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THE EUROPEAN XFEL WIRE SCANNER SYSTEM

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Abstract

The European-XFEL (E-XFEL) is an X-ray Free Electron Laser facility located in Hamburg (Germany). The superconducting accelerator for up to 17.5 GeV electrons will provide photons simultaneously to several user stations. Currently 12 Wire Scanner units are used to image transverse beam profiles in the high energy sections. These scanners provide a slow scan mode which is currently used to measure beam emittance and beam halo distributions. When operating with long bunch trains (>100 bunches) also fast scans are planned to measure beam sizes in an almost nondestructive manner. Scattered electrons can be detected with regular Beam Loss Monitors (BLM) as well as dedicated wire scanner detectors. Latter are installed in different variants at certain positions in the machine. Further developments are ongoing to optimize the sensitivity of the detectors to be able to measure both, beam halo and beam cores within the same measurement with the same detector. This paper describes the current status of the system and examples of different slow scan measurements.

INTRODUCTION

At the E-XFEL there are about 60 screen stations installed. Twelve of these screen stations are additionally equipped with wire scanner motion units. These wire scanner units are placed in groups of three upstream of the collimation section and upstream of the three SASE undulator systems. Each wire scanner unit consists of two motorized forks (horizontal and vertical plane). Each fork is driven by a separate linear motor [1]. This 90° configuration of motors helps to avoid vibration influences. The wire position is measured with a linear ruler (Heidenhain) which has a resolution of 0.5 µm. The motion unit is integrated by a custom front end electronic into the MTCA.4 [2] environment. A set of three 90° tungsten wires (50, 30 and 20 µm) and two crossed 60° wires (10 µm) are mounted on each titanium fork (see Fig. 1).

Figure 2 shows a wire scanner motion unit installed upstream of the collimation section. Different detector setups as well as regular Beam Loss Monitors (BLM) downstream of the wire scanner motion units are used for detection of scattered particles. Figure 3 shows a simplified overview of installed wire scanner stations and detectors.

DETECTORS

Dedicated Wire Scanner Detectors

Several dedicated wire scanner detectors (WSD) for scattered electrons have been developed and installed downstream of each set of motion units. They are based on photomultipliers (PMTs) of type Philips XP2243B. These fast,

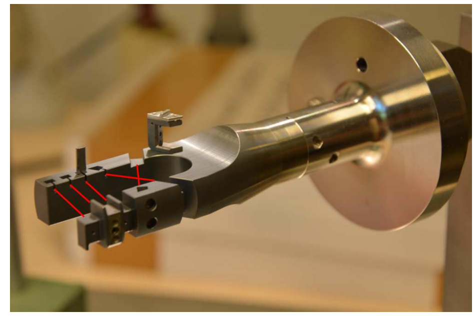

Figure 1: Titanium fork with tungsten wires which are indicated by red lines. From left to right: 50-30-20 µm, crossed wires 10 µm.

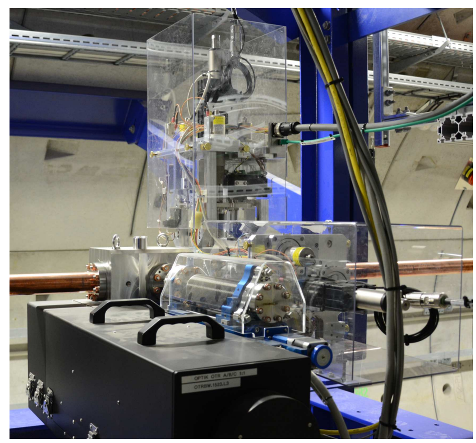

Figure 2: Wire scanner motion unit upstream SASE3 undulators. In the foreground a black optic box and a screen mover are visible.

red sensitive 6-stage tubes are well known from FLASH and HERA wire scanners for years. Currently two types of setups are installed. Plastic scintillating fibers (length: 4 m, diameter: 2 mm) optically coupled to the PMTs are wrapped around the beam pipe to be close to the beam showers. In order to gain more signal, paddles (made of NE110) with larger size compared to fiber detectors have been optically adapted to PMTs of the same type (Philips XP2243B). Measurements show that these paddle based detectors are much more sensitive and can be used better for measurements with low losses (i.e. study of beam halo distribution).

Regular BLMs

About 470 Beam Loss Monitors (BLM) are installed at the E-XFEL. They are used for machine protection and dark current measurement [3]. For detection of scattered electrons each of these BLMs can be used for the wire scanner analysis, too. Due to the non-linearity of these BLMs they cannot be used at a time for both beam halo and beam core

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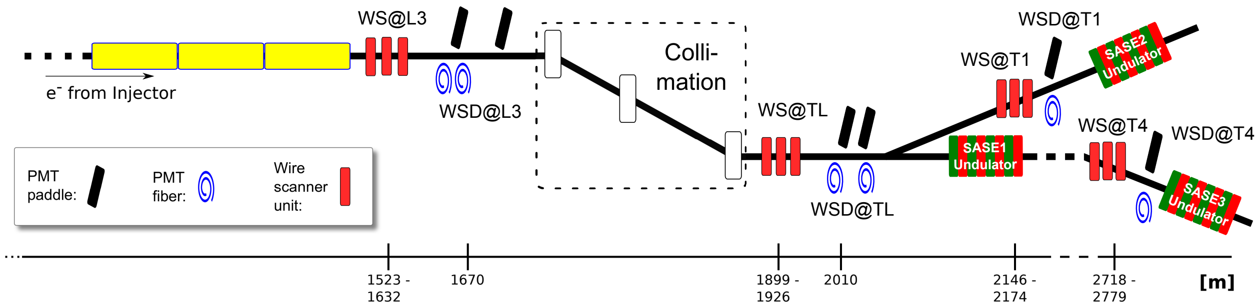

Figure 3: Simplified overview of 12 wire scanner units and detectors. Upstream and downstream collimation section two paddle and two fiber PMTs are installed. Upstream SASE2 and SASE3 undulators only one paddle and one fiber PMT is installed about 20 m downstream of the last wire scanner respectively. Regular BLMs are installed all over the machine at certain positions.

measurements. Therefore a combination of BLMs and dedicated detectors for wire scanners (for beam core) could be used [4]. Figure 4 shows different PMTs installed in the E-XFEL.

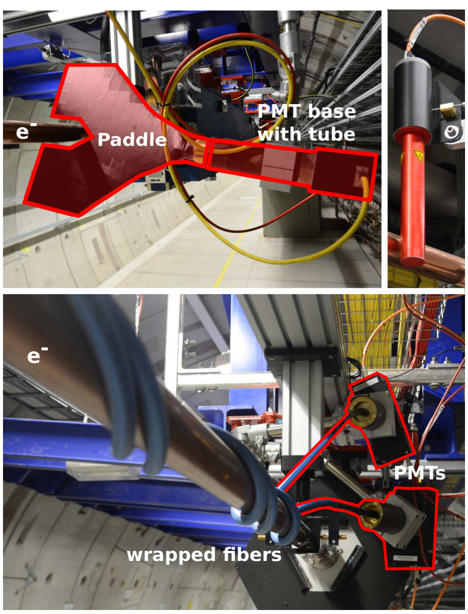

Figure 4: Different detectors in the tunnel: paddle applied to PMT (top left, highlighted red), regular BLM (top right) and two blue hoses with fibers wrapped around beam pipe and connected to PMTs (bottom, surrounded red).

WSD Readout

Read out of the WSD signals is also based on MTCA.4 components. An in-house developed RTM [1] implements front end electronics for signal conditioning and controlling of a high voltage power supply. The RTM is connected to a commercial Struck AMC [2] ADC SIS8300-L2D [5] with custom firmware. One pair of AMC and RTM can handle two PMT channels and control one external high voltage power supply (company iseg, 2 channels, 2 kV, 6 mA, ripple <2 mVss typ.).

[1] Rear Transition Module
[2] Advanced Mezzanine Card

SLOW SCAN MODE

A slow scan is performed by moving the fork with a continuous motion from a predefined start position for a desired length and number of points. During running motion at each macro pulse the wire position and the detector signal is saved and displayed. Figure 5 shows the GUI with three wire scanner units upstream collimation section. This GUI is mainly used for further developments of Wire Scanner device and middle layer servers and debugging of installed units. High level software connects to these servers performing emittance measurements during optics matching or to study beam halo distribution. For safety reasons slow scans are only allowed if the machine is running in single bunch mode to not destroy the wires. Therefore the wire scanner motion unit limits the number of bunches by a hard wired connection to the Machine Protection System [6].

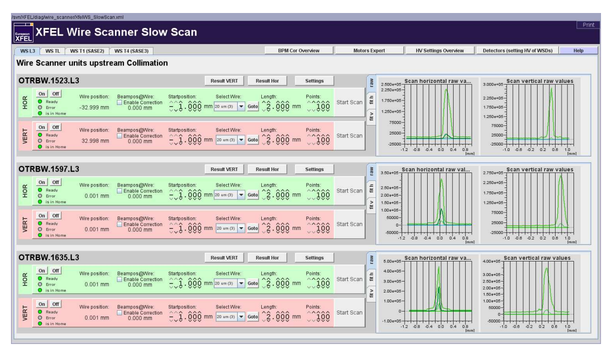

Figure 5: Graphical user interface for slow scan parameters and results for a set of 3 Wire Scanner motion units upstream collimation section. Plots on the right show performed scans with wire position (x axis) and several PMT signals (y axis) for horizontal and vertical plane.

MEASURE BEAM OPTICS MATCHING

Wire scanners are currently often used to measure the beam optics matching and emittance. Three wires in combination with two different beam optics (quadrupole magnet settings) were used in the measurement that is presented in Fig. 6. Thus six different beam sizes in both planes can be used to calculated the particle distribution in the respective transverse phase spaces at a position upstream the wires.

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The measured beam optics parameters can then be compared with the design values and, in case of lager deviations, be corrected [7].

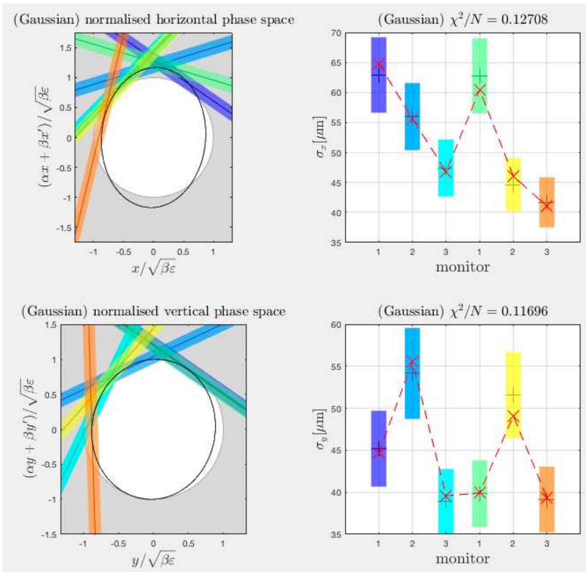

Figure 6: Results from a beam optics and emittance measurement downstream the linac of the E-XFEL using 3 wire stations and 2 different beam optics in between. The plots on the left hand side show the transverse phase spaces normalized to the design beam optics parameters at a position (called the beam optics reference position) upstream the wires. The plots on the right hand side show the measured beam sizes for all six measurements. Both upper plots represent the measurement in the horizontal plane while the lower plots present the results from the vertical plane. The reconstructed phase space ellipses are shown in the phase space plots as black lines. The white circles represent a perfectly matched beam with an emittance of 1 mm mrad.

MEASURE BEAM HALO DISTRIBUTION

Upstream of SASE 3 undulators wire scanner measurements have been performed during radiation tests. As the scintillating paddle applied to WSD is much more sensitive it is used for beam halo detection. WSD with scintillating fiber is used for beam core measurement. Figure 7 shows the fiber signal (beam core) scaled by factor 500 to overlap with the paddle measured beam halo (beam pipe center at 23 mm) [8].

SUMMARY AND OUTLOOK

A wire scanner system of 12 scanners and corresponding detectors have been installed at certain positions at the E-XFEL. Slow scans have been performed with these scanners for beam halo and emittance measurements and beam optics matching with reasonable results. Additional detector developments are on going to be more flexible with an adjustable

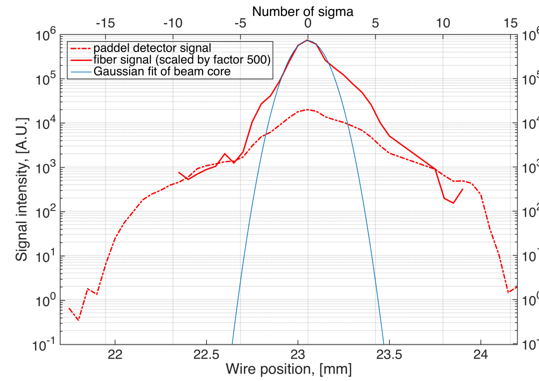

Figure 7: Beam Halo Measurement: fiber detector compared to paddle detector. The fiber detector signal is scaled by a factor 500 to overlap with the paddle measured beam halo.

electrical attenuation of the PMT signal and a variable intensity of light applied to the paddle PMTs. Besides that another type of 15-stage and more handy tube is planned to be installed and investigated. Furthermore an automated adjustment of high voltage settings for the dedicated wire scanner detectors is going to be implemented. Further work will be dedicated to the implementation of fast scan functionality, which is essential for the multi-bunch (>100 bunches) operation.

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