Performance test of Modulated X-ray Source using UV-LED and Channel Electron Multiplier

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A Modulated X-ray Source (MXS) with Channel Electron Multiplier (CEM) developed by NASA is a newtype of X-ray generator that uses UV-LED[1)]. MXS has many advantages compared with radioactive sources or X-ray generators that require hot filaments. For example, the timing of the X-ray output can be controlled using the modulated LED. Moreover, electronic amplification by CEM leads to the generation of short X-ray pulses (tens of nanosecond). These advantages make the calibration of an X-ray detector considerably easy. For example, we can determine the drift velocity of an electron in a gas using high-precision X-ray photon emission timing. It is important to calibrate an X-ray polarimeter using the Time Projection Chamber technique[2)]. In this progress report, we show the performance of MXS with CEM.

A basic layout of MXS with CEM is shown in Fig 1. When an UV-photon emitted from an LED hits a photocathode, the photon converts to a photoelectron. The photoelectron is accelerated onto a target through a potential difference and it produces an X-ray. In fact, the modulation of the LED provides modulated photoelectron and it leads to the generation of modulated X-rays eventually. The X-ray spectrum can be controlled by choosing the target material and the acceralating potential. To amplify the photoelectron, i.e., to obtain a high X-ray flux, CEM is set between a photocathod and the target. Figure 2 shows the MXS made at RIKEN. The assembly is based on the SUS304 cuboid that is 67×34×34 mm. We adopted MgO as the photocathode and Ti as the target.

To verify the performance of the MXS quantitatively, first, we checked the output X-ray flux. The pressure in the MXS is set at 10^{-7} torr with pumping. The voltage of the CEM and target are set as -2.25 kV and 10 kV, respectively. The frequency of the input pulse is fixed at 10 kHz. We used a Si detector, AMPTEK XR100CR, to evaluate the output X-ray. Figure 3 (left) shows the relation between the width of the input pulse with 10 kHz for the LED and the output X-ray flux. The results show that these two parameter have a linear relationship. When the width of the input pulse is 500 ns, the observed X-ray flux is 4000 counts/s/msr.

Next, we evaluate the duration of the output X-ray pulse using a Time-to-Digital Converter (TDC). We measured the time interval between the leading time of input pulse for LED (used as the start signal of the TDC) and the arrival time of the output X-ray photon (used as the stop signal of the TDC). Figure 3 (right) shows the derived TDC histogram at 5 different widths of the input pulse (50, 100, 200, 400, and 600 ns). The bin size of the histograms are 62.5 ns. The width of each histogram corresponds to the pulse width of the output X-rays. It means that the MXS output is controlled by choosing the input pulse, and we can provide a X-ray photon when needed at precisely known times. To reduce the cost and size, currently, we are developing a new MXS using a carbon nanotube instead of LED and CEM.

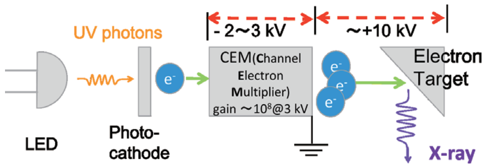

Fig. 1. Schematic view of MXS with CEM.

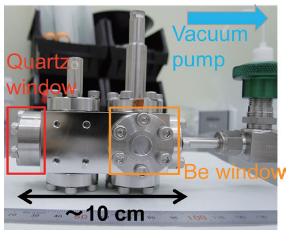

Fig. 2. MXS with CEM developed by our group.

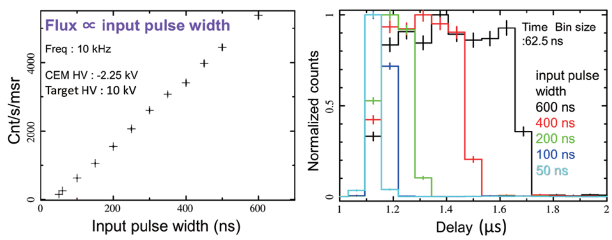

Fig. 3. Left : Output X-ray flux as a function of the width of input pulse for the LED (the frequency of the input pulse is fixed at 10 kHz). Right : TDC histogram at five different input pulse widths. The start and stop signal are the input pulse and the arrival timing of the output X-ray, respectively.

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References

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