunt impedance of 3.2 MΩ.

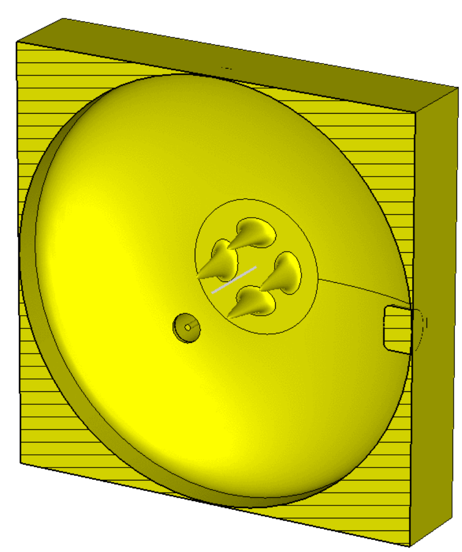

Figure 4: CAD design of our first TCAV prototype. Elliptical shape with protrusions based on sine function, two plungers and capacitive inputcoupler.

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A TCAV FOR BERLINPRO

After all low level HF-Test on the prototypes were in good agreement with the simulations done before, a final version of the our TM_{110}-deflector was planed, based on the second prototype and is currently under construction.

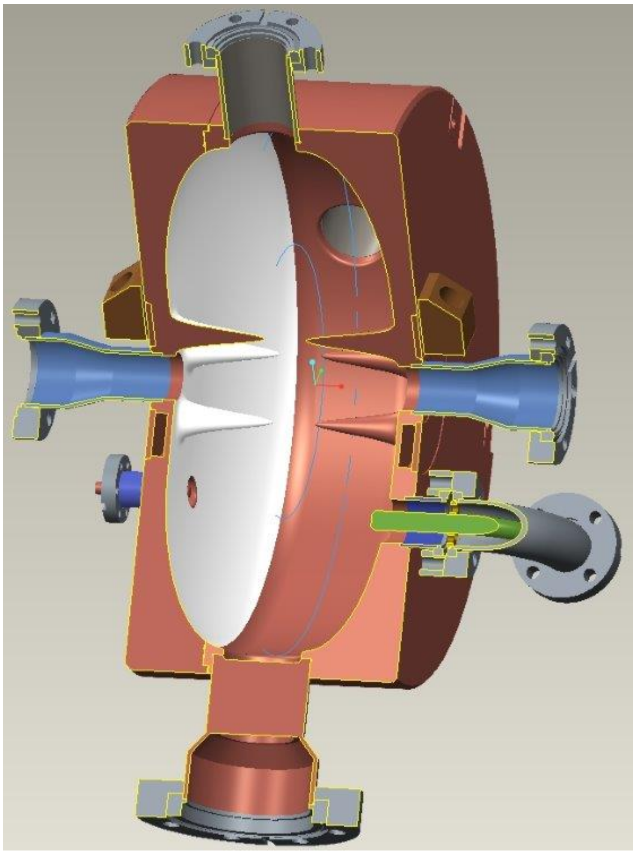

Figure 5: Final TCAV design for use in GunLab based on the second prototype [6].

SUMMARY AND OUTLOOK

We designed a novel type of transverse deflecting cavity for slice diagnostics at BERLinPro. This TCAV makes use of both polarizations of the TM_{110}-mode and allows to select between horizontal and vertical deflection by setting up two plungers. The final version of this novel TCAV is currently under construction and will be ready for use in GunLab in the beginning of 2016.

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