A high resolution Plane Grating Monochromator
Beamline for the VUV-FEL

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The VUV-FEL at DESY is dedicated to delivering extremely short VUV laser pulses of 20-200 fs duration with very high radiation energy in the range of few ten microjoules per pulse. This poses a powerful tool for molecular and cluster dynamics investigations, ionisation and fragmentation experiments. The intrinsic energy resolution of the VUV-FEL is in the order of 0.5%, which is not sufficient for quite a number of applications. To make this machine available for a broader range of questions two high resolution monochromator beamlines were prospected of which one is in operation since June 2005. This contribution presents the design and outlines its properties.

Beamline layout

To perform experiments at a higher resolution a monochromator is desired. The monochromator can furthermore be used to suppress the higher harmonics from the FEL. The layout of the dispersing unit follows the design of Follath and Senf [1] employing a plane grating monochromator with an SX700 pre-mirror grating optic. All optical active elements of the beamline are shown in figure 1. For all optical components Diamond-Like-Carbon (DLC) coatings are used to withstand the high power density of the VUV-FEL.

The beam is diverted out of the FEL axis and into the PG branch by the plane mirror M0. It is followed by the toroidal mirror M1, which focusses the beam horizontally onto a spot 2 m before the exit slit, while it is collimated vertically for the monochromator optics. The monochromator consists of the plane mirror M2 and a set of actually two plane gratings as described in Ref.[1]. To reduce the high power density on the pre-mirror M2 the dispersed FEL radiation rises behind the grating. An option exists to use the zeroth order from the grating for experiments and to analyse FEL pulses in first order. Past the dispersing unit a standard switching mirror unit with a sagittal focussing cylindrical mirror deflects the radiation into the PG2 branch and focusses it vertically onto the exit slit. A bitoroidal refocussing optic past the exit slit deflects the beam into horizontal direction for the use on the experiment.

The monochromator has been set up and the first branch started operation in June 2005. The second, micro-focussing branch is scheduled for the second half of 2006. [2]

Energy Resolution

The energy resolution is constrained by four parameters.

- slope errors
- vibrations
- grating and $c_{ff}$ parameter
- exit slit width

Whereas the first two parameters are hardware limitations. The last two parameters can be set by users. The slope errors have been extensively calculated in ref. [2]. The vibrations are a limitation which
Figure 1: The optical elements of the monochromator beamline TTF-PG2 are shown schematically.

Angular frequency measurements showed that the amplitude for both grating and premirror is in the arcsecond range and peaks around 25 Hz and 50 Hz. Unfortunately, this currently decreases our expected resolving power of the grating by a factor of three. For the 200 lines/mm the expected resolving power is depicted in fig. 2. The refocussing mirror M4 images the exit slit onto the sample. Thus, the vertical spectrum at the opened exit slit is imaged on the sample. The corresponding expected resolving power of the exit slit for three different slit widths is shown in fig. 3.

**Modes of Operation**

The monochromator is presently equipped with two gratings, one with 200 lines/mm for the lower energy regime up to 200 eV and a high resolution grating with 1200 lines/mm for the energy range from 100 eV to 600 eV. The gratings can be chosen in the first section in the monochromator control depicted in fig. 4.

The monochromator can be operated in three different modes depending on the experimental requirements. An overview of the energy range the monochromator can cover is depicted in fig. 5.
The different modes can be chosen in the second section of the monochromator control (see fig. 4) The constant fixed focus mode ($c_{ff}$) allows to set the virtual source point to a fixed position. This is the parameter to set the energy resolution as well as the maximum transmission. A high $c_{ff}$ value leads to a high energy resolution, but is accompanied by low transmission. The on blaze mode can be used whenever high transmission is required. The incident angle on the grating is constant in this mode and can be set in the monochromator control. However, a special blaze grating is required, which yields higher diffraction efficiency. The monochromator is not yet equipped with this kind of grating.

Finally, the monochromator can serve as spectrometer. The zeroth order, which normally is absorbed in the beamdump, can be used in a dedicated zeroth order beamline PG0 simultaneously.
Figure 5: Energy and $c_{ff}$ range of the monochromator: Due to the high power of the FEL radiation the incident angles of the VUV light on the optical components of the monochromator is limited to 4 degrees yielding the left border line of the individual operational regimes. The solid lines correspond to energy and $c_{ff}$ parameter when zeroth and first order are used simultaneously. As the figure shows it is not possible to use this mode for the 1200 lines/mm grating in the energy regime up to 200 eV.

with the first order in PG2. During commissioning and user experiments this has been used and tested by users [3].

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References