# WIRE SCANNERS IN THE UNDULATOR SECTION OF THE VUV-FEL AT DESY

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## Abstract

The design and implementation of wire scanners for the Vacuum Ultraviolet - Free Electron Laser (VUV - FEL) facility at DESY [1] is presented. In the undulator section of the VUV FEL a set of seven wire scanner stations determine the relative position of the electron beam within few  $\mu$ m and the absolute position related to the undulator axis with a precision better than 50  $\mu$ m. First results of beam trajectory and beam size measurements along the undulator section are shown.

### **INTRODUCTION**

Wire scanners have been in use for many years in accelerator facilities in order to measure the profile and the position of particle beams [2-4]. The basic working principle of wire scanners is shown in figure 1. A fork equipped with thin wires  $(10 - 50 \ \mu\text{m})$  passes the electron beam. The beam interaction with the wires produces high energetic radiation which is detected by scintillation counters. Simultaneously monitoring of the wire position allows the measurement of beam profile, and position. Constant wire velocities of up to 1 m/sec (fast scan mode) are needed to scan powerful particle beams.



Figure 1: Working principle of the wire scanner. Secondary particles are created when the wire passes through the electron beam.

The VUV FEL at DESY [5] is a 30 m long permanent magnet undulator structure with seven integrated wire scanner stations. The system is part of a test linac operated in superconducting technology. The FEL light (down to a wave length of a few nm) is created by Self Amplified Spontaneous Emission (SASE). The SASE effect takes place when the electron and photon beam overlap better than 50  $\mu$ m over the whole undulator

length. Critical alignment parameters for this interaction are:

- Alignment (< 50  $\mu$ m) of the electron beam trajectory to the magnetic center of the undulator.
- Electron beam parameters as beam position and beam emittance.

To measure these alignment parameters in the undulator section of the VUV FEL special wire scanners were developed [6].

## TECHNICAL LAY OUT OF THE WIRE SCANNER

The essential features of the wire scanner are the stroke of 48 mm combined with high position accuracy (few µm) over a working range of 30 mm. A scanning speed of 1 m/sec has to be realized to avoid destruction of the wire in multi bunch mode operation. In this case the electron beam with up to 7200 bunches within 800 µsec (at 10Hz) will heat up slowly passing wires and destroy them. Three thin wires (10 µm carbon, 10 µm and 50 µm tungsten) are clamped between the two teeth of a ceramic fork with a spacing of 10 mm. The linear movement of the fork is based on a slot winding cylinder transforming the rotation of a stepping motor into a linear motion. The cam of the slot winding cylinder uses the transfer function of a Bestehorn-sinuide. The interaction between the wire and the electron beam takes place in the linear speed range of the transfer function. The position of the wires is measured on axis with an incremental length gauge with a resolution of 0.1 µm.



Figure 2: A wire scanner station between two undulators.



Figure 3: The technical schema shows the different components of the station.

The wire positions relative to the theoretical beam position (undulator axis) is calibrated using the length gauge in combination with an optical calibration tool during the assembly procedure. This allows in combination with a wire alignment tool an absolute beam position measurement related to the undulator axis with a precision better than 50  $\mu$ m. The whole unit as shown in figure 2 and 3 was assembled under class 100<sup>\*</sup> clean room conditions.

A stepping motor with a torque of M > 2 Nm and 51200 micro steps per rotation is used to drive the slot winding cylinder. To ensure that the motor does not lose steps, a special power supply unit [7] is used. This power supply accomplishes a minimal step resolution of 2.8  $\mu$ m in the linear range of the slot winding cylinder. For the control of the wire scanner movement an IP-Stepper module [8] is used.

## FIRST MEASUREMENTS IN THE UNDULATOR SECTION OF THE VUV-FEL

The described systems were installed in the undulator section in 2004. All units are in operation and in use to align the electron beam.

A complete wire scanner station between two undulators is shown in figure 2. Figure 3 depicts the 3D drawing of the diagnostic set up with the two wire scanners, the quadrupoles with their driving units, and the base plate with the wire alignment system.

Figure 4 shows slow stepwise scans of all seven installed wire scanner stations in the horizontal and vertical plane perpendicular to the particle beam.

<sup>\*</sup> clean room classification according US Fed. Standard 209E



Figure 4: Example of horizontal and vertical beam scans at the seven wire scanner stations.

From these types of measurements the beam trajectory as well as the beam size can be deduced. A different evaluation of beam trajectories and beam sizes in horizontal and vertical direction is presented in figures 5 and 6.



Figure 5: Horizontal and vertical beam trajectories determined by wire scanner measurements along the undulator section.



Figure 6: The horizontal and vertical beam size at the position of the wire scanners.

#### CONCLUSION

A fast wire scanner system was designed and built for the undulator section of VUV FEL at DESY. Seven stations with two wire scanners are in operation now. The beam trajectory along the undulator section as well as the beam size and the beam position are determined. These measurements are used for beam based alignment.

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