THZ FACILITY AT ELBE: A VERSATILE TEST FACILITY FOR ELECTRON BUNCH DIAGNOSTICS ON QUASI-CW ELECTRON BEAMS

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Abstract

Superconducting radiofrequency (SRF) accelerator technology can provide relativistic electron bunches with quasi-cw repetition rates scaling from the kHz to GHz regime [1, 2, 3, 4]. The SRF accelerator ELBE [1] is up to now Europe's only quasi-cw linear electron accelerator (LINAC) that has been operating for more than 10 years as a driver for several secondary radiation sources. In the past four years the accelerator has been upgraded to eventually also allow for electron bunch compression down to the sub ps regime. Although recent combined electro-optic and interferometric measurements show that the sub ps regime has not yet been reached, exhibiting a shortest bunch duration of 1.2 ps (FWHM). The ELBE accelerator in combination with the super-radiant THz sources represents a novel test bed for diagnostics on quasi-cw electron beams. This has been recognized by the Helmholtz-Research Association by defining the THz sources at ELBE as a test facility for diagnostics on quasi-cw electron beams. The development of suitable diagnostic techniques is of great importance for various energy recovery linac accelerators (ERL) coming online in the next few years [2, 4] as well as facilities like the European X-FEL [5] and FLASH [6] when operated in long bunch train mode of operation.

LAYOUT

Between 2010 and 2014, the ELBE accelerator has been upgraded with a new fs-electron beamline which eventually shall allow compression of electron bunches down to the sub ps regime. One application of the compressed electron bunches is the generation of super-radiant THz radiation from two sources (a broadband coherent diffraction radiator (CDR) and narrow-band undulator) in two different modes of operation (*high field mode* and *high repetition rate mode*). According to preliminary electron beam dynamics simulations the high field mode in which the ELBE accelerators is operated with a novel SRF Gun and 1 nC bunch charge should provide 100 μJ pulse energies in a THz frequency range between 0.3 and 3 THz and at a repetition rate of up to 500 kHz. The high repetition rate mode where ELBE is operated with a thermionic injector and 100 pC bunch charge shall provide 1 μJ pulse energies in the same frequency range but at repetition rates of up to 13 MHz (see figure 1).

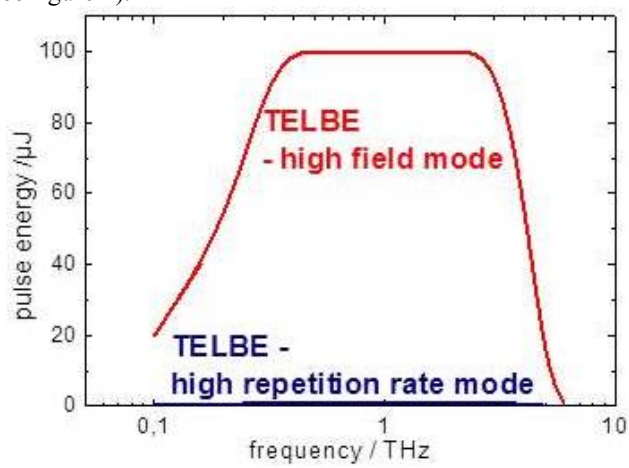

Figure 1: Design parameters for the super-radiant THz sources at ELBE postulated from electron beam dynamic simulations [7]. The *high field mode* utilizes the new SRF gun [8] and can operate up to a repetition rate of 500 kHz. The *high repetition rate mode* utilizes the standard thermionic injector and allows operation up to repetition rates of 13 MHz.

The super-radiant THz sources along with the surrounding diagnostic such as state-of-the-art beam arrivaltime monitors (BAM), bunch compression monitors (BCM), and a 1.5 m long part of the beamline reserved for testing different monitor concepts comprise the most important part of the test facility.

FIRST RESULTS

In the first beamtimes performed as an accelerator test facility new THz based monitor concepts for bunch arrival time measurements at high repetitionrates [9] and several electron beam dynamic studies were performed. Additionally a systematic study aiming at approximating the currently achieved electron bunch form has been performed [10]. As a result of this study, which combined single-shot electro-optic detection and different THz spectroscopy approaches, the currently shortest electron

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bunch duration was approximated to be 1.2 ps (FWHM). It was observed, that for such relatively long electron bunch durations interferometric measurements tend to underestimate the bunch length and are hence only suitable to provide qualitative information on the compression.

The peak pulse energy for an undulator tune to 3 THz was determined with a power meter calibrated by the Physikalisch Technische Bundesanstalt (PTB) and is, with roughly 10 nJ, more than two orders of magnitude smaller than the design goal of 1 μJ at this charge. Furthermore a BAM monitor with 40 GHz bandwidth of FLASH design from DESY has been tested and successfully cross-calibrated against the THz based beam arrivaltime monitor.

OUTLOOK

The next studies at the test facility will aim at further improving the electron bunch form diagnostics and arrivaltime measurements for quasi-cw accelerators. One particular effort is the development of a compact on-chip THz spectrometer that shall replace the single element detectors in the BCM at ELBE [11]. These diagnostic activities are pursued in a multi-institutional approach funded by the HGF society through the ARD program. The Implementation of a transverse deflecting cavity into the test facility would be very beneficial for future tests of refined diagnostic of the longitudinal electron bunch distribution.

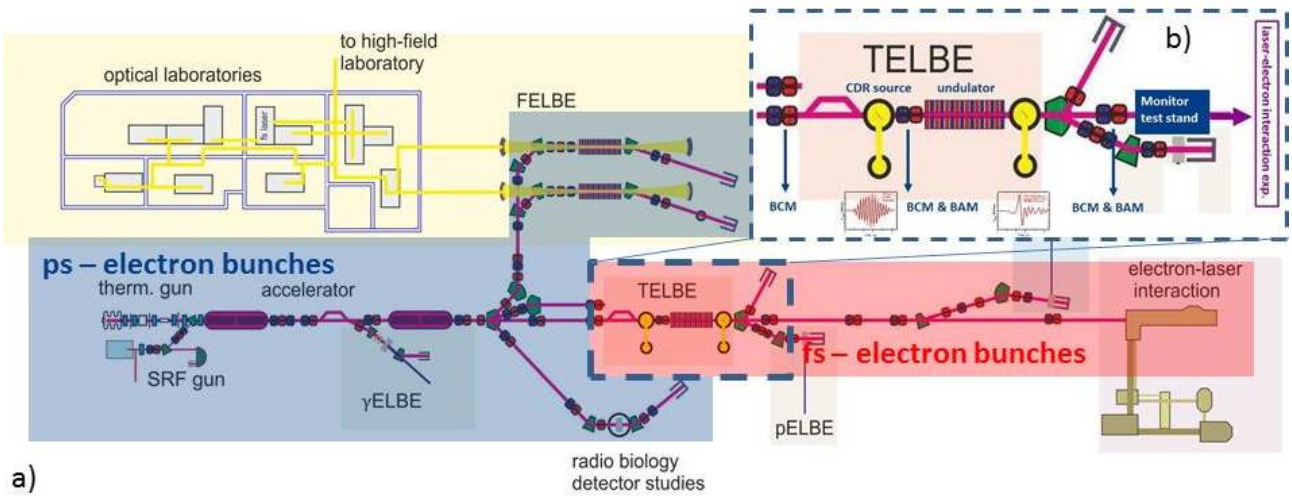

Figure 2: a) Upgraded ELBE accelerator with the test facility area marked by the dashed blue line. b) Detail of the test facility for quasi-cw electron beams.

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