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STATUS AND COMMISSIONING OF THE WIRE SCANNER SYSTEM FOR THE EUROPEAN XFEL

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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 stations 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. This paper describes the current installations and the latest developments of the system at European-XFEL. Furthermore, the commissioning status of the system and first results of beam halo studies will be shown.

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. 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 [1] 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 [2].

Figure 1 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 2 shows a simplified overview of installed wire scanner stations and detectors.

DETECTORS

Regular BLMs

About 470 Beam Loss Monitors (BLM) are installed at the E-XFEL. They are used for machine protection and dark current detection [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 measurements. Therefore a combination of BLMs (for beam halo) and dedicated detectors for wire scanners (for beam core) have been used [4].

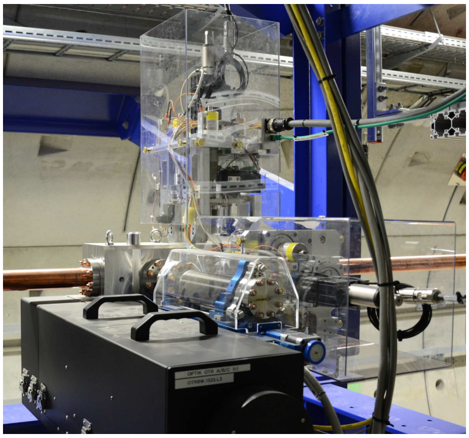

Figure 1: Wire scanner motion unit. In the foreground a black optic box and a screen mover are visible.

Wire Scanner Detectors

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

It turned out that these fiber detectors are not suitable for beam halo measurements since they are not sensitive enough to low losses. In order to gain more signal, paddles (made of NE110) with larger size compared to fibers and BLMs have been optically adapted to PMTs of the same type. First measurements show that these paddle based detectors are much more sensitive and can presumably be used better for future beam halo studies. A test LED is integrated into all types of detectors.

WSD Readout

Read out of the WSD signals is also based on MTCA.4 components. An inhouse developed RTM[1] (see Fig. 4) 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

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[1] Rear Transition Module

[2] Advanced Mezzanine Card

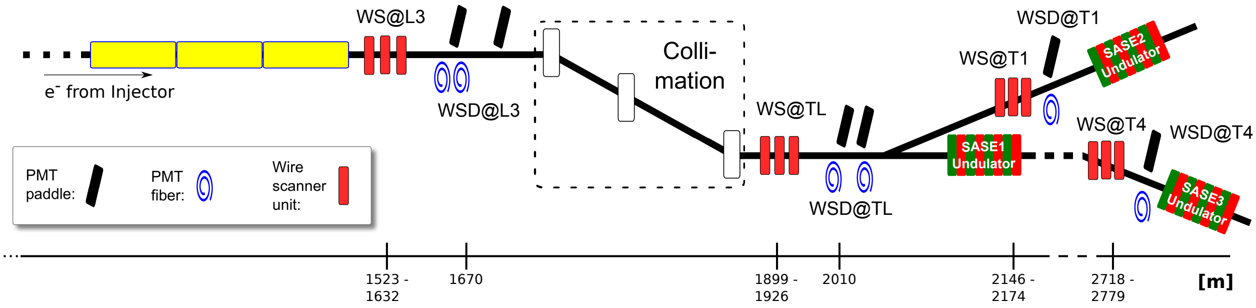

Figure 2: Simplified overview of 12 wire scanner units and detectors. Before and after collimation section two paddle and two fiber PMTs are installed. Before SASE2 and SASE3 undulators only one paddle and one fiber PMT is installed about 20 m downstream of the last wire scanner respectively. Regular BLMs are installed all over the machine at certain positions.

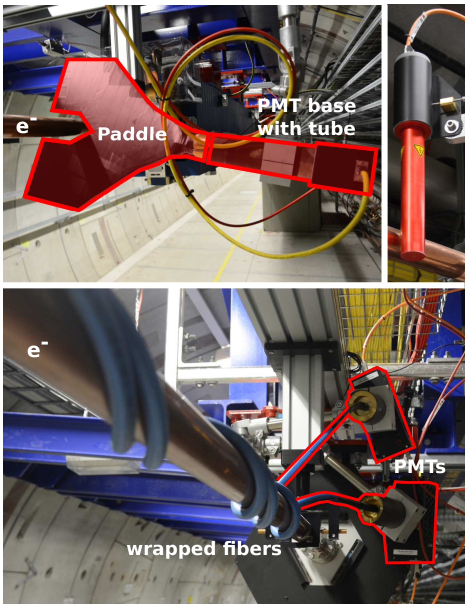

Figure 3: Different detectors in the tunnel: paddle applied to PMT (top left, highlighted red), regular BLM (top right) and two blue hoses with fibers wrapped around beam pipe and connected to PMTs (bottom, surrounded red).

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.).

WIRE SCANNER COMMISSIONING

First beam halo measurements have been performed in summer 2017 primary with the help of Matlab tools [4]. Experiences from this and fruitful discussions [6] flew into still ongoing development of firmware and software improvements.

Slow Scan Mode

A first slow scan approach by moving the fork in step manner resulted probably in wire vibration which could be seen on the PMT signal. This could be avoided by moving the fork with a continuous motion for a predefined start position, length and number of points. During running motion at each macropulse the wire position and the detector signal is saved and displayed. Figure 5 shows the full fork range scan for the horizontal and the vertical plane.

Figure 4: Wire scanner detector RTM (left) and PMT tube with base (right) standing on HV power supply. The PMT signals are connected to the RTM using differential cables with standard RJ45 connectors. In the background a black wrapped up paddle is visible partially.

Due to the wire-wire distance on the forks, signals are visible with a 5 mm space in between. The different wire thicknesses result in different amplitudes. Signals from the paddle detectors are significantly higher than the fiber detectors at the same position. Regular BLM signals can also be sampled during a scan if desired. Matlab scripts are used to calculate beam emittance after a complete scan using three wire scanner units or a quadrupole scan using one unit.

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.

BEAM HALO MEASUREMENT

Upstream of SASE 3 undulators wire scanner measurements have been performed during radiation tests. Figure 6 shows beam halo measurements with one fiber and one paddle detector. The fiber signal is scaled by factor 500 to overlap with the paddle measured beam halo (beam pipe center at 23 mm) [7].

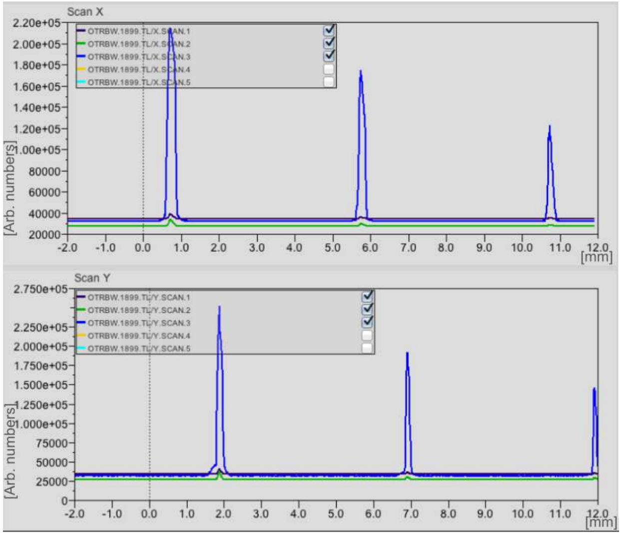

Figure 5: Complete scan with all three wires on one fork. The x-axis shows the wire position (0.00 mm beam pipe center); y-axis shows integrated signals from PMTs: light blue from paddle PMT, dark blue and green from fiber PMTs at the same position. HV settings of all three PMTs: 1.2 kV.

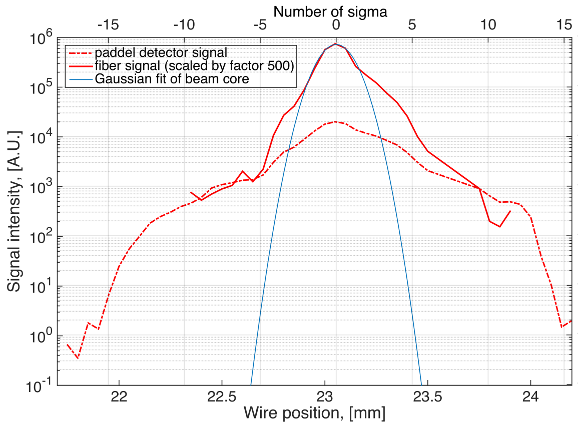

Figure 6: Beam halo measurement: fiber detector compared to paddle detector.

BEAM POSITION CORRECTION

During slow scans, pulse to pulse beam position jitter influences the emittance measurement. Using the design optics and the BPM data, the actual beam position at the wire is calculated at each pulse. By subtracting the result from the current wire position this jitter influence can be reduced. Figure 7 shows a horizontal scan with and without calculated and subtracted position correction. Please note that the data in Fig. 7 has been taken during machine set-up with large beam position jitter. During normal operation this jitter is much smaller (about 10% of rms beam size).

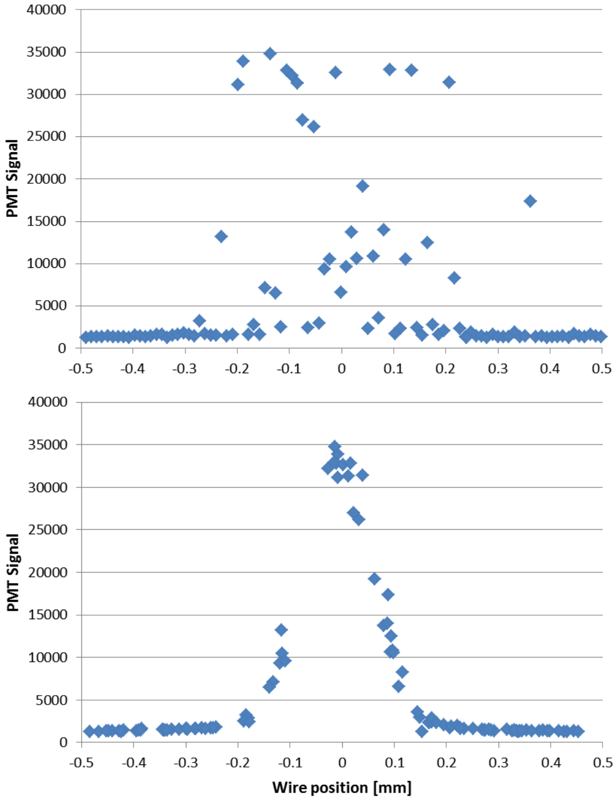

Figure 7: Measured horizontal beam profile without (top) and with (bottom) beam position correction.

SUMMARY AND OUTLOOK

A wire scanner system of 12 scanners and corresponding detectors have been installed at certain positions at the E-XFEL. Except three scanner units and detectors upstream of SASE2 all units are commissioned with beam. Slow scans have been performed with these scanners for beam halo and emittance measurements with reasonable results. Measurements comparison between the wire scanners and the screens is still on going. Different detectors had been installed. Additional developments are planned to be more flexible with an adjustable electrical attenuation of the PMT signal and a variable intensity of light applied to the paddle PMTs. In general the PMTs still need to be characterized more in detail. 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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