REMOTE CONTROLLED IR-DIAGNOSTIC STATION FOR THE FEL AT ROSSENDORF

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Abstract

The remote controlled diagnostic station delivers a small amount of the IR radiation by means of a system of relocatable mirrors, scraper mirrors and beam splitters to the spectrometer and to various power detectors working in different power ranges. Furthermore, a long wavelength MCT detector is integrated in the diagnostic station for gain and loss measurement in the whole wavelength range of the U27-FEL. The average FEL power for the users can be reduced by a remote controlled attenuator. We have built a non-collinear background-free autocorrelator as a part of the diagnostic station to characterize the optical micropulse duration. By using a CdTe single-crystal for second-harmonic generation a broad wavelength coverage is obtained. In order to decrease the average radiation power of the Rossendorf FEL, as required for certain experiments, the repetition rate can be reduced from 13 MHz to 1 kHz. For that aim a semiconductor plasma switch excited by a synchronized Nd:YAG amplifier is under commissioning and first results will be presented.

INTRODUCTION

The Radiation Source ELBE [1] at the Forschungszentrum Rossendorf in Dresden is centered around a superconducting Electron Linear accelerator of high Brilliance and low Emittance (ELBE), constructed to produce CW electron beams up to 1 mA beam current at 40 MeV. The electron beam is used to generate various kinds of secondary radiation, mainly to drive free-electron lasers in the infrared region (3-150 μm). Starting in the summer 2005, beam time is offered to external users in the frame of the EC funded "Integrating Activity on Synchrotron and Free Electron Laser Science" (FELBE project [2]). It is of great importance for routine user operation at ELBE that after changing the beam path or after beam interruptions stable operation in all wavelength ranges can be provided within a very short time (some minutes). Extensive diagnostics for the optical components of the FEL are very important to achieve fast availability.

DIAGNOSTIC STATION

Remote Controlled Power and Wavelength Measurement

We have developed an optical beam diagnostic system (see Fig. 1) to properly characterize and adapt the output of the two FELs (U27 and U100). The present system is compatible with a tuning range from 3 μm to 150μm, and can be extended beyond 150 μm, if necessary.

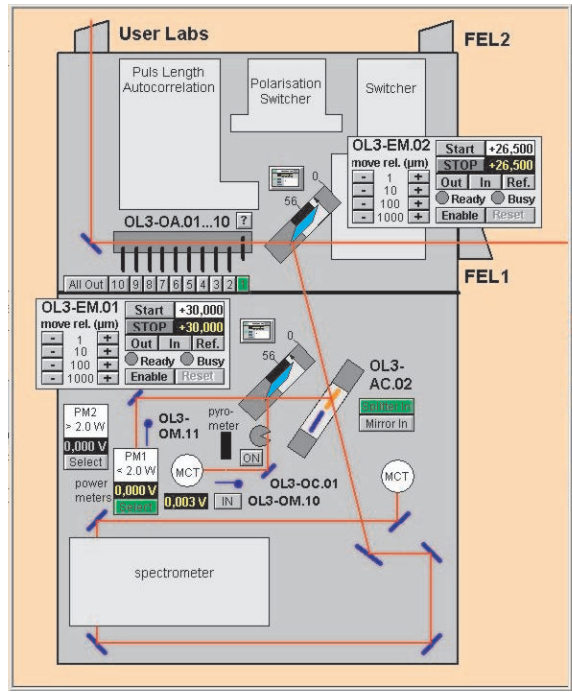

Figure 2: Interface of the remote controlled part of the IR-diagnostic station. One attenuator, two scraper mirrors on stepper controlled stages, one mirror and one beam splitter on a common pneumatic stage, spectrometer and different power meters are indicated. The red lines show different paths for the radiation when both scraper mirrors are not entirely within the beam.

The FEL beam from each undulator will be transported separately from the resonator to the diagnostic area through beam pipes using reflective optics. Both lines will be merged on the diagnostic table, which may be purged with dry nitrogen to avoid absorption in air, if necessary. From here both the beams follow the same path. From the main beam, approximately 1-5 percent of the total power will be separated by a scraper mirror on a translation stage for wavelength measurement and power monitoring. The transmitted beam passes an attenuator and can be delivered to 6 optical laboratories. In this attenuator precisely fabricated metal grids diffract a calibrated (3,5, and 3 $\times$ 10 dB) percentage of power out of the beam. The rejected power is absorbed in the walls of the housing. The mode structure and other properties of the transmitted beam in-

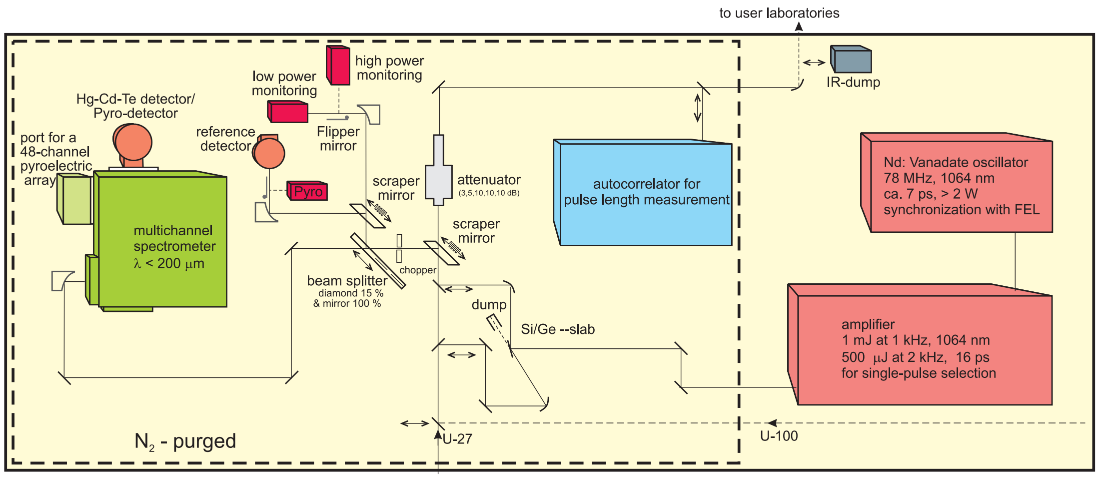

Figure 1: Arrangement of the different optical components and devices on the table.

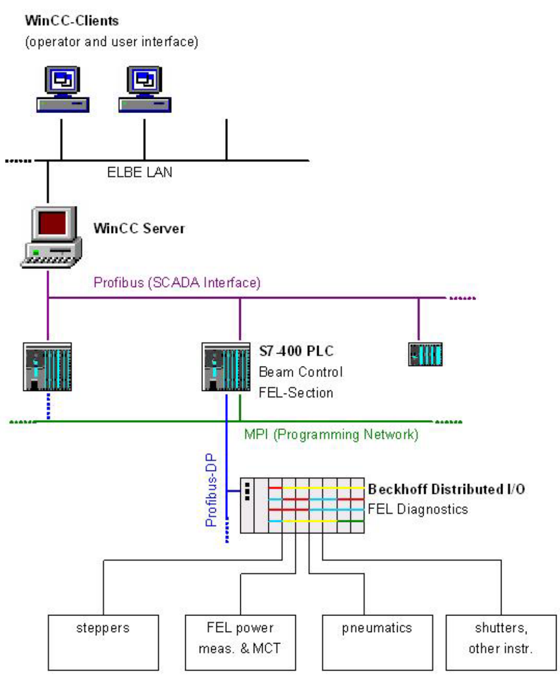

Figure 3: The existing Programmable Logic Control (PLC) and Human-Machine-Interface (HMI) environment of ELBE with the integrated FEL diagnostics instrumentation.

cluding the divergence and the M^2 parameters are fully preserved, the polarisation as well. The deflected part of the power goes through a synchronized chopper for measurement in CW-mode. Next to this the outcoupled beam is deflected by a mirror or a diamond beam splitter (350 μm thick, under 45 degrees, deflection 15 %) at a pneumatic translation stage. The beam transmitted through the diamond beam splitter (85 %) is transported to the spectrometer. The spectrum is measured with a Czerny-Turner type spectrometer which contains a turret with three different gratings to cover the whole wavelength range from 3 μm to about 200 μm. The monochromator will be equipped in near future with a 48-channel pyroelectric linear array detector. We use the second side exit slit equipped with a single Hg-Cd-Te or Ge-Ga detector for measurements with higher sensitivity. The part reflected from the pneumatic device is distributed with an other scraper mirror and two flipper mirrors to different power meters and reference detectors for monitoring the lasing process (see Fig. 2). The FEL diagnostic instrumentation has been integrated into the existing Programmable Logic Control (PLC) and Human-Machine-Interface (HMI) environment of ELBE (see Fig. 3). It ensures the access both for operators and users of the FEL. The basic technologies used are the WinCC server/client system, the SIMATIK PLC system and distributed I/O by Beckhoff Automation for control of pneumatic components (i.e. attenuators), analogue data logging (FEL power, MCT) and other instrumentation. The stepper control drivers for the scraper mirrors are integrated system components, whereby using (expensive) separate controllers could be avoided.

Characterization of the Optical Pulse

The optical pulse length can sensitively be tuned by varying the resonator length with respect to the nominal length resulting from the electron bunch repetition rate. At minimum detuning one yields the highest saturated power and the shortest optical pulse length. By detuning the resonator the spectral width can be decreased simultaneously increasing the pulse length. To characterize the ultrashort pulses generated by the FEL we built a non-collinear background-free autocorrelator system. We used a CdTe crystal as SHG medium [3], since it is transparent for a wide wavelength range in the FIR. We measured the autocorrelation function at maximum power in the detuning curve at a wavelength of 11.09 μm (see Fig. 4, upper part). We deduced a pulse duration of 0.89 ps (FWHM), assuming a Gaussian temporal pulse shape. The measured FWHM of the spectrum is approx. 176 nm. The cal-

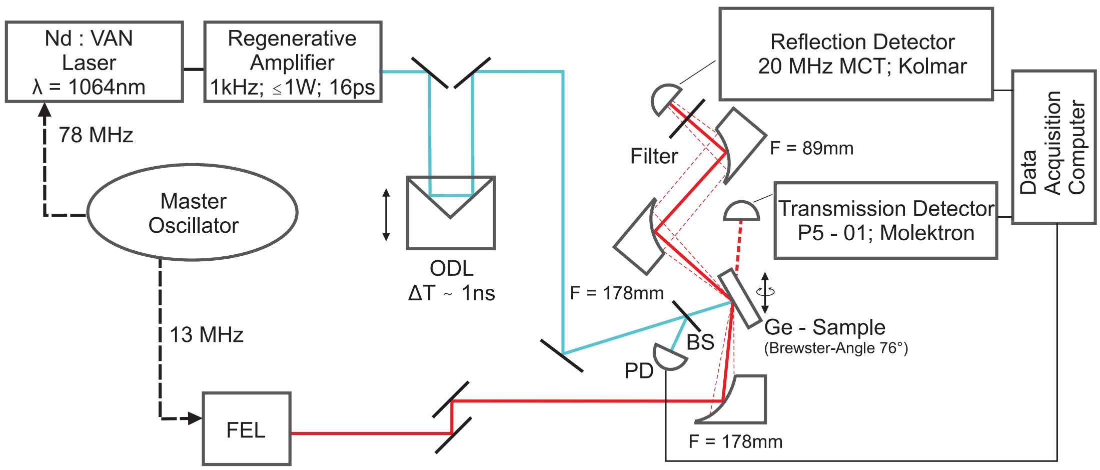

Figure 5: Setup for the plasma switch (see below).

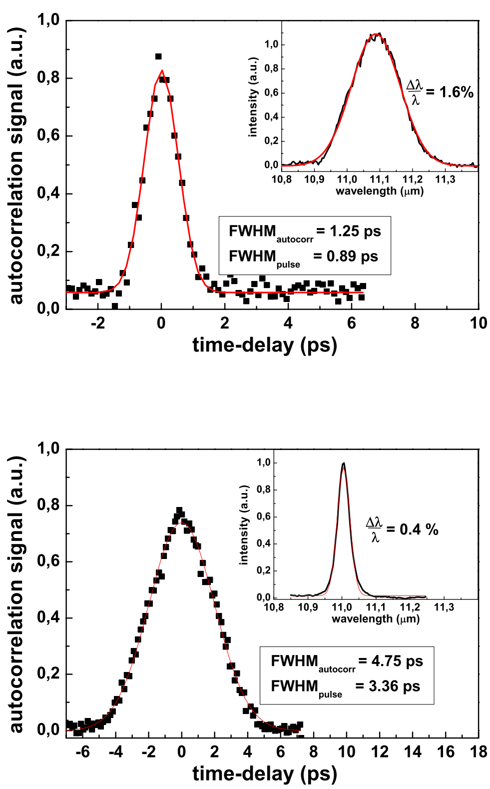

Figure 4: Pulse duration and the corresponding FWHM of the wavelength of 11 μm at maximum of the detuning curve (upper part) and from a detuned resonator (lower part).

culated time-bandwidth product is about 0.4 which indicates Fourier-transform limited operation. Long IR pulses with narrow bandwidth can be obtained from a detuned resonator (see Fig. 4, lower part).

Extraction of Single FEL Radiation Pulses Using a Laser-Activated Plasma Switch

In order to decrease the average radiation power of the Rossendorf free-electron laser FELBE, as required for certain experiments (high pulse energies but moderate or low average power), the FEL repetition rate can be reduced from 13 MHz to 1 kHz. To this end, plasma switching of FEL radiation pulses was demonstrated. The plasma switch bases on the principle of photo-induced reflectivity by an optically excited electron-hole plasma [4, 5]. Germanium serves as semiconductor material for the switch. The semiconductor was illuminated by a Nd:YAG laser amplifier system (1 kHz, λ = 1064 nm, $\tau \sim$ 16 ps, $\leq$1 Watt), generating an electron-hole plasma on the front surface of the semiconductor. The generation of sufficient plasma density leads to a variation of the optical semiconductor properties for the infrared FEL-radiation (strongly focused and under Brewster's angle). For realizing the pulse selection the frequencies of both laser sources (FEL and Nd:YAG) were synchronised with RF electronics. For the exact timing of both laser pulses, when they hit the semiconductor, they were detected with a photon-drag detector or a fast pyroelectric detector (FEL) and a photo diode (Nd:YAG) and were adjusted on each other with cables, phase-shifter (trombone) and through moving a precision linear stage. Fig. 5 shows the experimental set-up. A gold mirror served as a reference for determining the reflectivity of the Germanium. The selected FEL pulses were detected by a fast MCT detector with a bandwidth of 20 MHz. Fig. 6 shows the switched pulse in two amplitude scales. The signal from the switch laser (photo diode) is shown in red. From the comparison of the black and blue curves we obtained an amount of dark pulses in the switched beam of about 0.5 % due to the angle of beam spread from the focussing. The time-resolved measurement of the reflectivity yields an exponential decay with a time constant of 590 ps. For the highest value of the Nd:YAG laser amplifier peak fluence of 25 mJ/cm^2, a reflectivity of Ge for FEL radiation ($\lambda = 11\mu m$) of 100 % was achieved (see Fig. 7). We thus succeeded to extract single FEL radiation pulses out of the 13 MHz pulse train, indicating that this plasma switch is most suitable for the Rossendorf FEL. Further examinations will concentrate on achieving similar results for shorter wavelength. To integrate this plasma-switch into the existing diagnostic station we have to build an additional by-pass to the Germanium or Silicon slab which is under Brewster's angle (see Fig. 1). The selcted micro pulse will be refocused to the waist parameters outside of the by-pass line and transported to the user stations.

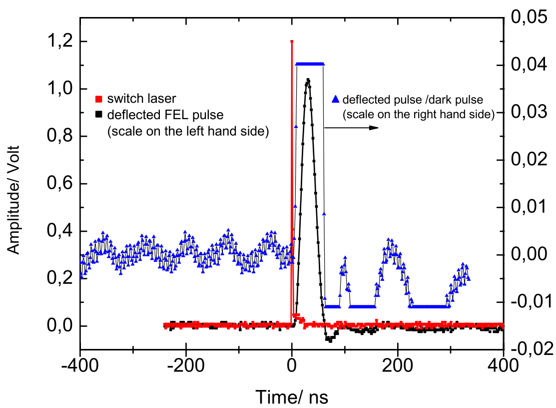

Figure 6: The switched FEL pulse at 11 μm in two different amplitude scales is measured by a fast MCT detector with a bandwidth of 20 MHz. The signal from the switch laser (photo diode) is shown in red. From the comparison of the black and blue curves we obtain an amount of dark pulse in the switched beam of about 0.5 %.

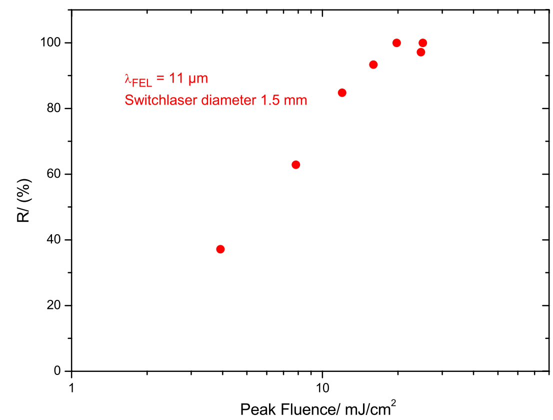

Figure 7: Dependence of reflectivity on the pump-laser peak fluence.

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