STATUS OF THE RADIATION SOURCE ELBE UPGRADE

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Abstract

ELBE is based on a 40 MeV superconducting Electron Linac able to operate in CW mode and provides manifold secondary user beams. The suite of secondary beams include: two free electron lasers operating in the IR/THz regime; a fast neutron beam; a Bremsstrahlung gamma-ray beam; a low-energy positron beam; and patented single-electron test beams. The primary electron beam is also used for radiobiology research, or in interaction with ultra-intense PW-class lasers. Through 2014 ELBE will be upgraded to a Centre for High Power Radiation Sources. The ELBE beam current was increased to 1.6 mA by using novel solid state RF amplifiers. The concept also contains additional broad and narrow band coherent THz sources and the development of a 500 TW TiSa Laser and even a 1.5 PW diode pumped laser system. Laser plasma electron acceleration and proton acceleration experiments for medical applications are planned. Additionally, coupled electron laser beam experiments like Thomson scattering or injection of ELBE electron into the laser plasma will be done.

INTRODUCTION

The ELBE radiation source was designed in the 1990ies as an infra-red free-electron laser light source based on a superconducting CW linear accelerator. The accelerator has delivered the first beam in May, 2001. The first secondary beams available were a polarized Bremsstrahlung gamma-ray beam and an X-ray source based on electron channeling in diamond crystals. At May 7th, 2004 for the first time IR light was generated with the mid-IR free-electron laer of ELBE. Since 2005 ELBE is operated as a user facility being open to users world-wide. With the installation of a second FEL for the far infra-red region in 2006, the ELBE FELs now cover the spectra range from 4 to 250 μm in routine user operation. In addition, low-energy positron and pulsed neutron beams are generated with the ELBE electron beam.

Since 2011 a major campaign is running to upgrade ELBE into a center for high- power radiation sources. This upgrade comprises upgrades of existing machine components as well as fully new installations. The main machine component to be upgraded is the power-RF supply to the 1.3GHz accelerator modules. In the original design of ELBE all accelerating cavities were driven by klystrons. In order to improve the reliability of the machine and to increase the maximum available power output all klystrons habe been replaced by solid-state power amplifiers. Increasing user demand of very long wavelength operation led to the decision to install a THz facility supplementing the existing far-IR free-electron laser. The third major upgrade concerns the high-power lasers installed at ELBE. Besides an upgrade of the existing 150 TW laser DRACO with a second 500 TW beam a fully new petawatt-class diode-pumped laser system (PENELOPE) is being installed.

THE POWER-RF UPGRADE

In the original design of ELBE each cavity was driven by a 10 kW CW klystron VKL7811St (CPI). In 2010 in close collaboration with Bruker a first prototype of an 1.3 GHz solid-state amplifier was tested and operated for more than a year without failures.

Figure 1: The RF power amplifier gallery of ELBE.

In spring 2011 eight improved power amplifiers were ordered, each equipped with nine transistor banks to provide 10 kW of RF at 1 dB compression and a modified control to implement the units into the ELBE PLC control system (SIMATIC S7).The delivery was in time in December 2011. During the winter shutdown in January 2012 the

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four klystrons were substituted by a pair of 10 kW solid-state power amplifiers, each. The enlarged cooling system for 10 SSPA (four cavities and the SRF GUN) had been installed in 2011.

The new ELBE RF-cabinets are shown in Fig. 1. Two of 10 kW SSPA are combined in parallel using 90-deg 3dB couplers. Since February 2012 ELBE is in permanent operation with the eight SSPA driving the four cavities of ELBE. Two more SSPA are used for the ELBE SRF Gun. The ELBE operation is much smoother than with the klystrons used before. For more details see [1].

THE ELBE THZ FACILITY

Following a high user demand on the far-IR free-electron laser of ELBE an extension of the facility into the THz and sub-THz region was planned. Two new sources have been installed in 2013 and are in test operation at present. Both sources rely on a electron bunch compression to sub-wavelength duration enabling a super-radiant emission mechanism. For details on the bunch compression see [8].

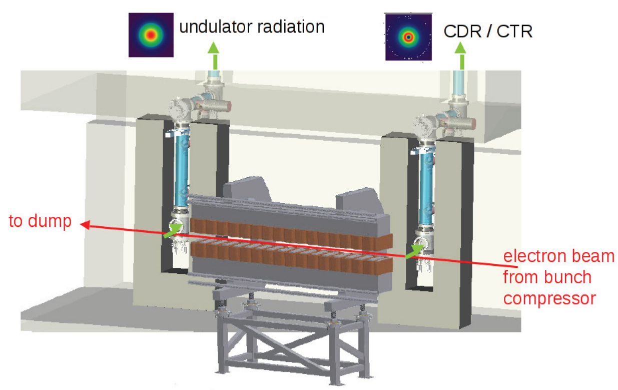

Figure 2: Design of the ELBE THz facility with 2 sources derived from the same electron beam.

The new THz facility comprises both a broad-band and a narrow-band source (see Fig. 2) derived from the same electron beam. For the broad-band source we utilize coherent transition or diffrction radiation. For a narrow-band emission an 8-period electro-magnetic undulator with a 300 mm undulator period is installed. Both sources can be operated in parallel and are inherently synchronized (see [9]) as the radiation is emitted from the same electron bunch.

HIGH-POWER LASERS

At HZDR an ultra-short pulse high-power laser DRACO (Dresden laser acceleration source) based on the Pulsar system by Amplitude Technologies is operated for laser-plasma experiments. Two independant beams with 150 TW and 500 TW are derived from the same oscillator and can be synchronized to the ELBE electron beam. One of the possible applications making use of the synchronized laser- and electron beams is a X-ray source [2] based on Compton backscattering. For more information refer to [3–7].

In addition, HZDR is pursuing the design of a fully diode pumped petawatt-class laser system named PENELOPE (Petawatt, Energy-Efficient Laser for Optical Plasma Experiments). The main challenge to this is the combination of a high pulse energy (about 200J) with broad-band short-pulse gain at a high repetition rate (10 Hz up to 1 J, 1 Hz at 200 J). Figure 3 sketches the multi-staged design of the laser system under construction.

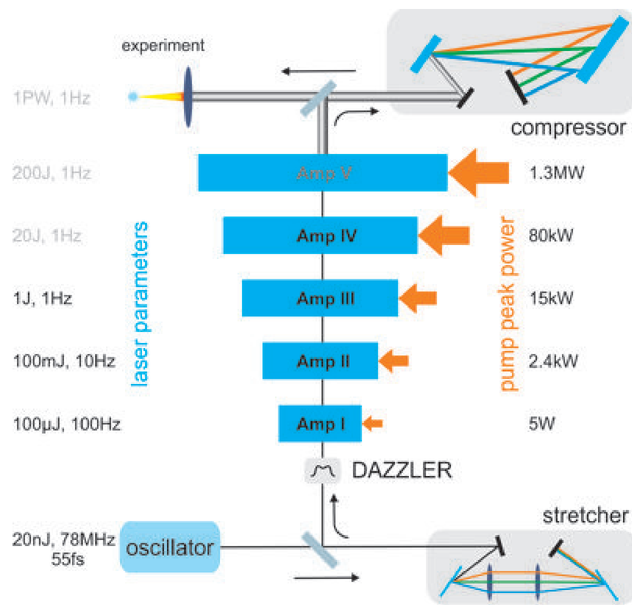

Figure 3: Design of the diode pumped petawatt-class laser PENELOPE.

CONCLUSION

The ELBE facility upgrade into a center for high-power radiation sources is nearing completion. Many of the planned improvements already have gone into routine operation. The upgrade has significantly enhanced the capabilities of the facility but also contributed to an improved reliability of the machine operation all user will benefit of.

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