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A Photon counting soft X-ray detector capable of gated operation at extremely high input fluxes

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Detection of soft X-ray photons with high spatial and temporal resolution often involves a process of electron multiplication as the charge produced by a single photon is not sufficient for an accurate event encoding. Microchannel plate (MCP) electron multipliers have been widely used in photon counting detectors where a photoelectron produced by the incoming X-ray photon is converted into a charge of 103-106 electrons. The position and time of incoming photon subsequently can be determined by various readouts with ˜6 ⊠m and few tens of ps resolution, respectively. Originally such detectors were developed for low light sensing applications, where registration of one photon at a time was sufficient, e.g. astrophysical observations of weak soft X-ray and UV radiation. Recent developments of pixelated readout configurations substantially increased the count rate capabilities of MCP-based detectors and enabled detection of many simultaneous photons. Placement of Readout Specific Integrated Circuit devices, such as Timepix, directly behind the MCPs enabled operation at very high counting rates exceeding 108 ph/cm2/s [1]. These detectors were recently utilized in several synchrotron based studies [2], [3]. However, one fundamental limitation on the counting rate capabilities of such devices is imposed by the minimum recharge time, required to resupply the charge extracted from the MCP pore. The gain of a specific MCP pore drops temporarily until the positive charge at the exit side of the MCP pore is replenished. This limitation is often referred to as a charge saturation effect. The speed of recharging is limited by the strip current flowing through the MCP, which cannot be increased beyond a certain level due to the Joule heat generated within the MCP leading to a thermal runaway.

The high intensity of modern synchrotron sources provides unique experimental capabilities and at the same time impose extreme challenges to the instrumentation which should sustain operation at these high fluxes. Among such experiments are those where only a fraction of incoming photons conveys useful information, while the rest of photon pulses need to be ignored, e.g. in pump-probe experiments where the frequency of laser-based pumping is much lower than the frequency of the synchrotron source.

We have developed an MCP- based soft X-ray detector which can be gated with ˜10 ns accuracy, preventing MCP saturation and enabling detector operation at high incoming fluxes which otherwise would be impossible.

In experiments where visible light is detected such gating can be performed on the photocathode itself, as in case of image intensifiers, where a semi-transparent photocathode is physically separated from the MCP and can be reverse-biased in a very short amount of time as virtually no current is flowing through it. It is much harder to perform gating for soft X-ray detection for which there are no efficient semi-transparent photocathodes and thus the entire MCP needs to be shut off in a very short time. A very large voltage drop (on the scale of a kilovolt) has to be implemented in order to turn off the MCP multiplication. Moreover, such a large dV/dt swing in the MCP bias voltage can couple to extremely sensitive readout electronics placed behind the MCP and thus permanently damage it.

We report here on the development and testing of a gated soft X-ray MCP detector with a Timepix readout. Our initial tests performed with a short-pulse UV LED demonstrated that gating time as short as ˜10 ns FWHM can be achieved. We have also demonstrated with UV LED that the detector is completely insensitive to the incoming photons when it is gated off.

Subsequent experiment was conducted at the BESSY II Femtoslicing facility (beamline UE56/1-ZPM and DynaMaX end-station) at Helmholtz-Zentrum Berlin. Figure 1 shows the measured intensity distribution as a function of synchrotron cycle (800 ns period/1.25 MHz). The intensity was measured here by turning the

detector on for only ˜10 ns (FWHM) at a given time relative to the synchrotron trigger. The frequency of the detector High Voltage gaiting was ˜6 kHz (each 125 s the detector was turned on for ˜10 ns, synchronized with the source trigger pulse).
The results of our measurements indicate that the detector can indeed turn on and off within ˜10 ns time. Another very important characteristic of our detector –there were no photons detected outside of the gated ON time period, indicating that the detector is completely turned off and the MCP does not extract any charge during off period. As a result, the detector can operate with extremely high (in terms of event counting detector) input fluxes without being "blinded". This mode of operation is intended for the future experiments with MCP/Timepix3 detector where fast dynamics will be studied with very high timing resolution enabled by slicing at this beamline at BESSY II.
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