WIRE SCANNER SYSTEMS FOR THE VUV FEL UNDULATOR AT DESY

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Abstract

The design and implementation of a new kind of wire scanner for the Vacuum Ultraviolet - Free Electron Laser (VUV - FEL) facility at DESY [1, 2] is described. In the undulator section of the VUV FEL a set of seven wire scanner stations determine the relative position of the electron beam within a few μm and the absolute position related to the undulator axis over 30 m with a precision better than 50 μm. Monte Carlo calculations are performed in order to get an optimal position for the scintillators, which are used to detect the secondary particles scattered by the wire.

1. 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 [3]. The basic principle of the measurements consists in detecting the secondary particles created when the wire passes through the electron beam with a constant velocity of up to 1 m/sec (see figure 1). Beam diagnostics within the undulator plays an important role to run and to understand the FEL process. Precision measurements of electron beam parameters like position, beam size, and emittance are mandatory. A good overlap (<50µm) between the electron and the photon beam over the entire undulator length (30 m) is required for the FEL process. The basic working principle of the presented wire scanner [4] is shown in figure 1. A fork equipped with thin wires (10 – 50 µm) is driven through the electron beam. The beam interaction with the wires produces high energetic radiation, which is detected with scintillation counters. Simultaneous monitoring of the wire position and scintillator intensity allows the measurement of beam profiles. The profiles are used to define position, size, and emittance of the electron beam.

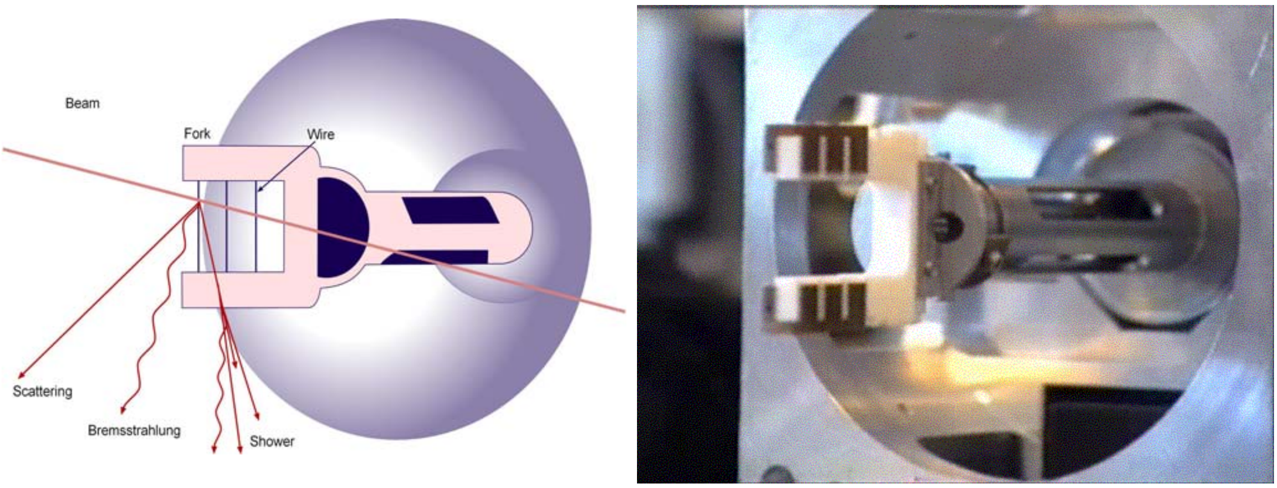

Figure 1: *Working principle of the wire scanner: secondary particles are created when the wire interacts with the electron beam.*

2. Technical lay out of the wire scanner

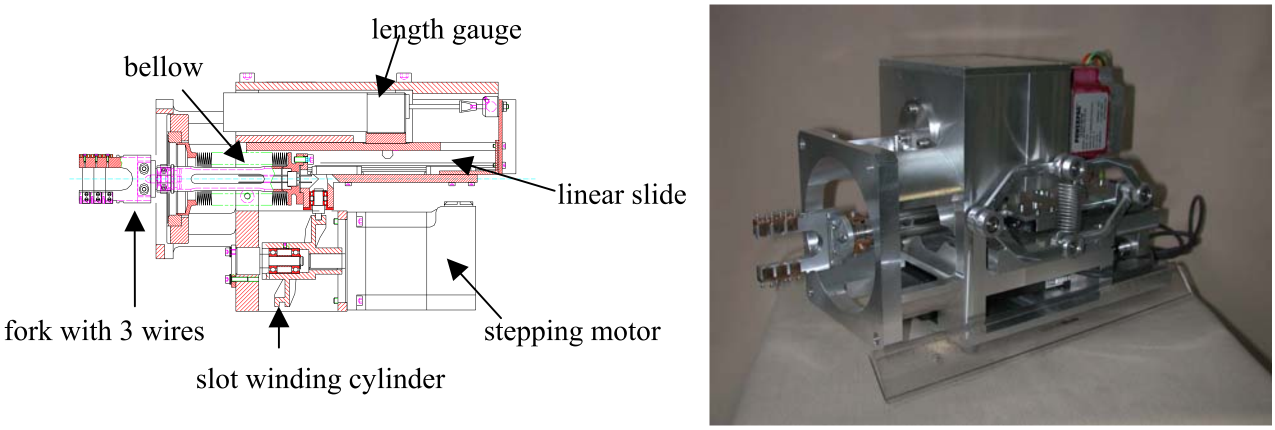

Figure 2: *Photo and cross section of the wire scanner unit.*

The essential features of the wire scanner are the stroke of 48 mm combined with a high position accuracy (few µm) over a working range of 30 mm. A fast scanning speed of 1 m/s prevents the destruction of the wire. Slowly passing wires will be destroyed in the case of a fully populated electron bunch train of 7200 bunches within 800µsec. Thin wires (10µm carbon, 10 µm and 50 µm tungsten) are clamped with a spacing of 10 mm between the two teeth of a ceramic fork (see figure 2). The linear movement of the fork is based on the so called "slot winding cylinder" (see figure 2 and 3) transforming the rotation of the motor axis into a linear motion. The cam of the slot winding cylinder follows the transfer function of a Bestehorn-sinuide [5] (see figure 4).

Figure 3: *The slot winding cylinder is used for the transformation of the rotation of the motor axis into a linear motion of the fork.*

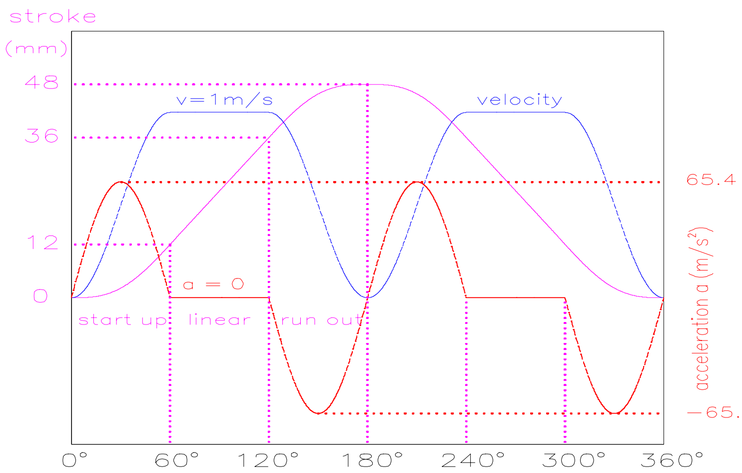

Figure 4: *The transfer function characteristic of the slot winding cylinder is the Bestehorn-sinuide[5] shown as pink solid line. The blue curve is the fork velocity while the red one shows the acceleration resp. the deceleration of the wires.*

The interaction between the wire and electron beam will take place in the linear speed range (1 m/s). The position of the wires relative to the undulator axis (theoretical beam position) is measured using the

incremental length gauge with a resolution of 0.1 µm. The beam axis is simulated using an optical calibration tool during the assembly procedure. The calibration will allow an absolute beam position measurement related to the undulator axis with a precision better than 50 µm. The whole unit was assembled under class 100* clean room conditions. The wire scanner is operated under ultra high vacuum conditions. A welded bellow is used as the vacuum feed through for the fork drive.
A stepping motor with a torque of > 2 Nm and 51200 micro steps per rotation drives the slot winding cylinder. A motor driver [6] provides a minimal step resolution of 2.8 µm in the linear range of the slot winding cylinder. For the control of the wire scanner movement an IP-Stepper module [7] is installed.

The following table summarizes the technical parameters of the wire scanner:

Total stroke	S = 48 mm
Stroke increment	$\Delta S = 2.8\ \mu m$
Velocity range	v = 0.1 to 1000 mm/s
Max. acceleration	a = 65.4 m/s
Step frequency range of motor	f_{mot} = 40 - 1400 Hertz
Step angle of the motor	$\varphi = 1.8^{0}$
Microstep of the motor	$\Delta\varphi = 1.8^{0} / 256 \doteq 0.0070312^{0}$
Wire diameter	d = 10 to 50 µm
Fork material	Macor – ceramics
Length gauge:	
Measuring range	s = 60 mm
Resolution	$\Delta S = 0.1\ \mu m$

3. First measurements

A prototype wire scanner was installed in the Photon Injector Test-Facility Zeuthen (PITZ). The low energy electron beam of 4 MeV consists of typically 20 to 50 bunches with a bunch charge of up to 1 nC. This small thermal load allows the so called slow scan mode where the fork moves with few mm/s through the electron beam. To determine the beam position and its shape, the ceramic fork was equipped with three 30 µm thick tungsten wires. Figure 5 shows the scintillator signal of a horizontal scan at a bunch charge of 107 pC. Assuming a Gaussian profile, the extracted width σ of the beam was about 1000 µm. The distance between the wires of 10 mm is represented by the mean values of the Gaussian profiles. The measurements performed at PITZ

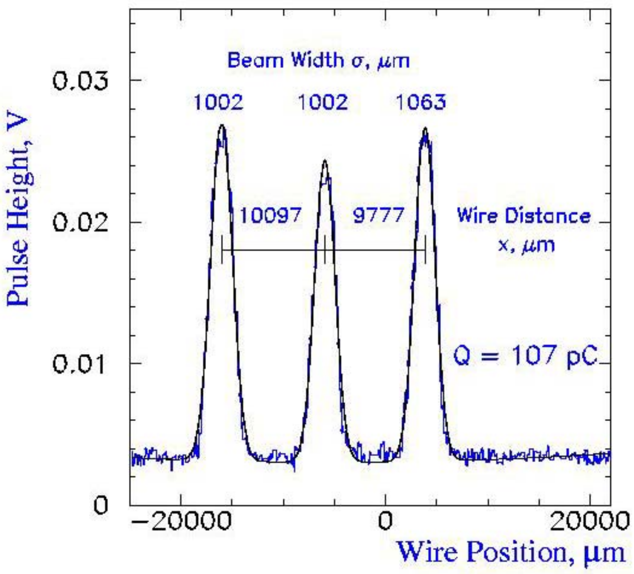

Figure 5: ***First measurements at PITZ***

* cleanroom classification according US Fed. Standard 209E

have shown that the wire scanner is an excellent tool to measure the shape and position of the beam. The scanner made it possible to optimise the operating parameters of the PITZ accelerator.

4. The wire scanner stations and scintillator counters in the undulator sections

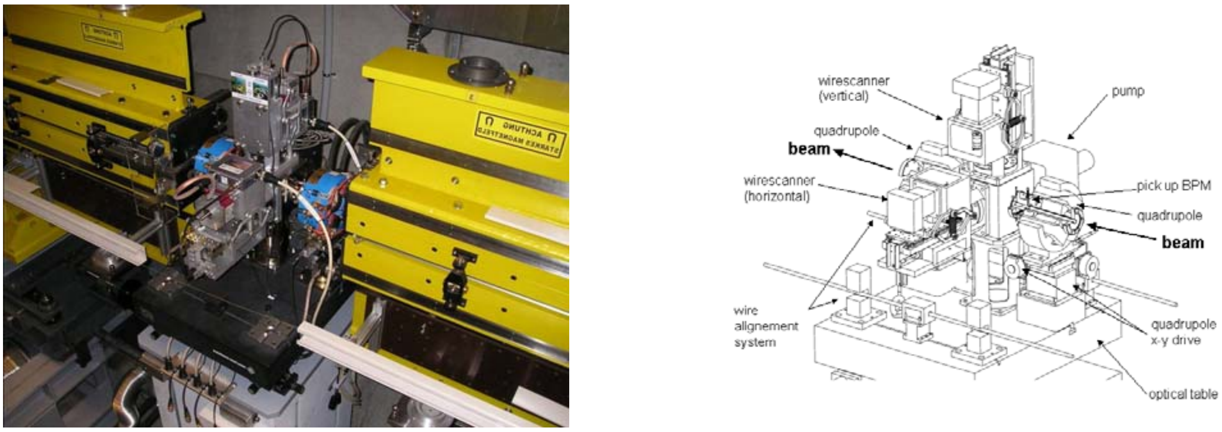

Figure 6: ***A wire scanner station as part of the quadrupole section between two undulators. The technical schema (right picture) shows the different components of the station****.*

The VUV - FEL will operate down to a wave length of 5 nm. The facility will be completed in 2005. The generation of the FEL photon beam will take place in the 30 m long undulator section which consists of six 4.5 m long undulator modules separated by 510 mm long quadrupole sections. To correct alignment errors of the quadrupoles horizontal and vertical drives are used (xy drive, see figure 6 on the right). Electron beam position monitors are installed to measure deviations of the beam from the undulator axis. The diagnostic and quadrupole steering between the undulators is necessary to achieve a sufficient (< 50 µm) overlap between the particle beam and the photon beam. Undulator vacuum chambers with an open aperture of 9.5mm guide the electron beam through the undulator section. Precision measurement of the electron beam position is performed with pickup beam position monitors (BPM) and fast wire scanners located in quadrupole sections. In total seven wire scanner stations are installed in the undulator for the VUV FEL.

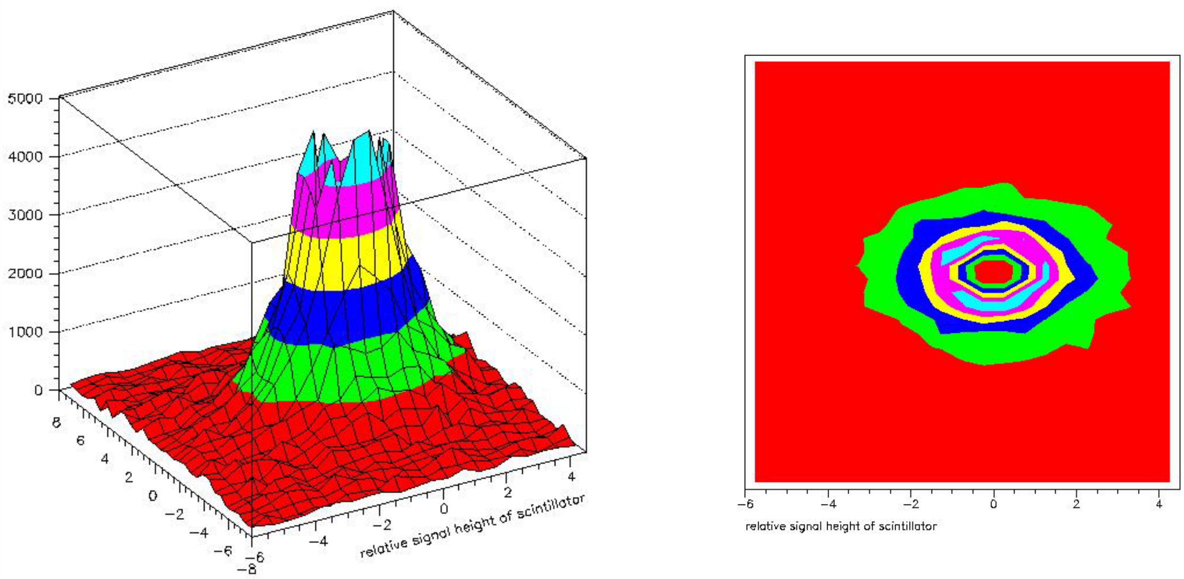

Figure 7: *Scattered particle distribution at the scintillator position. The intensity depends on the thickness and the material of the wire. The position of the scintillator relative to the wire is optimized for high collection efficiency for scattered particles.*

Each station has two individual wire scanners oriented in x- and y- direction. Vertical and horizontal scans provide vertical resp. horizontal measurements of the beam profile and the beam position with µm resolution.

The scattered particles are detected by means of scintillation counters. Simulations of the scattering process using the Monte Carlo method show, that scintillators are optimal positioned downstream of the wire scanner directly behind the next undulators and then directly attached to the beam pipe. Figure 7 shows the distribution of the scattered secondary particles as result of the Monte Carlo simulation. On the left a 3D intensity distribution is shown. The cut perpendicular to the beam axis on the right shows that most of the particles are scattered very close to the beam pipe.

5. Conclusion

Fast wire scanner systems were successfully designed, build, and tested. Seven stations are installed in the undulator section of the VUV FEL at DESY. Monte Carlo calculations were performed to optimize the position for the scintillator. The whole system will start operation in late summer 2004.

6. References

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