# MCP BASED DETECTORS INSTALLATION IN EUROPEAN XFEL

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*Abstract*

An important task of the photon beam diagnostics at the European XFEL is providing reliable tools for measurements aiming at the search for and fine tuning of the FEL creating SASE process. Radiation detectors based on micro channel plates (MCP) will be use at the European XFEL. Detectors operate in a wide dynamic range from the level of spontaneous emission to the saturation level (between a few nJ and 25 mJ), and in a wide wavelength range from 0.05 nm to 0.4 nm for SASE1 and SASE2, and from 0.4 nm to 4.43 nm for SASE3. Photon pulse energies are measured by MCP with anode and with photodiode. The photon beam image is measured by MCP imager with phosphor screen anode. Three MCP devices will be installed, one after each SASE undulator of the European XFEL (SASE1, SASE2, and SASE3). At present time MCP SASE1 and MCP SASE3 were installed in XFEL tunnel. Calibration and acceptance test experiments with MCP detectors and their electronic is under discussion.

## MCP DETECTORS

An important task of the photon beam diagnostics at the European XFEL is providing reliable tools for measurements aiming at the search for and fine tuning of the FEL creating SASE process (Self Amplified Spontaneous Emission). The problem of finding SASE amplification is crucial for the XFEL because of a large synchrotron radiation background. This requires a detector with a wide dynamic range, controllable tuning to the required wavelength range, and suppression of the unwanted radiation background. The JINR-XFEL collaboration manufactured MCP-based photon detectors as a primary tool for the search for and fine tuning of the SASE process. Three MCP devices [1,2] will be installed, one after each SASE undulator of the European XFEL (SASE1, SASE2, and SASE3).

Three different tasks can be fulfilled with the XFEL MCP-based photon detectors [1,2]: study of the initial stage of the SASE regime; measurement of the photon pulse energy; and measurement of the photon beam image. The MCP detector will resolve each individual pulse at a repetition rate of 4.5 MHz. The following wavelength ranges are to be covered by three MCP stations: 0.05-0.4 nm for MCP1 and MCP2, 0.4-4.43 nm for MCP3.

MCP detectors for SASE1 and SASE2 are installed after the deflecting mirrors [3-5]. The offset mirrors are used for two distinctive and separate purposes: firstly during early commissioning they cutoff high harmonics of spontaneous radiation and improve the ratio of FEL/spontaneous intensity, secondly they are used as additional attenuators of the radiation intensity. The diamond attenuator and the Ce:YaG screen are installed in front of the first carbon coated offset mirror. The attenuation range of the mirrors combined with the diamond plate attenuators is about $10^3$-$10^4$. The dynamic range of the MCP is $10^3$-$10^4$.

The MCP detector for SASE1&SASE2 consists of a silicon photodiode, three MCPs equipped with an anode as a pulse energy monitor and one MCP detector for imaging the photon beam. The first MCP detector port houses one silicon photodiode and two F4655 Hamamatsu MCPs, 18 mm in diameter. The PM 100-250 3D vacuum manipulator displaces these MCPs in the horizontal direction in a range of 250 mm. The range of vertical displacement is ±2.5 cm relative to the beam axis.

The second detector port houses two MCPs: F4655 for measurement of the pulse energies, and the beam observation system (BOS) MCP (model BOS-40-IDA-CH/P-47) of 40 mm diameter with a phosphor screen. The BOS MCP is set at an angle of $45^0$ with respect to the photon beam and a viewport allows imaging onto a CCD. The MCP detector for SASE3 will have an additional port with a movable semi-transparent mesh and wire targets to produce scattered FEL radiation similar to those used at FLASH [6-8].

## X-RAY CALLIBRATION TESTS OF SASE1 MCP DETECTOR

The calibration of the SASE1 MCP detector was realized in X-ray wavelength range at DORIS BW1 beamline before installation of this detector in the XFEL tunnel [9-10].

The absolute measurements of a photon pulse energy of 0.03 nJ and larger for hard X-ray radiation were




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performed with application of MCP and photodiode detectors.

The photon flux was in a range of $2 \cdot 10^{11}$ ph/s to $2 \cdot 10^{8}$ ph/s. The SR measurements were performed at photon energies of 8.5 to 12.4 keV. Vacuum pressure in the MCP-detector UHV chamber was $5 \times 10^{-9}$ mbar.

The gas ionization monitor (GIM) was used for measurement of the SR photon flux. Dependence of the MCP signal on the GIM signal is shown in Fig. 1. The linear behavior of the MCP 1 signal versus the gas ionization monitor signal is observed at an MCP1 voltage of 1.85 kV and below.

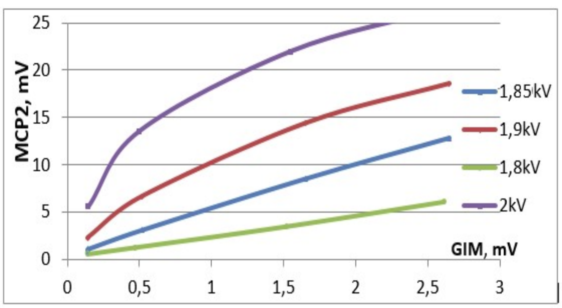


Figure 1: Dependence of MCP2 signal on gas ionization chamber signal at different MCP 2 voltages.

An essential influence of secondary ions produced by X-rays in the MCP chamber at a pressure of $5 \times 10^{-9}$ mbar was observed during MCP operation in DORIS BW1. The nonlinear dependence of the MCP signal on X-ray beam intensity was measured at MCP voltages higher than 1.9 kV. When the ion pump was switched on or off , we did not see any difference of the ion input in the MCP operation. Therefore, we assume that the X-rays produce secondary ions by ionization of residual gas atoms.

The ratio of the MCP2 signal to SR pulse energy corresponds to 0.11-0.16 V/nJ at photon energy of 8.5-12.4 keV and MCP voltage of 1.8 kV.

The SR photon flux was measured by a silicon photodiode and GIM. The linear dependence of the photodiode signal in pulsed mode versus the gas ionization monitor signal was demonstrated.

Time structure of SR pulses at a frequency of about 10 MHz was measured by both MCP and silicon photodiode.

The X-ray beam image was measured by MCP detector at intensity higher than $4 \times 10^{7}$ ph/s at a photon energy of 9.66 keV. The MCP beam observation system with a phosphor screen was effectively used for the search of the SR photon beam position.

However at SR tests the measured X-ray beam size at small slits of 0.2-0.4 mm was about 1.8 -2 mm caused by low contrast resolution of the phosphor screen and image spot spreading. The MCP imager can be applied for search of the SASE photon beam spot; however it cannot be used for detailed measurements of the spot shape and substructure.

## INSTALLATION OF MCP DETECTORS IN XFEL TUNNEL

The special acceptance position tests were performed with SASE1 MCP detector at application of laser positioner. The irradiation from laser positioner was directed to MCP BOS system at different angles and correspondently in different positions. This procedure was fully analogy as at recording of SASE radiation at variation of reflection mirror angle in mirror chamber. At each laser irradiation angle the MCP BOS system was moved in position at which the laser spot was observed in center of phosphor screen. The *x* and *y* coordinates of center of phosphor screen were measured. The information about these coordinates was transformed by software system to MCP1-MCP3 pulse energy monitors. The simulated coordinates in position of MCP1-MCP3 detectors were determined. The manipulator shifts one of the MCP pulse energy monitor to required coordinate $x_1$ and $y_{1.}$ The procedure of searching SASE irradiation was successfully tested at application of laser positioner.

The SASE1 MCP was installed in XFEL tunnel in November 2015 after callibration and acceptance tests.

The final tests of the SASE1 MCP detector were performed in XFEL tunnel in January 2017 (Fig. 2).

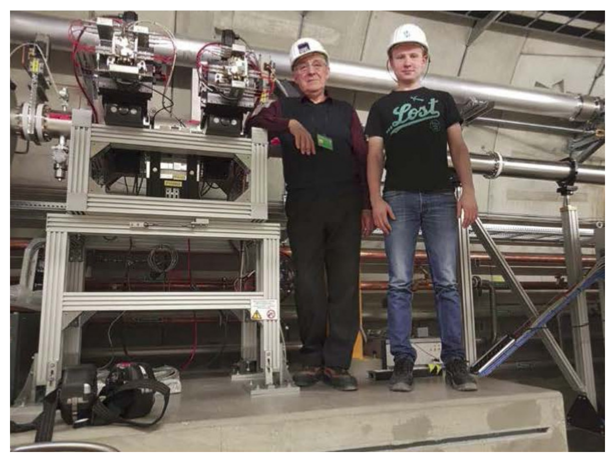

Figure 2: SASE1 MCP detector installed in XFEL tunnel.

The motor tests were done at initial stage. The information about motors was added into the control system. The movements of the motors and stops by limit switches were checked using Karabo GUI.

Then the high voltage (HV) tests with MCP and photodiode power supplies were performed.. The high voltage was checked by multimeter with HV probe. The BOS MCP was trained with step-by-step voltage rising.

After this procedure the low voltage (LV) tests with SASE1 MCP detector were done. The LV power supplies were tested and connected.

The final tests were performed with trigger for the flash lamp and microTCA crate. Data was checked by oscilloscope and digitized. High voltage of tested MCP power supply was 1700V. Flash lamp was installed at entrance of VP-UV-C100 Fused silica viewport. It was measured response of MCP1-MCP3 on UV flash lamp signal and its time structure (Fig. 3).

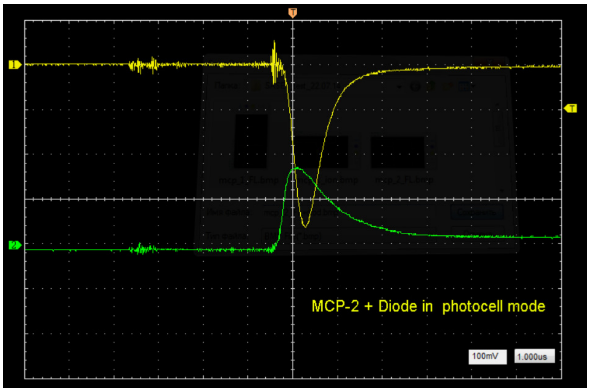


Figure 3: MCP2 and photo diode signals produced by flash lamp.

The test calibration was done with signal produced by ions from ion pump (Fig. 4). The response in MCP1-MCP3 on an ion produced in the ion pump was measured. The operation of MCPs and their amplifiers were tested during this experiments.

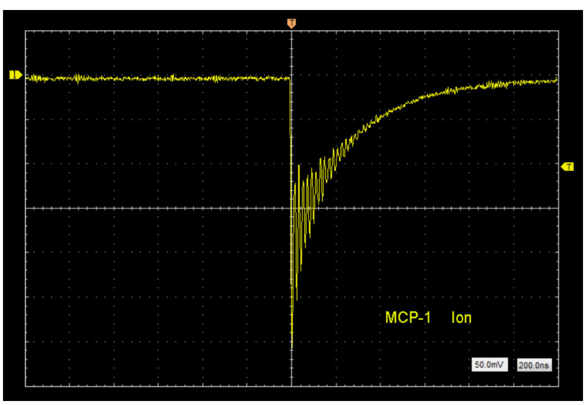


Figure 4: MCP1 signal from an ion produced in the ion pump.

The alignment of SASE1 MCP detector was done during final tests. The CCD camera and the MCP with phosphor screen were installed in a middle position of manipulators. Then manipulators were moved with 20 mm step. At each step the pictures were made and MCP position is controlled. If it is needed the alignment of the CCD camera box was done.

The SASE3 MCP detector consists of photodiode, three small MCPs, one imager MCP with phosphor screen and three meshes from Nickel and stainless steel.

Assembling of SASE3 MCP was done in XFEL during July 2015. Operability of small MCP detectors was performed on base of character signals from direct and reflected radiation of UV lamp produced at working parameters power supplies, preamplifiers and voltage dividers. Operability of photodiode was defined on base of the photovoltaic effect.

Check for particle contaminations in SASE3 MCP was performed under a clean room tent. Trotec particle counter PC200 operates in differential mode with measurement time of 1 min.

The SASE3 MCP was installed in XFEL tunnel (Fig. 5) in end of 2016 after callibration and acceptance tests.

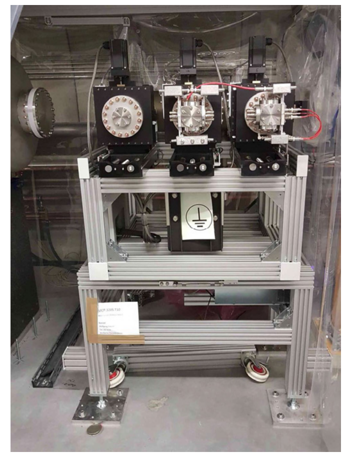

Figure 5: SASE3 MCP detector in XFEL tunnel.

The SASE 2 MCP detector test calibration was done with UV flash lamp and signal produced by ions from ion pump after assembling in final design and before its installation in XFEL tunnel. Operability of MCP with phosphor screen is defined at illumination of phosphor screen at action of UV radiation.

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## REFERENCES

[1] E. Syresin *et al.*, IPAC11, 1106 (2011).
[2] O.Brovko *et al.*, RUPAC12, 572 (2012).
[3] J. Grünert, FEL09 146 (2009).
[4] H. Sinn *et al.*, FEL10, 683 (2010).
[5] H. Sinn *et al.*, Conceptual Design Report X-ray Optics and Beam Transport, European XFEL (2011), 8.
[6] B. Faatz *et al.*, NIM A 483, 412 (2002).
[7] A. Bytchkov *et al.*, NIM A 528, 254 (2004),
[8] L. Bittner *et al.*, FEL 07, 334 (2007).
[9] E.Syresin *et al.*, IPAC 14, 2180 (2014).
[10] E.Syresin *et al.*, Physics of Particles and Nuclei Letters, 2014, V. 11, № 6, p. 730.