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DESIGN OF AN ULTRAFAST STRIPLINE KICKER FOR BUNCH-BY-BUNCH FEEDBACK

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Abstract

The CAEP THz Free Electron Laser (CTFEL) will have a fast transverse bunch-by-bunch feedback system on its test beamline, which is used to correct the beam position differences of individual bunches with interval of about 2 ns. In this paper, we are proposing an ultrafast wideband stripline kicker, which is able to provide a kick to the bunch in a 2 ns time window. The structure design and simulation results of this kicker are also discussed

INTRODUCTION

China Academy of Engineering Physics (CAEP) has developed a terahertz free electron laser (CTFEL) facility with Peking University and Tsinghua University, which is the first high average power FEL user facility in China [1]. CTFEL is a kind of oscillator type FEL and mainly consists of a GaAs photocathode high-voltage DC gun, a 1.3 GHz 2x4-cell superconducting RF linac, a planar undulator and a quasi-concentric optical resonator. The first saturated lasing of CTFEL was obtained in 2017 [2]. Since then, CTFEL has realized stable operation and some user experiments have been done. The repetition rate of THz beams is 54.17 MHz and the THz frequency can be adjusted from 1.87 THz to 3.8 THz continuously. The average output power in macro pulse is more than 10 W and the peak power is beyond 0.5 MW [3]. Now, fast machine protection system is under developed and CW operation will be realized soon. Moreover, CTFEL is expected to upgrade to cover the THz band from 1 THz to 10 THz and greatly promote the development of THz science as well as many other cutting-edge fields in the future.

The CTFEL will have a test beam line behind the 90 degree analysis magnet, a fast transverse intra-bunch train feedback system to stabilize the beam position will be developed. The time interval of the micro-pulse will set to be about 2ns. Several beam elements and diagnostics device will be installed in the test beam line. Figure 1 shows the location of the CTFEL diagnostics device. This paper gives an overview of the design and analysis of the strip-line kicker.

A stripline kicker consists of two parallel electrodes housed in a conducting vacuum pipe: each of the electrodes is driven by an equal but opposite polarity pulse. The most technology challenges are the following: first, good power transmission by achieving good impedance matching to the electrical circuit; second, the excellent field homogeneity was need in the center region of the vacuum pipe. The stripline design has been carried out by using CST MICROWAVE STUDIO and CST EM STUDIO[4].

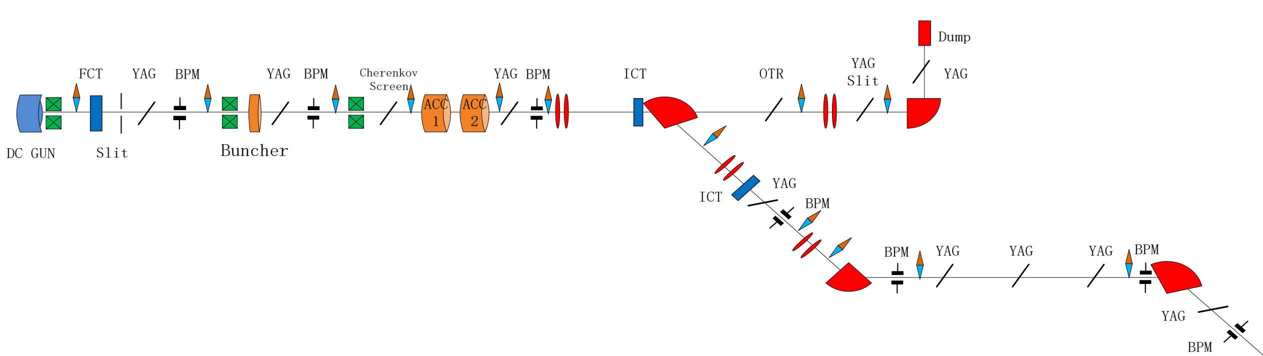

Figure 1: Location of CTFEL diagnostics device.

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DESIGN STUDY OF THE STRIPLINE KICKER CROSS SECTION

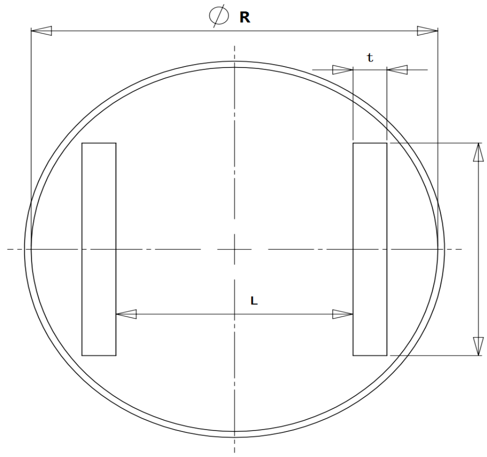

Figure 2: Geometry of the cross section.

The stripline kicker has 2 electrodes connected to electrical feedthrough at both ends. The cross section of the striplines defines the characteristic impedance and homogeneity of the electromagnetic field in the center region. The geometry of the cross section is showed in Fig 2. The model is parameterized for changing and optimizing the shape of the electrode. The distance between the electrodes was chosen to be 35mm for avoiding disturbing of the beam. The parameters of the model and the specification of the kicker is listed in table 1.

Table 1: Parameters of the Stripline Kicker

Parameter	Symbol	
diameter of the vacuum pipe	R	60 mm
distance between the electrodes	L	35 mm
thickness of the electrodes	t	5 mm
width of the electrode	h	35 mm

A feedthrough is needed to transfer the power to the strip-line electrode. The characteristic impedance of the connection form the feedthrough to the stripline electrode is not 50 ohm. This impedance mismatching will introduce reflection to the transmission of the pulse power. So a 3D model (see in Fig 3) with 4 feedthroughs is studied to analyse the influence of the geometries on the reflection.

Set the input side of feedthroughs as waveguide port1, port2, port3, port4. The plot of S11 parameter for strip-line kicker is showed in Fig. 4.

It presents the reflection coefficient vs the frequency. The S11 is small than -20 dB in 500 MHz, so the reflected power can be estimated less than 1%.

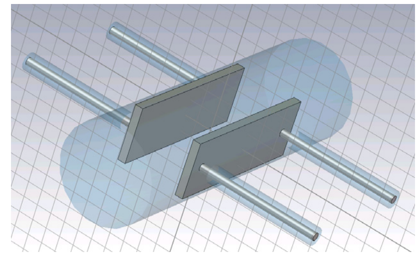

Figure 3:3D model of the stripline with 4 feedthroughs.

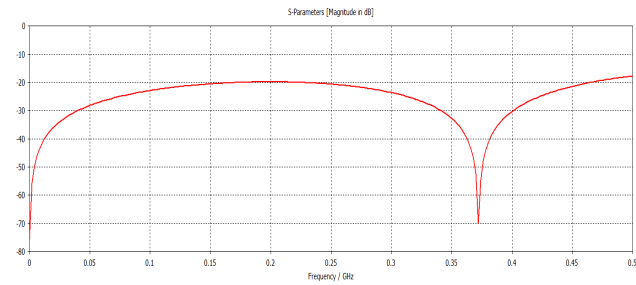

Figure 4: S11 plot for strip-line kicker.

The feedthrough position refer to the stripline and the inner radius of the feedthrough were studied to analyze the influence on the reflection parameter magnitude, but no significant differences were found through parameters sweep.

The field homogeneity was analysed using the CST EM STUDIO. The same magnitude but opposite polarity voltages were imposed on the two striplines as the excitation. The E-Field distribution of the working space was got using the E-Field solver which is showed in Fig.4.

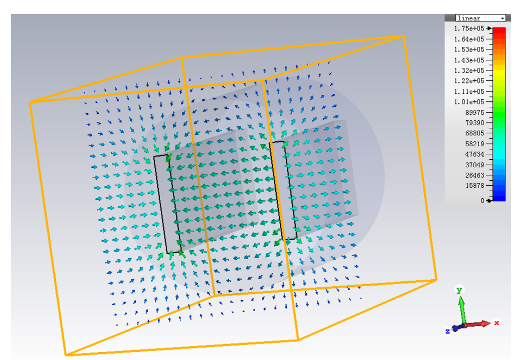

Figure 4: E-Field distribution of the kicker.

The E-Field strength vector of any point in the working space can be got through post-processing of the CST EM STUDIO data. The X direction field strength of the region ‘ z=0, x(-5,5), y(-5,5) ’was used to analyze the field homogeneity. The field homogeneity is about 3% in this region with the step of the region is 1mm.

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SUMMARY

The preliminary geometry design of the stripline kicker for the CTFEL is presented. The cross section optimization of the stripline kicker is almost complete: the 50 ohm characteristics impedance and less than 1% reflection coefficient from the port. But the field inhomogeneity 3% is beyond the specification of the design. Ongoing simulation include: further studies of the geometry to optimize the field inhomogeneity, studies of the shunt impedance and beam coupling impedance of the kicker.

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