Karlsruhe Institute of Technology

4th European Advanced Accelerator Concept Workshop
ID 74, WG4 – Application of compact and high-gradient accelerator.

First Operation Experience and Magnetic Characterization of a Superconducting Transverse Gradient Undulator for the Compact Laser Wakefield Accelerator-Driven FELs

K. Damminsek, J. Gethmann, A. Grau, S. C. Richter, M. Ning, R. Rossmanith, A. Bernhard, E. Bründermann, A.-S. Müller

Introduction

The application of Laser Wakefield Accelerators (LWFA) is a potential key for realizing extremely compact Free Electron Lasers (FELs) due to an unprecedented high longitudinal electric field inside the laser-driven plasma wave. LWFA-based electron beams exhibit challenging initial conditions in terms of beam divergence and large energy spread. The superconducting transverse gradient undulator (TGU) scheme is a viable option to compensate the challenging properties of the LWFA electron beam and to enable FELs amplification.

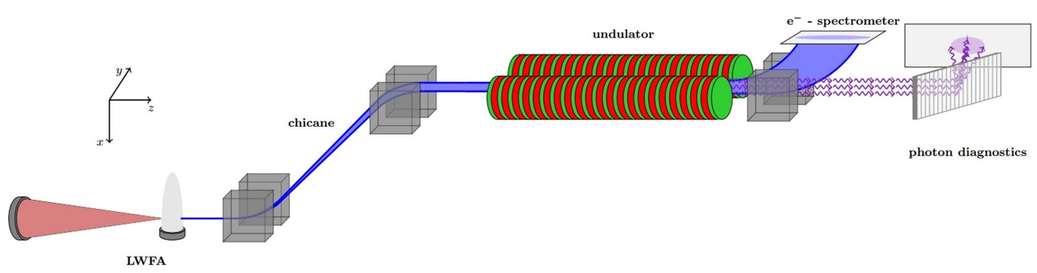

Figure 1: Schematic layout of a LWFA-based TGU radiation source [1].

Electron energy (E_0)	120	MeV
Energy spread ($\Delta E/E_0$)	±10	%
Period number (N_u)	40	
Period length	10.50	mm
Pole radius	30.00	mm
Gap width @120 MeV	2.40	mm
Peak field on axis	1.74	T
Undulator paremeter @120 MeV	1.10	
Superconducting wire material	Nb-Ti	
Superconductor wire dimension (bare)	1.00 x 0.60	mm
Cu:SC ratio	1.35:1	
Operating temperature	4.2	K
Average current density	1000	A/mm²
Radiation wavelength (λ)	150	nm
Radiation bandwidth ($\Delta\lambda/\lambda$)	0.5	%

Table 1: Design electron beam and undulator parameters of KIT; scTGU [2]-[4].

Plan & Prepapration for Magnetic Characterization

The TGU and the magnetic field measurement system with 7-Hall probe array are placed in vacuum and conduction-cooled inside a specially designed cryostat. The TGU transverse field measurement will be performed at liquid Helium temperature (4.2 K).

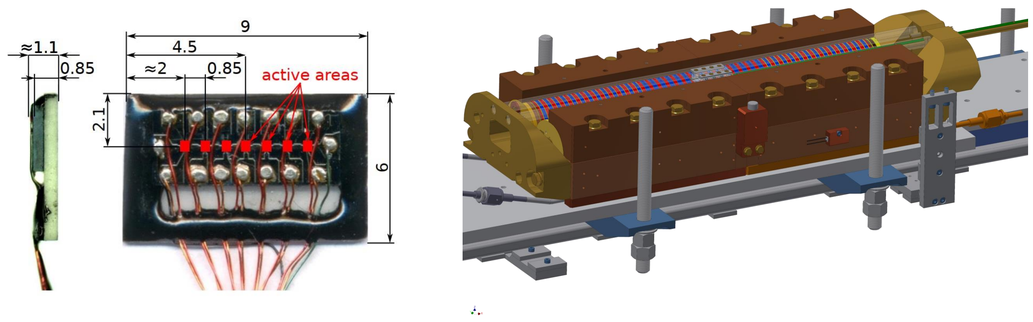

Figure 5: (left) Photo of the Hall probe array [2]. (right) Instllation of a magnetic field measurement system on the undulator [5].

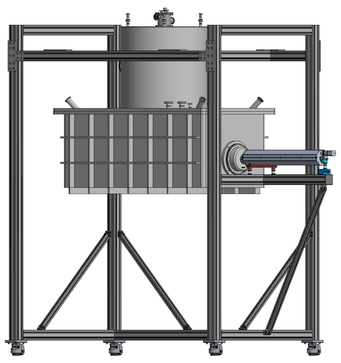

Figure 6: A chamber for the magnetic measurement system installed on the cryostat's outermost shielding wall [5].

Improvement of experimental set-up

- Alignments of the TGU and measurement system inside the cryostat
- Positioning of the Hall probe in a TGU coordinate system
- Special shielding wall for a moving part of measurement system
- Control system and field analyzing program

TGU cool down process & Powering test

In this investigation, the TGU was cooled to 4.2 K and the magnet powering tests were performed by using one of the undulator coils. The preliminary test showed a quench occurs when an applied current was 410 A.

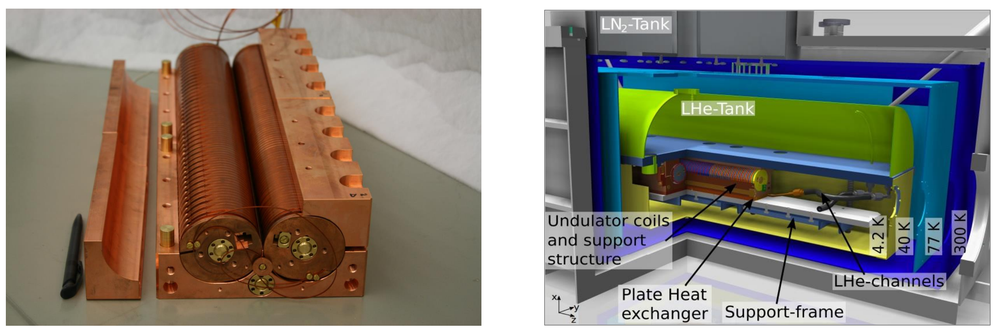

Figure 2: (left) Photo of TGU coil together with a support structure. (right) Sectional view of the cryostat assembly with different temperature regions and the TGU installed on the support structure [2].

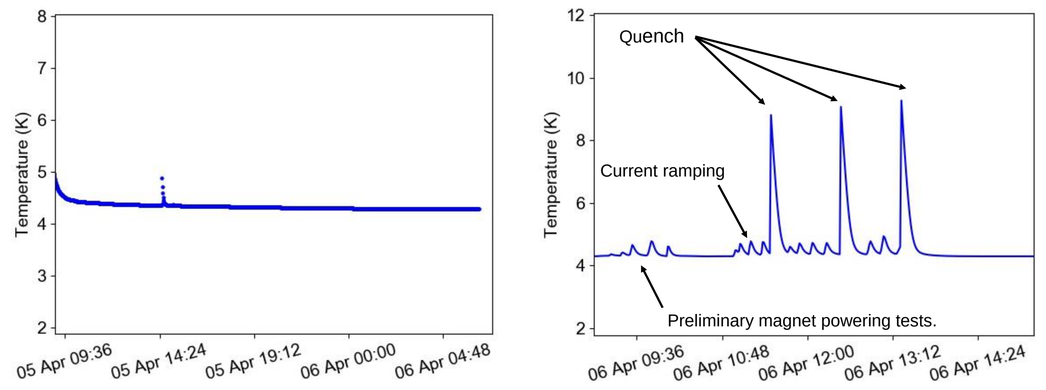

Figure 3: (left) Stability of the TGU coil temperature after operation conditions were reached. (right) The TGU coil temperatures during ramping when a quench occurs.

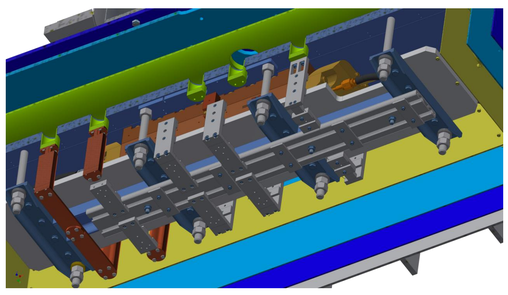

Figure 4: Improvement of the SC wire guiding support structures and the wire connections [5]

Improvement of experimental set-up

- Insulation layers:
  - TGU and liquid helium tank
  - TGU and heat exchanger plates
- Temperature sensors:
  - At the SC wire connection positions
- Heaters
- SC wire connection method

TGU studies with narrow energy-spread beams

Currently, a discussion between Jena University, DESY and KIT is going on with the plan to install the TGU in one of the electron beam lines of the SINBAD facility. The linear accelerator at SINBAD provides a narrow energy and momentum spread. This TGU study will provide additional insights in the operation principle to prepare for LWFA experiments. The LWFA-TGU experiment will use the JETI-Laser at Helmholtz Institute Jena. ***Please refer to a poster in the name of "Plans for a Transverse Gradient Undulator (TGU) Experiment at the ARES Linac at SINBAD" , which is presented by F. Jafarinia.***

Outlook and Conclusion

The cool-down process, operation and characterization of the TGU inside the cryostat were investigated. The TGU's coil temperatures were reduced to around 4.2 - 4.3 K. The TGU coils reach the superconducting state. A magnetic field measurement system was installed. According to a discussion between Jena University, DESY and KIT, the future TGU studies at the SINBAD facility are the preparation before move forward to the experiments with the LWFA in Jena.

Reference

[1] Widmann, C., PhD Thesis, Karlsruhe Institute of Technology (2016)

[2] Afonso Rodriguez, V., PhD Thesis, Karlsruhe Institute of Technology (2015)

[3] Bernhard, A. et al., NIM A, 909 (2018), 391-397.

[4] Afonso Rodriguez, V. et al., IEEE Transactions on Appl. Supercond., vol. 23(3), 4101505 (2013).

[5] Courtesy: ,,S. Schott", Karlsruhe Institute of Technology.