VUV-FEL User Facility at DESY

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The free electron laser (FEL) at the TESLA Test Facility (TTF) at DESY achieved first self amplified spontaneous emission (SASE) in the vacuum-ultraviolet in early 2000 [1]. In 2001, SASE FEL gain up to saturation was reached between 80 –120 nm [2, 3]. During an on-going upgrade which will be completed at the end of 2004, the VUV-FEL at DESY is transformed into a full user facility with five experimental stations using the FEL beam alternately [4, 5]. Expected FEL parameters are summarized in Table 1. Three experimental stations use the direct SASE FEL beam and are equipped with focusing mirrors providing spot sizes of approximately 100 or 10 μm. Two experimental stations are served by a high resolution monochromator for experiments requiring a spectral bandwidth narrower than the natural FEL bandwidth of ~ 0.5 %. The plane grating monochromator has a resolution of 80000-10000 while providing a wide tuning range from 10 eV to 1 keV.

The exponential amplification process of a SASE FEL starts from spontaneous emission of the electron beam [6]. Hence, individual radiation pulses differ in intensity, temporal structure, and spectral distribution. Extensive characterization of the FEL beam [1-3, 7, 8] as well as a first set of experiments on the interaction of such VUV radiation with cluster beams [9] and surfaces [10] was carried out during TTF Phase 1 and showed that exploitation of the unique FEL properties requires suitable pulse-resolved diagnostic tools.

A FEL intensity monitor has to cover the full spectral range from 6 to 120 nm as well as a very large dynamic range from spontaneous undulator emission to SASE in saturation. For that purpose, an absolutely calibrated gas-monitor detector based on photoionisation of noble gases at low target densities has been successfully tested during TTF Phase 1 [12]. Currently, the gas-monitor detector is upgraded with split electrodes allowing time-resolved determination of the horizontal and vertical beam position. In addition, a 15 m long windowless noble-gas-filled section of the beam tube with adjacent differential pumping units will be used as a means to attenuate the FEL radiation intensity without changing the FEL beam characteristics.

The spectral distribution of individual FEL pulses will be determined online by a variable-line-spacing (VLS) grating spectrometer serving the three “SASE beamlines” [11]. One of the plane mirrors in the FEL beam distribution system will be replaced by the VLS grating which reflects most of the radiation in zeroth order to the experiment and disperses only a small fraction in first order for spectral analysis.

The degree of spatial coherence of FEL radiation is very high [8], but it varies slightly with the degree of saturation. Also, beamline optics will affect the wavefront propagation. Therefore, tools to measure and eventually to correct the wavefront are developed to provide a uniform intensity distribution in the focal spot on the sample and to achieve smallest spot sizes for high-brightness applications.

The short X-ray pulse duration of typically 100 fs or potentially shorter is one of the most attractive features of linear accelerator (linac) based free electron lasers. To exploit these ultrafast pulses in two-colour pump-probe experiments, the FEL is complemented by an optical laser system. The optical laser comprises a Ti:Sa oscillator and an optical parametric amplifier pumped by a high-power Nd:YLF laser which is based on the design of the photocathode laser of the linac injector. This concept was chosen because it provides a great deal of flexibility for later upgrades in terms of tuning range, pulse duration and average output power. The most demanding task of the project is the synchronization of FEL and laser, including beam and signal transport over long distances and the development of suitable diagnostics for pulse duration and exact phase control between the FEL and the optical laser pulses.

Alternatively, an autocorrelation setup using grazing incidence plane mirrors will be integrated into a beamline for FEL pulse duration measurements. Also, single-colour pump-probe experiments or, using suitable filters, a combination of first and third harmonic FEL radiation will be possible, allowing ultimate time resolution independent of the pulse timing [13].

TABLE 1. Expected parameters of the VUV FEL at DESY.

Electron beam	
Energy	0.2 – 1 GeV
Number of bunches per train	up to 7200 in 800 μs
Repetition rate	1 - 10 Hz
Bunch charge	1 nC
FEL radiation	
Wavelength	120 – 6 nm
Pulse energy	0.1 – 1mJ
Pulse duration (FWHM)	30 – 400 fs
Peak power	0.3 - 2.8 GW
Spectral width (FWHM)	~0.5 %
Spot size at undulator exit (FWHM)	1.4 – 0.14 mm
Angular divergence (FWHM)	170 – 24 μrad
Peak brillance	1x 10^{28} – 3x10^{30} photons/sec/mrad^2/mm^2/0.1 %bw

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