§21. Research and Development of the Ultra High Speed X-ray Framing Camera

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The purpose of the present work is to evaluate the spatial resolution of the ultra high speed X-ray framing camera with a proximity photo multiplier under strong magnetic field. In general, the decrease of the spatial resolution of the proximity photo multiplier by magnetic field is negligible. Therefore, under a very strong magnetic field such as the environment near the LHD vessel, the spatial resolution decrease was not evaluated. The influence of the magnetic field for spatial resolution was estimated under a static magnetic field by the numerical analysis and the experiment with visible light.

The proximity focused framing camera consists of a photo cathode, a MCP (Micro Channel Plate) and a phosphor screen. An X-ray image is converted to an electron image by the photo cathode. The image intensity is amplified by the MCP. Finally, the electron image is reconverted to visible light image by the phosphor screen. The electrons are affected by the magnetic field in three regions: between the photo cathode and the MCP input, in the MCP channels, and between the MCP output and the phosphor screen.

In the numerical analysis, the spatial resolution is mainly affected by the magnetic field in the region between the photo cathode and the MCP input and in the region between the MCP output and the phosphor screen. We analyzed the electron trajectory in consideration of the fourth-order Runge-Kutta method into the equation of motion. The effect of the magnetic field within MCP is considered by refering to the literature[1]. The electric field in each region : between the photo cathode and the MCP input, in the MCP, and between the MCP output and the phosphor screen, is given 200V/0.2mm, 9000V/0.4mm, and 5100V/1.3mm, respectively.

In the experiment, we use a proximity focused framing camera for visible light. The spatial resolution is examined in a steady operation mode and in the circumstance of 0.1 T magnetic field, which is applied by a permanent magnet. In order to evaluate the spatial resolution, we calculated the MTF (Modulation Transfer Function).

In the case that the implied magnetic field is perpendicular into the photo cathode, a photoelectron gyrate on the parallel plane to the photo cathode by Larmor motion. The electrons can gyrate almost one cycle between the photo cathode and the MCP input with the 0.7 T magnetic field under the assumption that the electrons emitted cosine profile for emission angle with 0.7 eV energy. Thus, the perpendicular magnetic field is available to suppress spreading the electrons. When the magnetic field exceeds 0.5 T, more improvements of the spatial resolution cannot be expected. The reason is that the convergence area of the electron distribution at the MCP input is smaller than the diameter of the MCP.

In the next place, in the region between the MCP output and the phosphor screen, the electron that has average emission energy converges under the magnetic field 0.6 T. Therefore, about the 0.5-0.6T longitudinal magnetic field is available for space resolution improvement. The MTF characteristics of the results of both the analysis and the experiment in the cases that the magnetic fields are 0 T and 0.1 T are shown in Fig.1. It shows both the improvement by the magnetic field and the qualitative agreement between the analysis and the experiment. In the past research[1], it was reported that the maximum tolerable of the magnetic field to the MCP is 0.5 T.

When the parallel magnetic field to the photo cathode is applied, the image shifts to parallel direction to the photo cathode. In the case of the magnetic field strength over 0.2T, a photoelectron emitted from photo cathode cannot reach to the MCP input, according to the numerical analysis.

In concluding, the tolerable maximum of the applied longitudinal magnetic field is 0.5 T and the maximum of the transverse magnetic field is 0.3 T. In the circumstance above these limits of magnetic fields, a magnetic shield should be adapted.

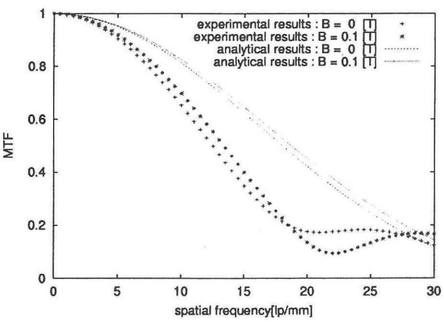

Fig. 1 MTF of experiment and analysis

Reference
1) G. W. Fraser, Nuclear Instruments and Methods in Physics Research, A291, 595-606 (1990).