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PROPOSED BEAM TEST OF A TRANSVERSE GRADIENT UNDULATOR AT THE SINBAD FACILITY AT DESY

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Abstract

While Laser Plasma Accelerators produce beams with the high output energy required for FELs, up to now the relatively high energy spread has prohibited FEL lasing. Therefore it was proposed to replace the standard FEL undulators by Transverse Gradient Undulators (TGUs). For a first, small scale test of the TGU concept, a 40 period prototype of a high gradient superconductive TGU was built at KIT and will be tested with beam at the ARES-linac in the new accelerator test facility SINBAD (Short Innovative Bunches and Accelerators at DESY) at DESY. The proposed tests are summarized in this paper.

INTRODUCTION

In a conventional undulator the radiation wavelength is given by

$$\lambda = \frac{\lambda_u}{2\gamma^2}\left(1 + \frac{K^2}{2}\right) \quad (1)$$

Where λ_u is the period length of the undulator, γ is the Lorentz factor and K is the undulator parameter according to

$$K = 0.934.\ \lambda_u[\text{cm}]B\ [\text{T}] \quad (2)$$

Here B is the maximum magnetic field strength in the beam plane. To compensate the effect of energy spread on the radiation the transverse gradient undulator was proposed [1]. In a TGU the energy of the particle, γ, in a beam is matched to the undulator parameter, K, such that the modified undulator equation is given by [2].

$$\lambda = \frac{\lambda_u}{2\gamma^2(x)}\left(1 + \frac{K^2(x)}{2}\right) \quad (3)$$

This can be done by tilting undulator poles and introducing a linear field gradient according to

$$\alpha = \left(\frac{1}{x}\right)\left(\frac{\Delta K(x)}{K_0}\right) \quad (4)$$

The resonance condition holds if dispersion function, D, of incoming beam is satisfied by

$$D = \frac{(2 + K_0^2)}{(\alpha K_0^2)} \quad (5)$$

The working principle for a TGU is shown in Fig. 1. Electrons with different energies enter the undulator at different transverse positions.

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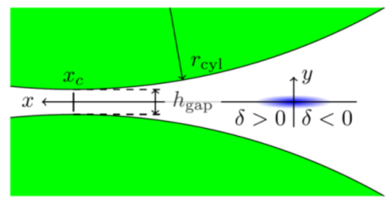

Figure 1: Geometries of a cylindrical TGU [2].

BEAM TEST AT SINBAD

The SINBAD project at DESY is the framework for all R&D activities in this area and intends to set up multiple independent experiments in ultra-fast science and high gradient accelerator modules. The first experiment is the ARES (Accelerator Research Experiment at Sinbad) which is a linear accelerator for the production of low charge (from few pC to sub-pC) electron bunches with 100 MeV energy [3, 4]. Figure 2 shows the schematic view of the ARES Linac with two traveling wave structures (TWS). For the tests of the TGU the 4 m long straight part in the dogleg section will be used. The lattice from the end of the linac to the entrance of the TGU is depicted in Fig. 3.

The superconducting TGU which will be used for the experiment has been designed and constructed at KIT. The parameters of the device are listed in Table 1 [5].

Figure 2: Overview of ARES Linac.

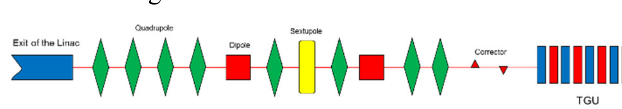

Figure 3: Lattice of the experiment.

BEAM TEST : STAGE 1

In the first test the position of the incoming beam will be changed by steering magnets. Figure 4 shows the simulated radiation with SPECTRA [6] for a 123 MeV, 10 pC charge beam simulated with ASTRA [7] from the photocathode up to the exit of the Linac and then tracked by ELEGANT [8] up to the entrance of the TGU. Since

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there is a field gradient inside the TGU, Fig. 5, the radiation wavelength for each case would be different.

Table 1: TGU Parameters

Parameter	Unit	Value
Period Length	mm	10.5
Number of Period	-	40
Pole Radius	mm	30
Gap Width	mm	2.4
Flux Density Amplitude at the beam center	T	1.1
Transverse Gradient	1/m	139.7

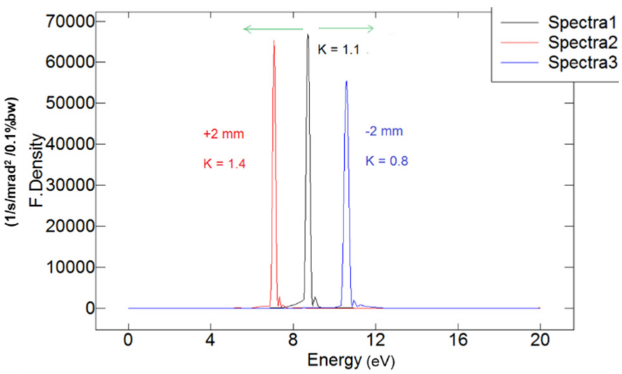

Figure 4: Photon spectrum produced in stage 1.

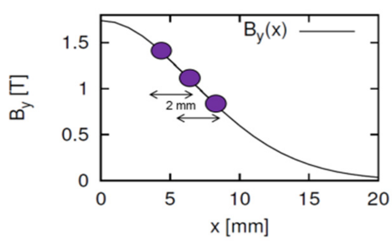

Figure 5: The beam entering the undulator gap at different beam position.

BEAM TEST : STAGE 2

In the next step the measurement is repeated with two beams, 76 MeV and 85 MeV at positions where the field gradient is matched to the energy of each beam. This can be done by including correctors before the TGU. The radiation for each beam is depicted in Fig. 6. In this case 10 pC charge beams simulated by ASTRA and tracked by ELEGANT along the beam line.

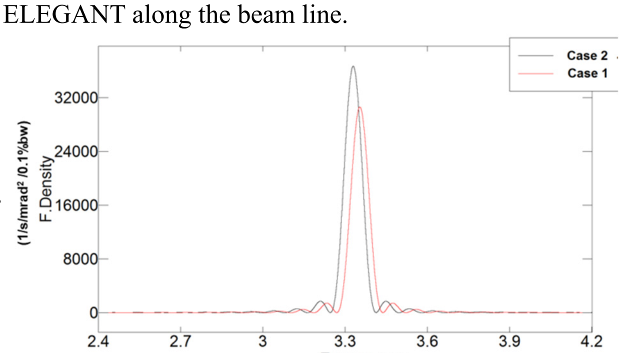

Figure 6: Photon spectrum produced in stage 2.

BEAM TEST : STAGE 3

In the final experiment, an electron beam with a finite energy spread will be produced by detuning the phases of the cavities of the linac. For this case, a beam with 80 MeV and 1% energy spread is simulated by ASTRA. Table 2 shows the parameters of this simulated beam at the linac exit.

To produce dispersion within the beam two bending magnets are used in the beam line. The sextupole in between the two dipoles allows reducing chromatic effects due to energy spread and CSR effect. Figure 7 and Figure 8 show the beta functions and dispersion along the beam line respectively. The beam parameters at the entrance of the TGU are listed in Table 3. Note that the dispersion function is matched to the magnetic field gradient according to equation (5).

Table 2: Beam Parameters at the Linac Exit for Stage 3

Parameter	Unit	Value
Energy	MeV	80
Charge	pC	10
Energy Spread	-	1%
Geometric Emittance	nm	1.8
Bunch Size	mm	0.32
Bunch Length	µm	161

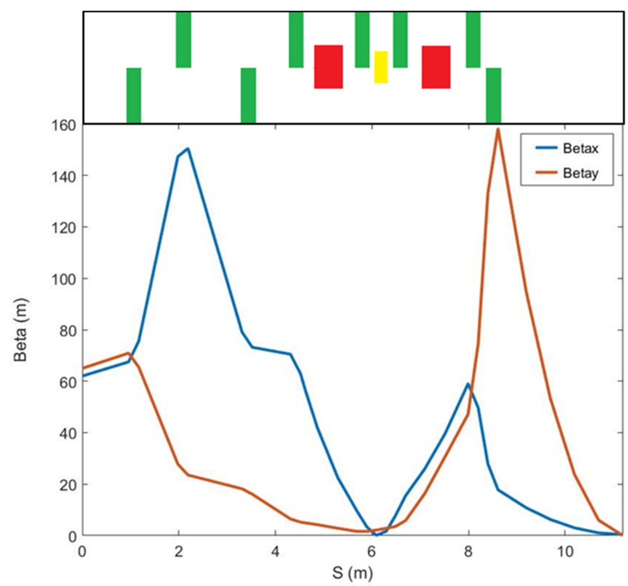

Figure 7: Evolution of beta functions along the beam line from the exit of the Linac up to the entrance of the TGU.

CONCLUSION

It is planned to test the recently built 40 period superconducting Transverse Gradient Undulator (TGU) with the SINBAD accelerator at DESY. The first goal is to use a monochromatic electron beam and to test the field quality of the TGU. In a second experiment, an electron beam will be produced with a wider energy spread and it will be tested if the TGU concept allows producing a monochromatic photon beam from this non-monochromatic electron beam. If the results measurements are successful in a next step an electron beam produced by a laser plasma

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accelerator (LPA) will be used. Electron beams produced by LPAs have an energy spread in the percent region. It will be investigated if the TGU allows producing photon beams with a lower energy spread.

Table 3: Beam Parameters at the Entrance of the TGU

Parameter	Unit	Value
Geometric Emittance x	nm	12
Geometric Emittance y	nm	3.3
Bunch Size x (σ)	mm	0.2
Bunch Size y (σ)	mm	0.02
Bunch Length	µm	80
Dispersion	mm	-20

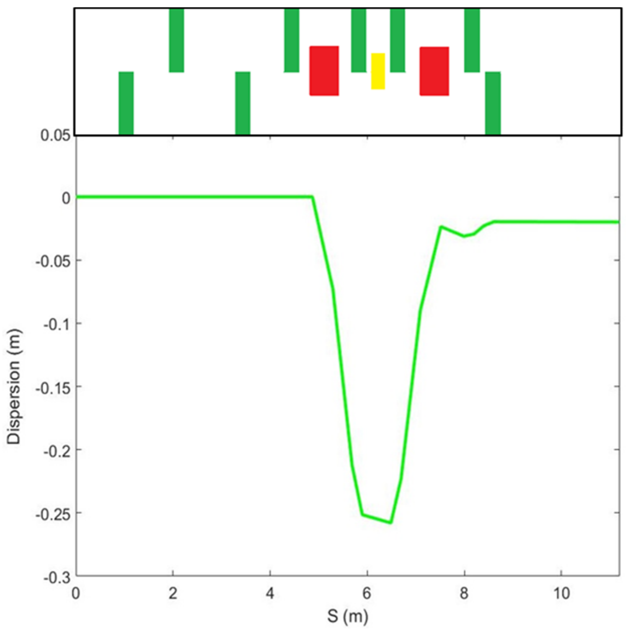

Figure 8: Dispersion function along the beam line from the exit of the Linac up to the entrance of the TGU.

REFERENCES

[1] T. I. Smith et al., “Reducing the Sensitivity of a free electron laser”, *J. Appl. Physics*, vol. 50, p. 4580, 1979.

[2] A. Bernhard *et al.*, “Radiation emitted by transverse-gradient undulators”, *Phys. Rev. ST Accel. Beams*, vol. 19, p. 090704, 2016.

[3] U. Dorda *et al.*, “Status and objectives of the dedicated accelerator R&D facility “SINBAD” at DESY”, *Nuclear Instruments and Methods in Physics Research Section A.*, vol. 909, pp. 239-242, 2018.

[4] B. Marchetti *et al.*, “Status Update of the SINBAD-ARES Linac under Construction at DESY”, in *Proc. 8th Int. Particle Accelerator Conf. (IPAC'17)*, Copenhagen, Denmark, May 2017, pp. 1412-1414. doi:10.18429/JACoW-IPAC2017-TUPAB040

[5] V. Afonso Rodriguez *et al.*, “Construction and First Magnetic Field Test of a Superconducting Transversal Gradient Undulator for the Laser Wakefield Accelerator in Jena”, in *Proc. 5th Int. Particle Accelerator Conf. (IPAC'14)*, Dresden, Germany, Jun. 2014, pp. 2022-2025. doi:10.18429/JACoW-IPAC2014-WEPRO036.

[6] T. Tanaka and H. Kitamura, *J. Synchrotron Radiation*, vol. 8, no. 1221, 2001. https://doi.org/10.1107/S090904950101425X

[7] K. Floettmann, ASTRA, 1999. http://www.desy.de/~mpyflo

[8] M. Borland, “Simple method for particle tracking with coherent synchrotron”, *Phys. Rev. ST Accel. Beams*, vol. 4, p. 070701, 2001.