CONCEPT OF FEMTOSECOND TIMING AND SYNCHRONIZATION SCHEME AT ELBE

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Abstract

The Radiation Source ELBE (Electron Linear accelerator with high Brilliance and low Emittance) at Helmholtz-Zentrum Dresden-Rossendorf (HZDR) is undergoing an extension to offer capacity for various applications. The extension includes the setup of a THz-beamline with a dedicated laboratory and a section for electron-beam - high-power laser interaction.

For pump-probe experiments using optical lasers and Thomson backscattering, the desired synchronization between the pump and the probe pulse should be on the femtosecond scale.

THOMSON BACKSCATTERING

The most demanding experiment at ELBE regarding synchronization and timing is the Thomson Backscattering setup. That combines the 30 MeV, 80 pC ELBE electron beam with the 150 TW, 30 fs DRACO laser pulse in one chamber to generate narrow bandwidth X-ray pulses. Preliminary experiments are carried out with a cw-based synchronization system. The accelerator master clock is modulated on a cw laser signal and distributed to the laser laboratory via non stabilized optical fibers. That means all temperature drifts and mechanical vibrations affect the quality of synchronization.

Nevertheless the current head-on geometry allows a drift which corresponds to twice the Rayleigh length of 1 cm or 30 ps (see Figure 1). The disadvantage is that the last mirror has to be placed into the X-ray beam [1].

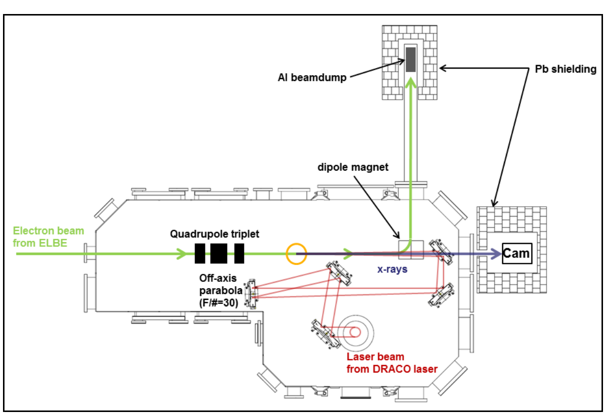

Figure 1: Setup of Thomson Experiment

To overcome this drawback the setup will be changed and the beams will collide under a small angle. Because of that the last mirror needs no hole for the X-rays anymore, but the synchronization requirements are much more stringent.

SYNCHRONIZATION SYSTEM

Introduction

In collaboration with DESY, a new synchronization system will be set up. The system will be based on a pulsed optical master oscillator and the latest version of the fiber link stabilization units developed by DESY. This system is operating successful at the X-ray free-electron laser FLASH in Hamburg and is still subject of research and development to improve the performance continuously [2].

Optical Master Oscillator

As optical master oscillator (OMO) a commercial SESAM-based laser will be used, which generates very short pulses with low phase noise. It will be locked to the accelerators RF master oscillator and provide the reference signal to all remote laser systems. The reference signal will be split and amplified in a fiber distribution box which is temperature stabilized. This part is very crucial because it is not actively stabilized, such all drifts will affect the quality of the fiber link and cannot be compensated. The repetition rate of 78 MHz was chosen because most of the laser systems used at ELBE are operating at that frequency.

Table 1: Optical Master Oscillator Specifications

Parameter	Value
central wavelength	1571 nm
spectral bandwidth	35.6 nm
pulse length (FWHM)	76 fs
output power	89 mW
RMS Jitter [1kHz; 10 MHz]	< 10 fs
repetition rate	78 MHz

Link Stabilization Unit

Recently, the third revision of the link stabilization unit was commissioned [3]. In these units the laser pulse train is split in a reference part and a signal which is sent to the remote station. The signal is partly reflected by a Faraday rotating mirror and travels back to the stabilization units. Heart of these units is the balanced Optical Cross-Correlator (OXC) which is very sensitive to any change of the phase between the reference and the reflected pulse. This signal is used to control two actuators, a fast piezo fiber-stretcher and a slow mechanical delay stage to keep the round-trip time constant. At the far end the signal can be used either directly to lock a laser or can be converted into a RF signal for a conventional lock scheme.

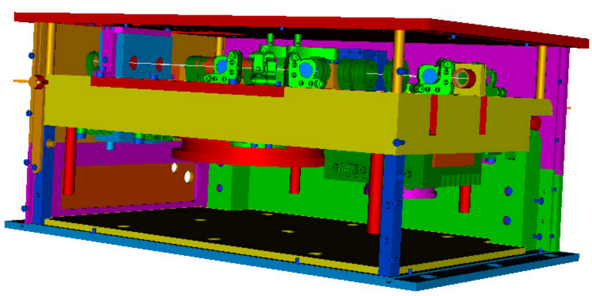

Figure 2: Design drawing of a fiber link stabilization unit.

The stabilization units have to be integrated into the ELBE control system to drive the actuators and to monitor all status signals. Most of the fast data processing tasks at ELBE are implemented in PXI technology, so the link units will be controlled like this as well. The fast control loops will be realized on a FPGA module while the slow loops are running on a PC environment.

Layout

The main part of the synchronization system will be installed in a synchronization laboratory close to the injector section and the low-level RF (LLRF). This laboratory with clean room characteristics and stable environmental conditions will contain the optical master oscillator, fiber distribution section and all link stabilization units including most of the needed electronics. This location was chosen to minimize the path length between the accelerators master clock and the optical master oscillator. In addition the synchronization of the adjacent cathode laser for the superconducting RF electron source (SRF gun) is less critical [4]. The SRF gun will be able to generate a cw electron beam with a bunch charge up to 1 nC. Many of the planned activities benefit of the high bunch charge in terms of efficiency and photon yield. The THz generation scales with the bunch charge as well as the number of X-ray photons in the Thomson Backscattering experiment. Figure 3 shows the Layout of the extended ELBE facility and a schematic of the new synchronization system.

The optical fibers will be installed in dedicated fiber ducts which are already installed. The ducts are routed to the THZ- laboratory and the DRACO clean room. After finishing its construction, the new PW Laser Penelope will be connected to the new synchronization system. In the synchronization laboratory spare space is foreseen to enable future extensions for other applications.

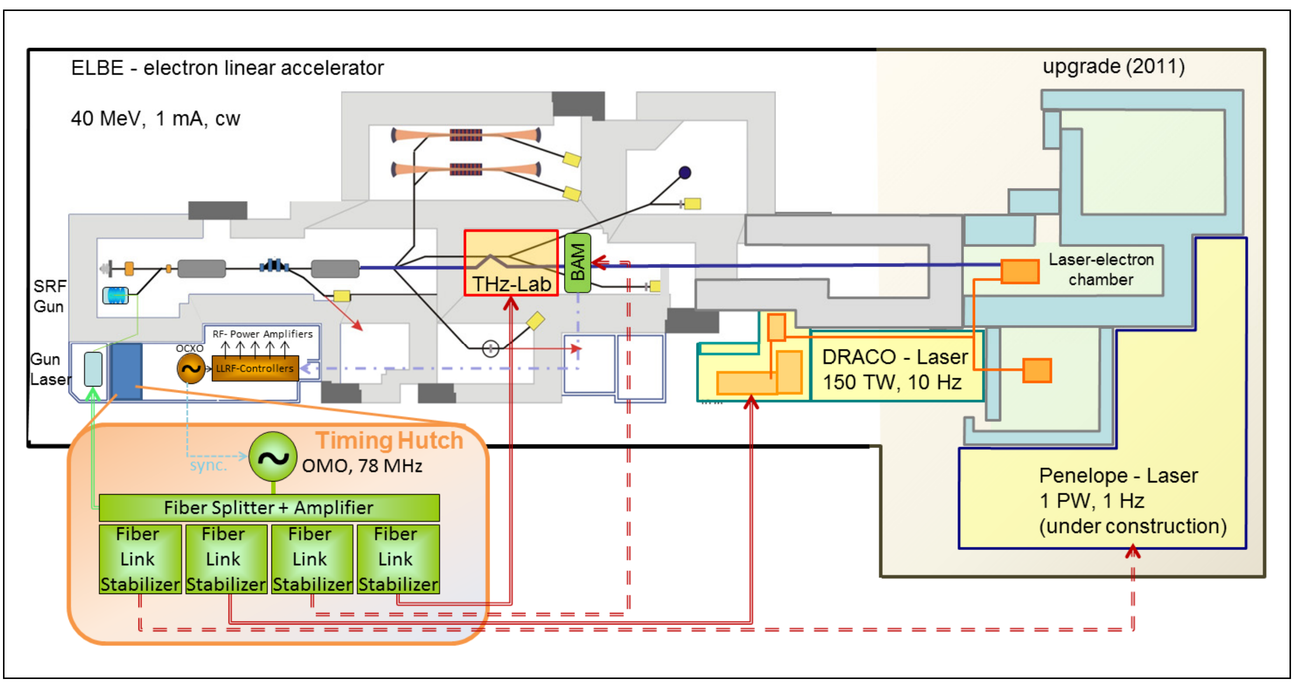

Figure 3: ELBE Layout after extension including synchronization scheme currently under construction.

DIAGNOSTICS

The pulsed synchronization system offers a variety of advantages. The possibility to use the stabilized pulse train for measuring the bunch arrival-time and the electron bunch jitter is one of these. Using an electro-optic modulator the intensity of the laser signal can be changed by a pickup signal coming from the electron bunch. DESY has put this technique into practice and is using bunch arrival-time monitors (BAMs) to stabilize the electron beam [5].

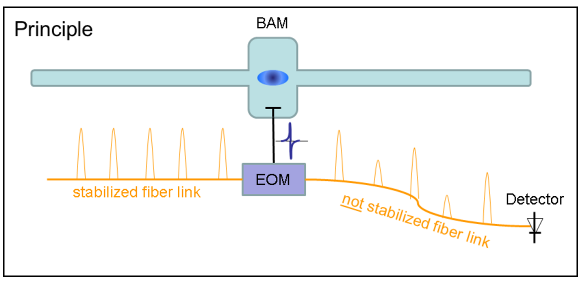

Figure 4: BAM Principle

In a first step BAMs will be used at ELBE to evaluate the stability of the electron beam and to identify possible noise sources. Afterwards it will be used in a feedback loop on the accelerating cavities to improve the electron stability on the target. The low-level controller was modified to enable an input of a phase offset signal which compensates for the arrival-time fluctuations.

OUTLOOK

It is planned to install the first two stabilized fiber links by the end of 2011. Beginning of 2012 these links will be commissioned and characterized and connected to the ELBE control system. The first links will synchronize the THz laboratory and the DRACO Ti:S Oscillator with high precision to the accelerator.

In the new beamline which will be installed by 2012 RF pickups for the bunch arrival-time monitors will be installed to enable precise measurements.

REFERENCES

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