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

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In order to decrease the average radiation power of the Rossendorf free-electron laser FELBE (FELBE project [1]), 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 for cw operation.
The plasma switch is based on the principle of photo-induced reflectivity by an optically excited electron-hole plasma [2, 3]. Germanium serves as semiconductor material for the switch. The semiconductor was illuminated by a Nd:YAG laser amplifier system (1 kHz, $\lambda = 1064$ nm, $\tau \sim 16$ ps, <1 Watt), generating an electron-hole plasma at the front surface of the semiconductor. The generation of a sufficient plasma density leads to a variation of the optical semiconductor properties for the infrared FEL-radiation (strongly focused and under Brewster's angle of 76^o). 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. 1 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. 2 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. 3). 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 [4]). The selected micro pulse will be refocused to the waist parameters outside of the by-pass line and transported to the user stations.

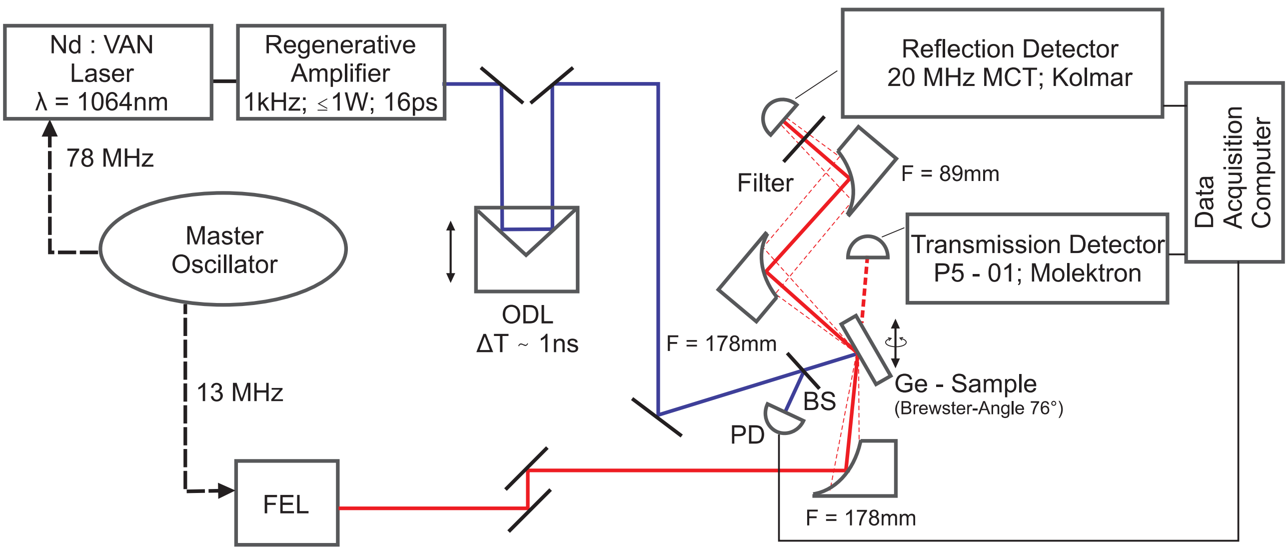

Fig. 1 *Setup for the plasma switch (for details see above)*

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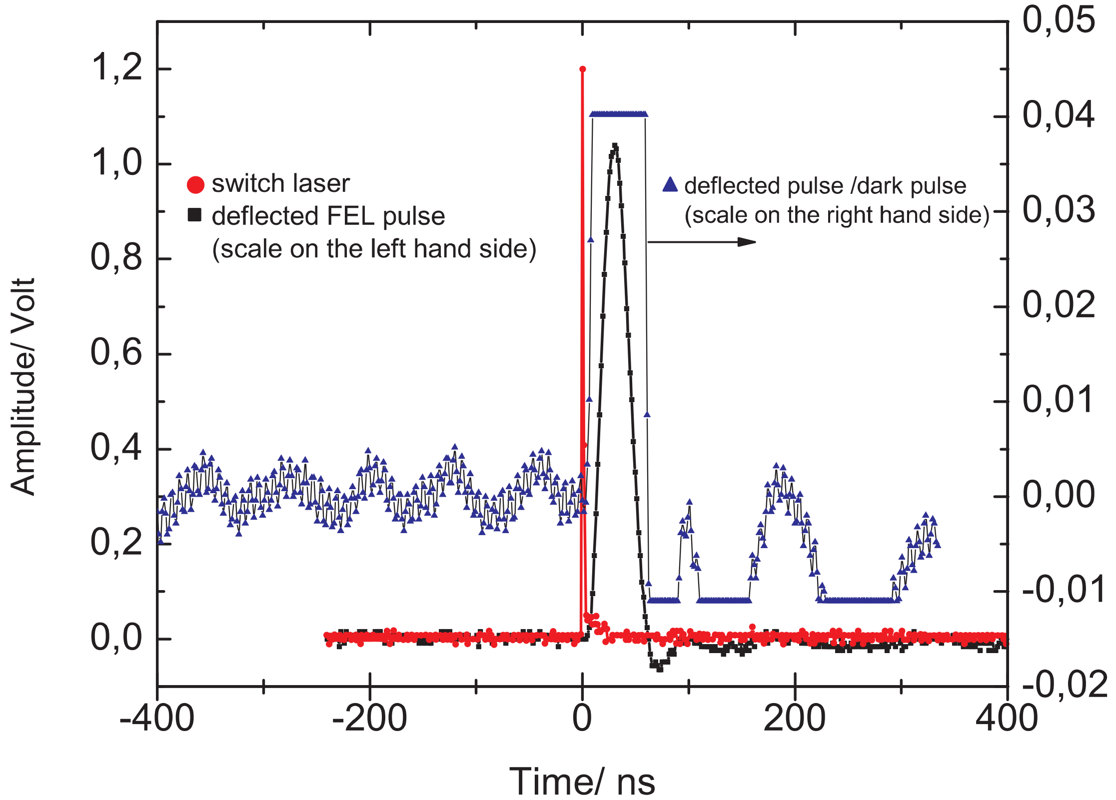

Fig. 2 *The switched FEL pulse at 11 μm in two different amplitude scales is measured by a fast MCT detector with a bandwidth of 20 MHz. The signal from the switch laser (photo diode) is shown in the curve with circles. From the comparison of the curve with squares and curve with triangles we obtain an amount of dark pulse in the switched beam of about 0.5%.*

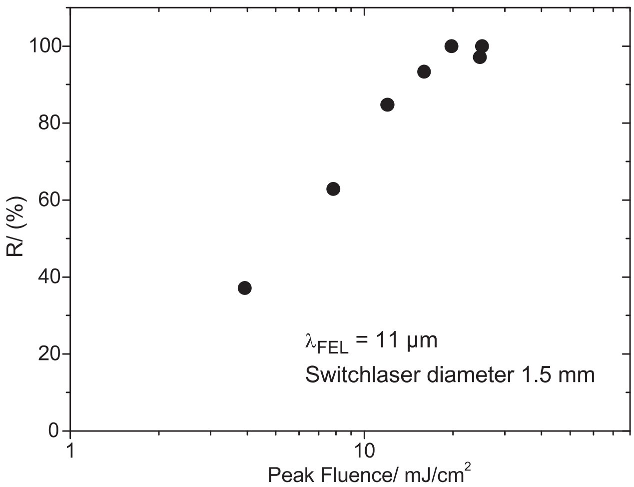

Fig. 3 *Dependence of reflectivity on the pump-laser peak fluence.*

[1] http://www.fzd.de/elbe

[2] P. Haar, Ph.D. thesis, Stanford University (1996)

[3] E.H. Haselhoff et al., Nucl. Instr. and Meth. A358 (1995) ABS28

[4] W. Seidel et al., this Report, p. 72