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EOS AT CW BEAM OPERATION AT ELBE

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Abstract

The ELBE accelerator is a super conduction electron cw machine located at the Helmholtz Center Dresden Rossendorf Germany with 1 mA current, now tested for up to 2 mA. Besides other important diagnostics for setting up the machine for user beam time and further improvement of the machine – a THz source is momentary under commissioning – a EOS measuring station for bunch length measurements is locate right behind the second super conducting Linac.

Measuring with a crystal in the vicinity of an up to 2 mA cw beam implies higher beam loss and also higher radiation exposure of the crystal and hence also a safety risk for the UHV conditions of the super conducting cavities in the case of crystal damage. Therefore the EOS measuring principle is adapted to larger measuring distances and also for beam requirements with lower bunch charge at ELBE. A description of the setup, considerations of special boundary conditions and as well results for 13 MHz cw beam operation are presented..

INTRODUCTION

One of the frequently used experimental end stations at ELBE [1] are the free electron lasers U27 and U100. Their single pass gain so as the saturation depends strongly on the bunch length of the electron beam. For specific wavelength ranges the tuning of the FELs is very sensitive to the adjustment of ΔE and bunch length which can't be effected independently.

The generation of THz radiation at TELBE requires very short electron bunches in the range smaller 150 fs. Whereas the EOS setup described in the report is not capable to reach such resolutions it is very necessary to understand the beam transportation and phase space in ELBE precisely and hence also the bunch length before the electron bunch is compressed down to very small values.

Similarly the electron beam laser interaction requires a very precise timing and knowledge of the bunch length.

Therefore the EOS setup (pioneering work see e.g. [2]) is installed after the second Linac in ELBE before the beam branches to the different user beamlines.

EOS SETUP AT ELBE

At the ELBE EOS setup the electron bunch form was sampled with 150 fs (FWHM) pulses from a 78 MHz / 775nm fiber based laser (Toptica) for measurements with a ZnTe crystal and with a 100 fs (FWHM) 78 MHz / 1050 nm fiber laser (Menlo) for GaP crystals. The laser oscillator has been phase locked to the 13 MHz master clock of ELBE. A 0.8 mm ZnTe (110) crystal and a 1 mm GaP (110) crystal were used as an electro-optic pick up for the passing electron bunch. The change of polarization via the electro optic pockels effect was detected by a crossed polarizer set up for the ZnTe and for the GaP measurements with a Wollaston prism and a balanced detector (new focus mod. 1617). Because of the very small EOS signals a Lock-In technique was used. For cross check the two Lock-In amplifiers Stanford Research SR844 and the Zurich instruments HF2LI are employed. The electron bunch was scanned by shifting the laser lock phase relative to the 13 MHz system phase. See Fig. 1. The 78 MHz laser lock phase was adjusted coarsely relative to the bunch arrival at the EOS station with an OTR signal from the bunch (screen and fast photo detector) and at a later date with a BPM signal.

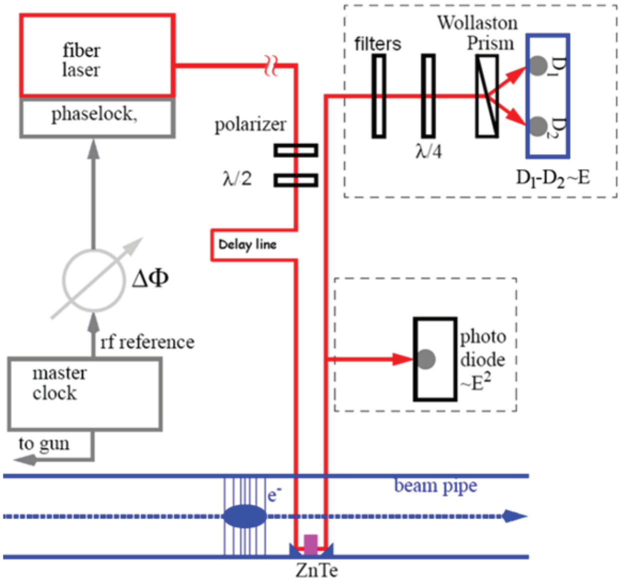

Figure 1: Basic detection schema of the EOS signal at the ELBE bunch length measuring station.

MEASURMENTS AT 100 KHz BEAM REPETITION RATE

Fundamental cw measurements were performed at an electron bunch repetition rate of 101562.5 Hz (128th sub harmonic of accelerator master clock base frequency of 13 MHz).

Since ELBE is a multi-purpose electron machine, there are also experiment requirement with small mean currents or low bunch charges. Figure 2 shows the dependence of the EOS signal amplitude as function of the charge of the electron bunch. A usable bunch length signal could be reached down to a charge of 3 pC.

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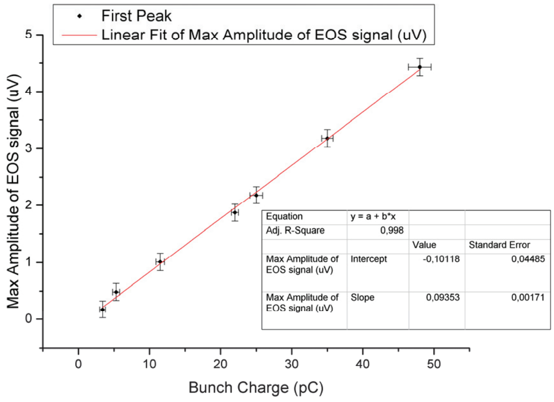

Figure 2: Amplitude of the EOS signal with increasing bunch charge. The linear dependence was measured down to a charge of 3 pC.

There were carried out studies to measure the dependence of bunch length for different phase space altering elements of the ELBE accelerator like buncher or cavities. They are comparable with similar previous investigations [3].

DIAGNOSTIC OF PULSE LENGTH AT 13 MHz CW OPERATION

The beam power of ELBE at cw 13 MHz operation at a mean current of 1 mA and e.g. 30 MeV is 30 kW. In cw operation it is therefore necessary not to have any diagnostic element in the beam pass. Measuring the bunch length in situ implies therefore to have a large distance between beam and EOS crystal. Despite the distance of around 17 mm to the beam tube wall it is still possible with the Lock-In amplifier technique to measure a proper signal.

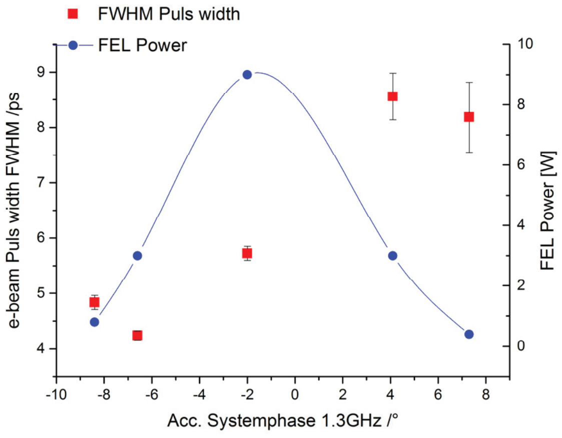

Figure 3: Electron bunch length and FEL-U27 power versus the system phase. Optimal FEL power (blue circles) is reached for a compromise between small bunch length (red squares) and small ΔE (not shown) at higher system phase values.

Figure 3 shows the measured bunch length for different system phase setpoints and the corresponding power of the FEL-U27.

CONCLUSION

The resolution of the used sampling EOS-Setup is limited mainly by the jitter of the beam, the jitter and drift of the beam synchronisation signal (Laser synchronisation and Lock-In technique), the relativistic broadening of the coulomb field at the crystal, and the THz generation in the crystal (crystal thickness) to around 1.5 ps.

For 101 kHz cw operation the bunch length can be measured down to a bunch charge of 3 pC. Whereas measuring bunch charges < 10 pC at 13 MHz cw a further improvement of the stability of the beam synchronous signal and reduction of noise floor at the measuring station must be achieved.

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