WIRE SCANNER INSTALLATION INTO THE MICROTCA ENVIRONMENT FOR THE EUROPEAN XFEL

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Abstract

The European XFEL (E-XFEL) is a 4th generation synchrotron radiation source currently under construction in Hamburg. The 17.5 GeV superconducting accelerator will provide photons simultaneously to several user stations [1]. For the transverse beam profile measurement in the high energy sections Wire Scanners are used as an essential part of the accelerator diagnostic system, providing the tool to measure small beam size in an almost nondestructive manner. The scanners will be operated in a fast mode, starting from a trigger the wire will be accelerated to 1 m/s and hitting about 100 bunches out of the long bunch train of E-XFEL within a single macropulse. Slow scans with single bunches are also possible. In the first stage 12 stations are planned to be equipped with Wire Scanners where each station consists of two motion units (horizontal and vertical plane). The new concept uses linear servo motors for the motion of the wires and a new mechanical design has been developed at DESY [2].

This paper describes the electronics developments for the motion part of these Wire Scanners and the integration into the MicroTCA environment.

MOTIVATION

At DESY wire scanners have been used for diagnostic purposes for many years in HERA or Flash, operated with the control systems TINE and DOOCS. Rotating motors or pneumatic cylinders had been used as drive units [3]. The goal was to build the E-XFEL wire scanner as an improved system based on these experience. The new system has to be based on MicroTCA (MTCA.4) in order to be well integrated into the controls hard- and software as well as the timing infrastructure.

OVERVIEW

It is planned to start the commissioning of the E-XFEL with 12 wire scanner stations and about 60 screen monitors. Each station consists of a set of two motion units (horizontal and vertical plane). These wire scanner stations are placed in groups of three stations with well designed phase advance before the collimation system and before each of the 3 SASE undulators, allowing to measure emittance and twiss parameters without changing the magent settings. Additional 15 positions can easily be equipped later with wire scanners if this turns out to be useful.

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Mechanics and Motor

For the E-XFEL wire scanners the mechanics of the motion unit was developed from scratch. A lot of experience from FLASH and HERA wire scanners went into the design to ease service and thus improve the availability. As a driver for the wire scanner forks linear motors from LinMot [4] were chosen. A catch unit had been added into the design to keep the fork mechanically out of the beam area during times of no scans. The catch unit has to be opened electrically to be able to move the fork into the beam. An end switch inside indicates, when the fork is in parking position and locked. Furthermore magnetic springs guarantee moving the fork back to this out-position in case of failure. Figure 1 shows the mechanical setup of the wire scanner prototype with almost complete cabling and safety housing. Table 1 gives some basic specifications of the device [5].

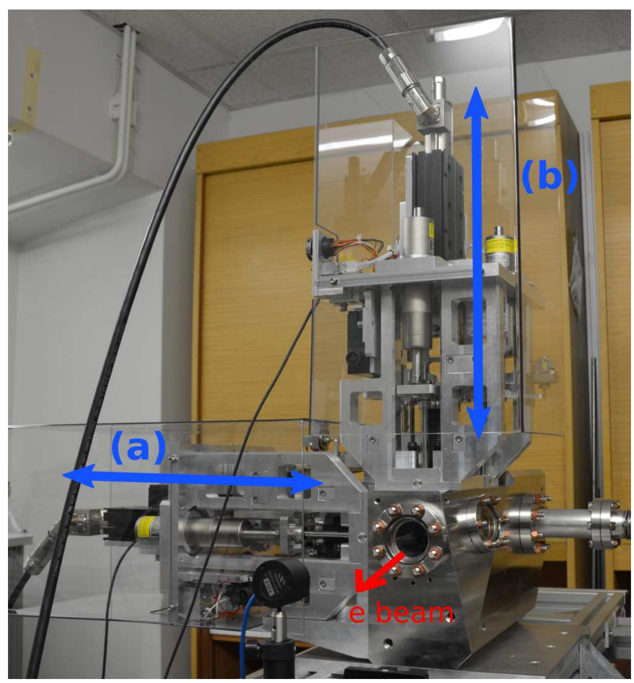

Figure 1: Mechanical Prototype station with horizontal (a) and vertical (b) motion unit.

Wire Scanner Forks

The wire scanner forks are made of titanium to improve the weight im comparison to steel by an comparable rigidity. From experience with former fork designs a lot of detailed improvements were made to ease wire assembly and adjustment. Five wires are installed in total to be able to use different wire thicknesses and to have spare wires. Three

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Table 1: E-XFEL Wire Scanner Specifications

Parameter	Value
Stroke	53 mm
Scanning Modes	Fast (1 m/s), Slow
Number of wires per fork	5 (see Fig. 2)
Motor to beam sync	$< 10\ \mu s_{rms}$
Wire material	Tungsten
Fork gap	15 mm
Wire - wire distances	5 mm (90°)

of these wires are mounted in 90° and one pair in ±60° in relation to the fork gap. It is planned to use Tungsten wires with thicknesses between 10 – 30 µs.

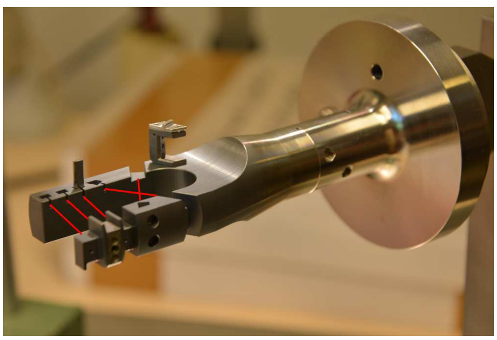

Figure 2: Titanium fork at assembly workstation. Wires are indicated by red lines.

Planned Detector Layout

In the current lattice of the machine there are four reasonable positions for detectors, one for each of the wire scanner groups. Each position will be equipped with two detectors to measure the particles scattered by the wire. The readout will be realized using MTCA.4 standard components, in this case four STRUCK SIS8300 ADC [6] with a custom made Rear Transition Module (RTM) which holds the analog signal conditioning and additional interfaces for controlling the High Voltage Power Supplies of the detectors. Since the detectors might be distributed along the accelarator, each SIS8300 ADC with RTM will control two detectors and a high voltage supply only to prevent long cable distances.

MicroTCA for the E-XFEL

The MTCA.4 standard will be used as a base of the electronics hardware of the E-XFEL and thus will also be used for the E-XFEL Wire Scanners [7]. The MTCA.4 standard defines modules, power supplies, cooling, racks, etc. Advanced Mezzanine Boards (AMC) are connected typically by PCIe to the control system. Multi LVDS connections over the backplane are used for connection to the timing system or between dedicated AMCs. Rear Transition Modules (RTM) connect to an AMC from the rear side. Many commercial products are available. More information can be found at [8] and [9].

WIRE SCANNER ELECTRONICS HARDWARE

For the implementation of the wire scanner motion control electronics the DAMC2 digital AMC FPGA board was chosen. This board is a non commercial DESY development [10]. Its FPGA firmware framework [11] implements the control system interface via PCIe, backplane interfaces to the timing system and connections to the RTM. Figure 3 shows a block diagramm of AMC and RTM for the wire scanner motion unit. Figure 4 shows a pre-series RTM.

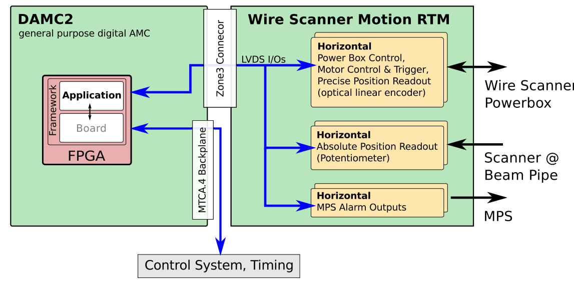

Figure 3: Couple of DAMC2 digital board and wire scanner motion RTM.

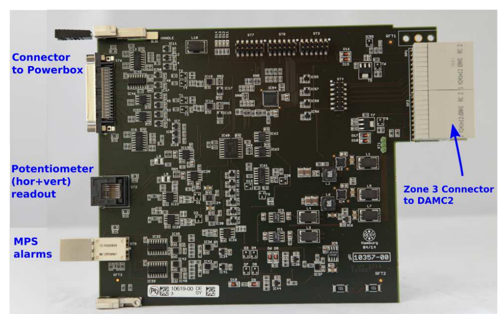

Figure 4: Pre-Series Wire Scanner motion RTM.

Wire Scanner Motion RTM

The interfaces to the scanner hardware (position readouts, motors, end switches, etc.) are implemented on a RTM which is under development at DESY. For high precision position read out a Heidenhain optical linear encoder [12] is used. This device achieves an accuracy of 0.5 µs. Hence this encoder gives a relative position value without initialization a linear potentiometer [13] with a resolution of 50 µs is used for safety purposes. The potentiometer value is captured by an ADC on the RTM. Furthermore the RTM implements motor control and trigger interfaces as well as Machine Protection System (MPS) outputs. One RTM implements the interfaces for two channels of one station with horizontal and vertical motion unit.

Wire Scanner Power Box

The RTM is connected to a 19" 5HU so called power box, which houses motor controllers and power supplies (which are volumious and have weights about 12 kg) for a set of horizontal and vertical motion unit. Additionally the power box implements some electronics for galvanic isolation of signals. A microcontroller is used to reduce the number of cables between RTM and power box by transmitting slower and uncritically signals over a serial data link. Figure 5 shows an overview of a complete wire scanner station. Figure 6 shows the prototype power box during assembly.

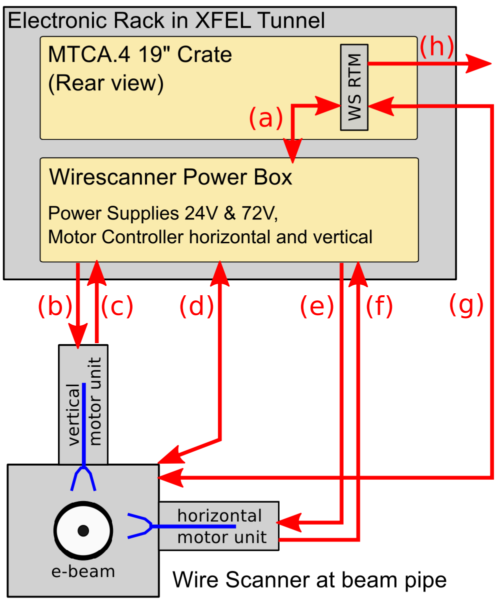

Figure 5: Overview of a complete wire scanner motion unit with RTM to Powerbox cable (a), motor cables (b, e), Heidenhain linear encoder readout cables (c, f), end switches and catch units cable (d), potentiometer readout cable (g) and cable with alarms to MPS (h).

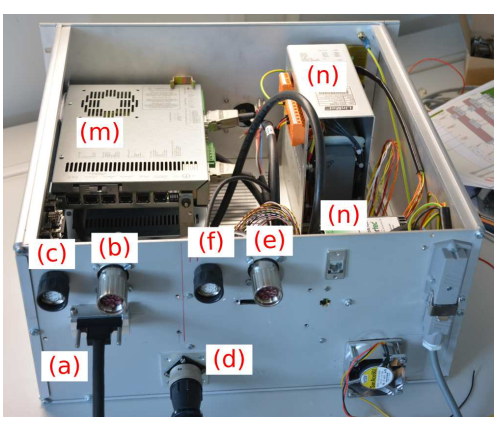

Figure 6: Prototype of Wire Scanner Powerbox (rear view) with LinMot Motor Controllers (m), Power Supplies (n), horizontal and vertical Heidenhain linear encoder readout cables (c, f) and motor cables (b, e), RTM to powerbox cable (a) and cable for end switches and catch units at the scanner (d).

MOTION APPLICATION FIRMWARE

Wire scanner related functionalities for motion units are implemented in the application part of the VHDL framework mentioned above.

Scan Modes

A fast scan is performed by receiving a pre-trigger (from timing system) 60 ms before arrival of the first bunch. Derived from the pre-trigger a configurable delayed trigger in dependency of the beam position and the desired wire to be hit is generated. This trigger is transmitted from the FPGA, through RTM to the corresponding motor controller into the wire scanner power box. Upon reception of a trigger the motor controller starts the motor with a jitter of $< 1\ \mu s$. To achieve a repetitive high accuracy of the motion (motor to beam sync) a special trigger input had been implemented into the motor controller firmware by LinMot company on request by DESY. For slow scans the motor is moved to certain positions or by incremental steps. This mode can also be used for calibrating the Beam Loss System.

Data Readout

If a fast scan is performed the encoder position is sampled and stored into an FPGA internal buffer with the bunch frequency (4.5 MHz). Figure 7 provides a sketch of a wire scanner station with a corresponding detector readout system. Both installations can be seen as two independent systems where the synchronisation of position and detector data on a bunch by bunch basis is done with the help of makro pulse numbers provided by the timing system.

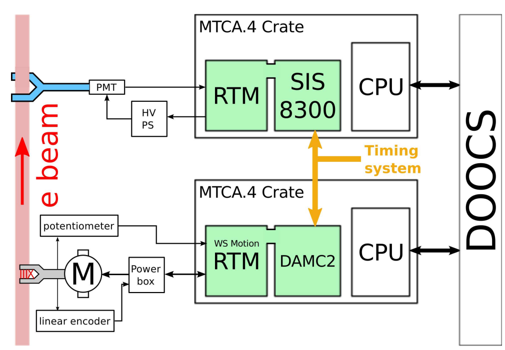

Figure 7: Overview of wire scanner station with corresponding detector readout. Only one motion plane is displayed. The detector can be meters apart from the motion unit.

Safety Aspects

Protecting the wires is an essential part of the system. To prevent the wire from melting the firmware has to make sure that number, frequency and charge of the bunches (bunch pattern received from timing system inside FPGA firmware) are limited and the fork achieves the design speed of 1 m/s in a certain position range (where the wire could hit the beam) in fast scan mode. For slow scans only single bunch is allowed. In case of incompatible bunch pattern the scan

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will not start. In case the speed is too slow due to motor failure during fast scan the beam will be stopped within the makropulse by an alarm given to the MPS. As the precision incremental linear encoder needs an initialisation the position and speed for the safety functionalities is measured with the linear potentionmeter as this is the only device in the system which gives an absolute value. Furthermore the potentiometer is radiation resistant. The end switch inside the catch unit masks the MPS alarm outputs electrically independend of the status of the wire scanner electronics so that system failures have no impact on the machine operation if the fork is out of the beam inside the parking position. To start a fast or slow scan the catch unit has to be opened electrically to allow the motor moving the fork out of the parking position.

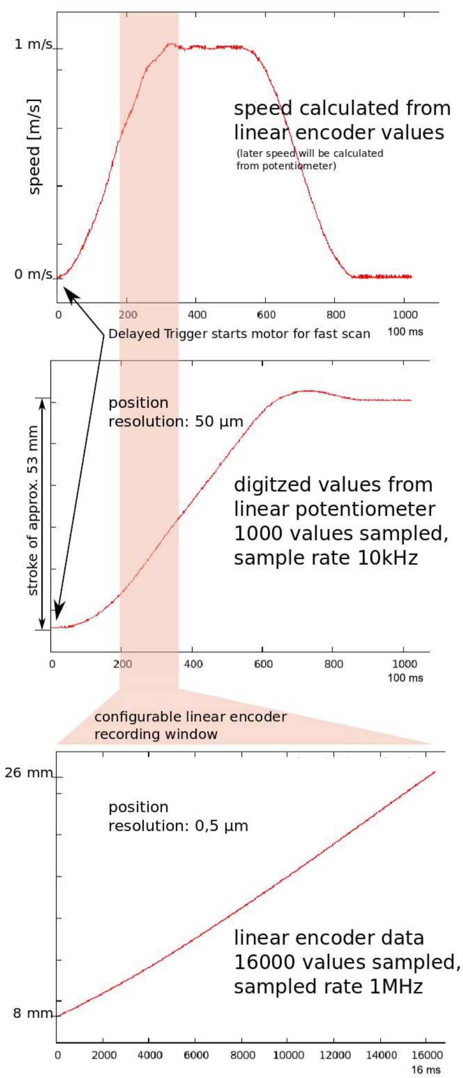

Figure 8: Complete triggered stroke showing speed, linear potentiometer data and high precision linear encoder data.

STATUS AND FIRST TESTS

Tests with mechanical design including the motor controller and motor itself has been evaluated and discussed in [5]. Based on this, first tests had been done with a prototype RTM and a first application firmware on a DAMC2 board. Figure 8 shows position readout of the linear potentionmeter, the more precise readout of the linear encoder and the calculated speed. By configuring thresholds for speed and position range an MPS alarm could be demonstrated.

OUTLOOK

After the first tests a two channel (horizontal and vertical) RTM has been designed and a pre-series has been built. Lose wired components like power supplies and LinMot motor controllers are currently installed into a prototype power box so that an initial test of the almost complete system of MTCA.4 crate, power box and mechanics will follow by the end of 2014 in the lab without beam.

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