A NEW EMBEDDED RADIATION MONITOR SYSTEM FOR DOSIMETRY AT THE EUROPEAN XFEL

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Abstract

The European XFEL, a X-Ray Free Electron Laser user facility based on superconducting RF-technology with a length of about 3.4 km is currently build between the campus of the DESY, Hamburg and Schenefeld, a small town in Schleswig-Holstein. Commissioning is planned 2015. The XFEL utilizes various electronic systems for machine control, diagnostics and safety. To achieve a cost efficient facility, the beam pipe and its nearby electronic supply systems are located inside the same tunnel. Therefore they are irradiated by an evident amount of radiation in certain sections of the XFEL. To insure the lifecycle and function of electronics and magnetic structures like undulators in these XFEL radiation fields, all electronic systems located inside the tunnel will be sufficiently shielded according to preestimated radiation levels. In addition, the impact of Gamma- and Neutron-radiation onto the electronics and the undulator parts will be monitored for by a new versatile and compact radiation monitor system. It measures the accumulated dose in the electronic cabinets along the XFEL to ensure an exchange of radiated parts before significant radiation damage occurs. First prototype measurements at different radiation sources will be presented.

INTRODUCTION

The European XFEL (E-XFEL), currently under construction in Hamburg is a 4th generation synchrotron radiation source, [1,2]. Driven by a 17.5 GeV superconducting accelerator, it will be able to provide several user stations with photons simultaneously, based on different Free-Electron Laser and spontaneous sources. High average as well as peak brilliance can be produced due to superconducting technology, even providing high duty cycle electron beams. Pulse lengths up to 600 µs and bunch repetition rates up to 4.5 MHz can be accelerated up to 17.5 GeV with a RF repetition rate of 10 Hz (lower gradients enable even higher rep rates). Optimum tuning to the experiments demands will be achieved by flexible bunch patterns[3].

As the E-XFEL is based on a single tunnel construction, all electronic racks of the frontend-systems will be located inside the tunnel close to the accelerator beam pipe sections. Therefore, these racks will be exposed to parasitic accelerator radiation fields.

RADIATION-RELATED CONCEPT AND REQUIREMENTS

The prevention and control of parasitic radiation inside the E-XFEL tunnel will be accomplished by the following prioritized radiation-control concept:

- surveillance and control of the beam generation and transport to achieve and transport an almost ideal beam with respect to the spacial and temporal structures of the accelerator
- accelerator-wide measurement and control of …

1. specific beam properties (e. g. control of beam transmission along the accelerator by a transmission interlock system)
2. halo parts of the beam (e. g. dark-current measured by dark-current-monitors), that could lead to parasitic radiation on occurrence (loss of charge, emerging dark-current)

- measurement of parasitic radiation inside the tunnel will be done due to …

1. the protection of certain sensitive areas at the accelerator (e. g. BLMs mainly at the undulator sections, BHMs only at the dumps), device- and electronic-safety-dosimetry in the undulator sections and all front-end electronic racks, as presented in this paper)
2. personal radiation dosimetry, mostly at radiation-intensive accelerator-sections
3. auxiliary information, derived from measurement systems for special beam properties (e. g. detector-BLMs of wirescanner systems).

As foreseen for the E-XFEL [4], all frontend-electronic racks will be equipped with a radiation shielding, reducing the γ- and n-radiation inside the racks to a level sufficient for normal specified electronics operation and lifetime. A comprehensive derivation of the radiation generating effects in conjunction with the corresponding estimations for sufficient radiation shielding of the electronic racks inside the E-XFEL tunnel has been determined, based on detailed radiation measurements from 2005 to 2009 at the DESY FLASH FEL accelerator [4]. Highest dose rates of parasitic radiation can be expected during accelerator commissioning and later operational phases due to inadvertent misoperation, control system failures or malfunction of devices or systems. Worst case estimations extrapolate a maximum accumulated γ-dose of 8 Gy and a maximum neutron fluence of 5.6e+10 neutrons/cm^2 over 10 years each inside the E-XFEL frontend-electronic racks, shielded by a sufficient amount of heavy concrete in combination with boron rubber sheet [4]. For the protection of undulators against damage by high γ-dose, detailed investigations and measurements at FLASH between 2005 and 2008 as shown in [5] resulted in a worst-case estimation of approx. 2 kGy/a (at reduced undulator lifetime), leading to a theoretical overall accumulated γ-dose of approx. 20 kGy per 10 years, which is the upper limit for the dynamic measurement range of the external γ-sensor part at this radiation monitor system.

DOSIMETRY SYSTEM

The electronic and device safety dosimetry system described here is foreseen for measurement of accumulated dose values for gamma and neutron radiation inside the shielded electronic racks in the E-XFEL tunnel. Measurement data from this

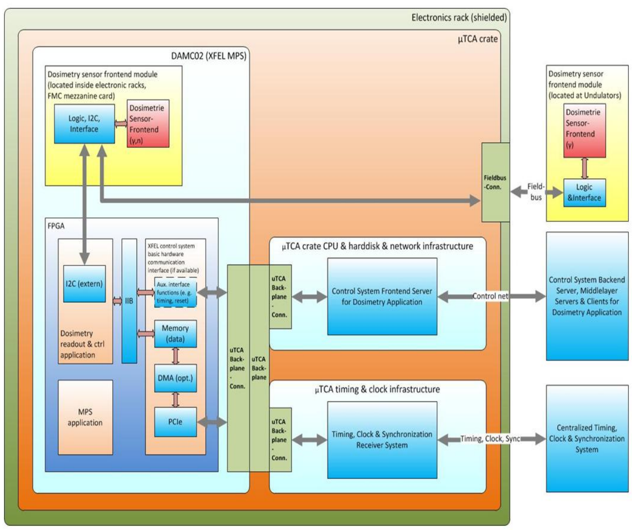

Figure 1: XFEL machine dosimetry system integration into MPS- and Control System environment.

system will be used to estimate the remaining system lifetime and to determine preventive maintenance dates for all electronic subsystems located inside of each rack.

In addition, this dosimetry system offers special γ-sensors located apart from the electronic racks in the near vicinity of the undulators, that can be used for measurement and estimation of accumulated γ-dose absorbed by the corresponding undulator. In addition to the accumulated dose measurements, the dosimetry system will also provide dose rate information for online estimation of electronic system- and component-lifetime. As this dosimetry system is planned to be incorporated in each of the electronic racks inside the E-XFEL tunnel, the dose rate information can also be used to identify unexpected radiation sources inside the tunnel. This can be achieved either by correlation with online-dosimetric information of other measurement systems or as a stand-alone information-source at accelerator regions without other dosimetry systems like the E-XFEL LINAC sections.

The system architecture is shown in Fig. 1. The rack-internal sensor part is located in the upper-left corner of the diagram and carries a γ- and a neutron-sensor. This part is located on a FMC [6] mezzanine card that resides on the 'DAMC02' versatile Desy AMC [7] carrier board, which is a standard board used in the E-XFEL Machine-Protection-System (MPS)[8]. The rack-external sensor part is shown in the upper-right corner. It is connected by cable via a fieldbus-connection to the FMC frontpanel and carries a γ-sensor for the undulator radiation control.

The system development has been separated into a sensor preselection phase, a prototype phase (γ- and neutron-sensor test boards) and subsequent phases of preseries and series production and testing (FMC- and external sensor board design), followed by the accelerator assembly and technical commissioning. First, a set of γ- and neutron-sensor types were preselected and a γ- and a neutron-sensor testboard were designed for test and final selection of the radiation-sensors and the accompanying temperature reference sensors, utilized for temperature logging. The γ-sensor testboard is ready and is currently under commissioning.

TEST AND SIMULATION

First tests have shown reasonable readout data output and functionality for the preselected γ-sensor (RadFet). Analysis of the first measurements is in progress and the evaluation of the data is still under discussion due to overlying fading and temperature effects.

In parallel, first extensive γ-radiation tests have been conducted with this type of sensor on a radiation teststand at the e^-/e^+-converter of the LINAC II at DESY (400 MeV beam, 80nC bunches, 10Hz mixed mode rep rate). In addition, the radiation field in the region of the converter has been simulated for estimation of the expected dose rates and energy spectra using FLUKA 2011 [9][10]. Figure 2 shows an energy dose plot of a vertical/longitudinal section (averaged over x) of the converter region for the corresponding operation mode of LINAC II. In the left half of the plot, the converter block is shown with its different material parts serving as the main radiation source. The γ-sensor probes were located on a probe-carrier-plate, that is shown (cross-section) in the lower right of the plot between z = 60 – 70 cm. The test setup also included a set of TLD-100/800 Thermo-Luminescence dosimeters for reference that were fixed at a certain central position on the test plate near the γ-sensors.

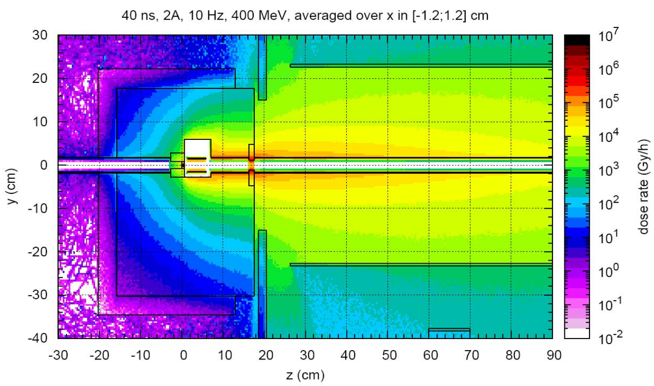

Figure 2: simulation of radiation field near teststand at DESY LINAC II converter (FLUKA 2011[9][10]).

For correct interpretation of the measured data, the energy spectrum of the simulated beam has also been calculated. Influence of the sensitivity energy spectra of the γ-sensor (device under test) and the TLDs will be investigated in detail in the next step.

The RFT-300-CC10G1 sensor chip (REM Oxford Ltd., [11]) was preselected for the external (undulator) γ-sensor board, as its dynamic range spans the whole range needed for the external γ-sensor for undulator dosimetry. A more sensitive circuit version for this sensor type is currently planned to be used for the rack-internal γ-sensor. First experience with this sensor type was gathered at the FERMI FEL at Synchrotrone Trieste (Italy). The data taken here from the machine protection dosimetry system are now used in collaboration with the FERMI team as a base for sensor reference- and calibration.

CONCLUSION AND OUTLOOK

A dosimetry system for the E-XFEL accelerator was described. First γ- and neutron-sensors have been preselected. First extensive tests of the preselected γ-sensor (RadFet) over the dynamic dose range (0-20kGy), specified for undulator dosimetry at the E-XFEL have been described showing comprehensible results. Additional radiation-field simulation of the radiation teststand at the DESY LINAC II converter section has been shown. A γ-sensor testboard has been designed and produced. Full testboard functionality, including different internal and external temperature reference sensors is currently under commissioning. First tests with preselected γ-sensors show reasonable results.

In the next steps, the newest radiation test results will be discussed and evaluated in detail. A testboard for evaluation of preselected neutron sensors in combination with different temperature reference sensors has been designed for production in September 2011. Temperature reference sensors will be tested for temperature and irradiation performance at the DESY LINAC II converter teststand.

The remaining preselected γ- and neutron-sensors as well as the electronic sections used for the frontend undulator sensor board series will be tested afterwards and irradiated in subsequent tests at different radiation sources. After evaluation of the irradiation tests, final selection of all sensors will be done. Selected γ- and neutron sensors will be combined for preseries boards development and production afterwards.

In cooperation with other parallelized MicroTCA-based electronic-, firmware- and software-system-developments (MPS, DAMC02) for E-XFEL and the FLASH FEL at DESY, control system integration will be done in subsequent steps, preparing for the precommissioning phase [7].

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