DESIGN OF A STRIPLINE KICKER FOR THE ELBE ACCELERATOR*

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Abstract

ELBE is a linac based cw electron accelerator serving different secondary beams one at a time. Depending on the user demand the bunch repetition rate may vary from single pulse up to 13 MHz. For the future different end stations should be served simultaneously, hence specific bunch patterns have to be kicked into different beamlines. To use e.g. one bunch out of the bunch train very short kicking durations have to be realized. The variability of the bunch pattern and the frequency resp. switching time are one of the main arguments for a stripline-kicker combined with high voltage (HV)-switches as basic concept. A nearly homogenous field in the kicker has to be realized for uniform deflection of the electron bunch and keep the emittance growth of the bunch as low as possible. Furthermore the fast switching ability of the kicker demands for a fast decay of the HV-pulse resp. its reflections in the structure implying a specific design of the kicker elements. For this reason a design with two tapered active electrodes and two ground fenders was optimized in time and frequency domain with the software package CST. Additionally a first prototype was manufactured for laboratory and first beam-line tests.

INTRODUCTION

At ELBE (see Figure 1) the electron beam is mainly used for conversion in different secondary radiation; infrared, terahertz, gamma, positron, neutron und electron laser interaction. While for every beam line dedicated energies and optimized settings have to be adjusted, not every experiment demands the full 13 MHz cw capability of ELBE.

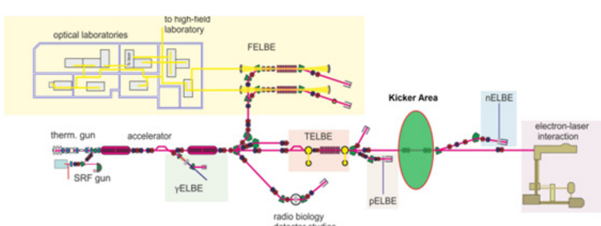

Figure 1: Overview of the ELBE layout with the position of the kicker station.

For example the end stations from neutron an electron laser interaction are using high bunch charge but 200 kHz and 10 Hz respectively and are separated by just one beam line branch. It is therefore straight forward thinking about using one beam for both experiments by kicking patterns of bunches into the other beamline. On the way to use ELBE as a multiuser machine, the first step is to implement a kicking device in front of the neutron and laser interaction beam line. The electrical and magnetic fields used for the bunch kick will be in reality not absolutely homogenous and therefore can induce an emittance growth in the beam. Since the electron laser interaction is much more sensitive to beam emittance the basic concept is to kick the uninfluenced beam with 200 kHz (max. 500 kHz) into the neutron beam line.

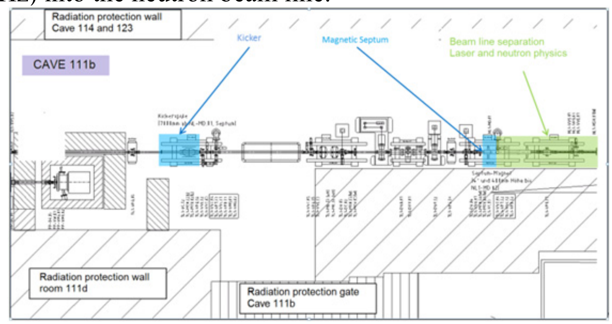

Figure 2: Detailed sketch of the ELBE kicker area.

A magnetic septum is installed to align the beam either to the neutron or laser interaction beamline (see Figure 2). The separation for the magnetic septum is about 10 mm beam displacement. The distance between kicker and septum will be around 7 m. Hence a kick angle of around 1.5 mrad must be realized. Assuming a strip distance of 30 mm and an active length of 700mm, for a first estimate the Panofsky-Wenzel-Theorem [1] for a strip line kicker can be used:

$$\theta \approx \frac{2\ \int_{Stripline} E_{\perp} dt}{Energy/e}$$

The estimation yields for a voltage on the strips of ~ 1 kV and a beam energy of 30 MeV an angle θ ~ 1.6 mrad.

DESIGN AND OPTIMISATION

The ELBE strip-line kicker design uses the common approach [2, 3] with two tapered active electrodes and two ground fenders. The slightly difference is the placing of the two ground fenders in the outer area of the electrodes.

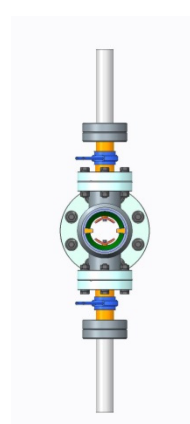

Figure 3: Sectional drawing of the ELBE kicker in the area of the connection ports.

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The distance between the electrodes was chosen to 30 mm having a balance of lower HV supply and still feeding the electron beam in a homogenous field area through the kicker (see Figure 3). The design was optimized with the CST package to fit best to 50 Ω impedances, for optimal S-parameters (see Figure 4) in the frequency domain as well as having best field flatness (see Figure 5) in the significant area between the electrodes.

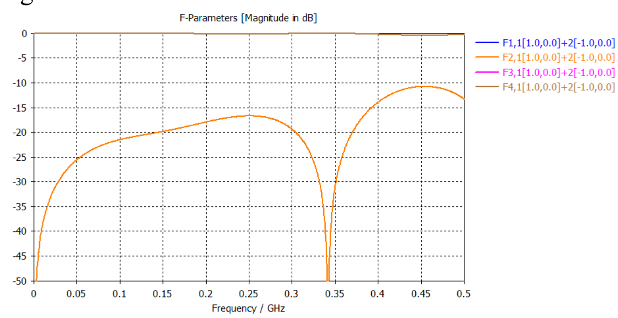

Figure 4: F-parameters from the CST calculation plotted for a. frequency range up to 0.5 GHz. In CST F-parameters are renormalized S-parameter for simultaneous excitation.

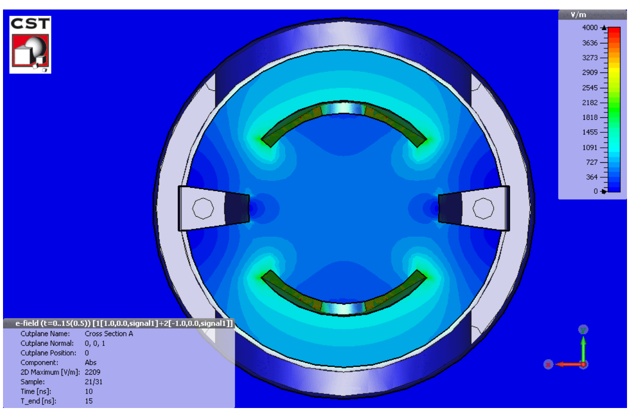

Figure 5: Sectional plot of the electric field in the medium section of the kicker structure.

PARTICLE TRACKING SIMULATION

For understanding the influence of the kicker field to the phase space distribution of the beam, the PIC-Solver of the CST package was used for tracking bunches through the structure. To disentangle the various effects Gaussian distributions in all 6 phase space dimensions had been generated by white noise as tracking input.

Concentrating on the emittance two effects can play a role, the influence of beam wakefields and that of the kicking field itself.

By that way a problem using the PIC solver in CST was encountered. Simulating the kicker with a very small starting emittance distribution as well as a beam pipe or beam pipe cross e.g. with 1 nC bunch charge a value of around ε_y~3.2 mm mrad arises (see Table 1). This seems due to the fact that the PIC-solver starts to create the bunch at t=0 within the simulation domain and therefore inducing a coulomb field in the beam pipe that is not perpendicular to the direction of propagation. This is then creating a wakefield that is increasing the emittance with respect to the bunch charge. Taking this into account a simulation without bunch charge results in a small emittance growth of only ε_Y ~ 0.7 mm/mrad, the reason is the field of the kicker itself. An additional wakefield induced emittance growth is negligible.

Table 1: Results from CST Particle Tracking

	Kick amplitude=0 V	
Bunch charge	CST Mesh	ε_Y /mm mrad
1nC	186 Mio (Mesh 0.3-0.3-0.1)	**3.276137**
	Kick amplitude=427 V4	
1 nC	186 Mio (Mesh 0.3-0.3-0.1)	**3.346724**

In the PIC-simulation a voltage of 427 V per strip-line was used. This results in a mean kicking angle of the phase space distribution of 1.5 mrad.

OUTLOOK

A picture of the ready manufactured kicker is shown in Figure 6. All the elements of the kicker are momentarily in the assembly phase. Therefore first network analyzer measurements to check the S-Parameter of the real structure with respect to the model calculations can be performed soon. Accordingly it is planned to perform first tests under beam line vacuum conditions in the second part of the year.

Figure 6: A picture of the manufactured ELBE kicker in the clean room.

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