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Development of a Multi-pattern Gas Detector for Beam Monitoring in Proton Therapy

IV. 1. Development of a Multi-pattern Gas Detector for Beam Monitoring in Proton Therapy

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A pencil beam scanning technique in hadron therapy provides a three-dimensional dose distribution optimized to match the maximum dose distribution to the tumor shape, while the normal tissue in front of the tumor usually receives the same dose as the tumor in a conventional irradiation method using a constant spread-out Bragg peak. Although the scanning irradiation shows therapeutic benefits, its operation requires accurate real-time information about quickly varying characteristics of scanned beams for avoiding under- or over-dosage. Recently, a gas electron multiplier (GEM) technique has been developed[1] and used in various fields as a new type of a gas detector system. The GEM system has advantages over a multi-wire proportional chamber such as the excellent special resolution and higher counting rate, and can be expected to meet severe requirements for beam monitoring in the scanning irradiation. In this report, we describe a multi-pattern gas detector (MPGD) based on GEM developed at CYRIC as a prototype of a beam monitor for the pencil beam scanning method.

A schematic view of the MPDG system is illustrated in Fig. 1. The MPDG consists of a GEM plate, a cathode plate, a readout and two window foils, and filled with a gas mixture (Ar 90% + CH_4 10%). The GEM plate consists of a 100 μm thick liquid crystal polymer (LCP) sandwiched between 9μm thick cupper electrodes, and has holes in 70μ in diameter with 140 μm distance. Electrons induced by an incident proton beam are multiplied by GEM and detected with the readout plate. It will be possible to evaluate a two-dimensional (2D) intensity distribution of the pencil beam from the readout data. In

the present study we used the GEM plate with an active area of 50×50 mm, and the readout plate having a 2D array of 8×8 channels to verify the fundamental concept of the MPDG based on GEM.   The channel pitch is 3 mm for both lateral directions.   When obtaining high-resolution 2D distribution of the pencil beam, we have to use a new readout having a large number of channels.   Energy loss of the incident beam in the MPDG is about 2.5 MeV for an 85-MeV proton.

In order to evaluate characteristics of the MPDG for beam monitoring, beam tests were performed using an 80-MeV proton beam provided from the K=110-MeV AVF cyclotron at CYRIC.   The experimental setup is shown in Fig. 2.   The MPDG was placed in the horizontal irradiation system of the CYRIC proton therapy facilities[2], and irradiated with a proton pencil beam.   As shown in Fig. 3, lateral intensity distributions measured with the GEM-based MPDG are in good agreement with those measured using an Imaging Plate[3] (IP) located at the same position.   In addition, when the pencil beam was deflected using the scanning magnets before the MPGD, the intensity distributions obtained from the MPDG were shifted according to the beam deflection.   Thus, we can obtain high-resolution 2D intensity distributions for the scanned beam if the number of the readout channels of the MPDG is increased.

Figure 4 shows typical relationships between current outputs from the MPDG and those from the ionization chamber used for dose monitoring located behind the MPDG (See Fig. 2).   Since the current of the MPDG is induced by the incident proton beam, it is likely that the amount of the output current of the MPDG is proportional to that of the dose monitor.

In conclusion, the present experimental results have demonstrated that the MPDG system can be used not only as a beam position and 2D-intensity monitor but also as a dose monitor to obtain real-time information about beam parameters in the pencil beam scanning operation.

References

1) Sauli F., Nucl. Instrm and meths. **A386** (1997) 531.
2) Terakawa A., et al., Proceedings of the 16th Pacific Basin Nuclear Conference (16PBNC), Oct. 13-18, 2008, Aomori, Japan, PapaerID P16P1378, p1-p6.
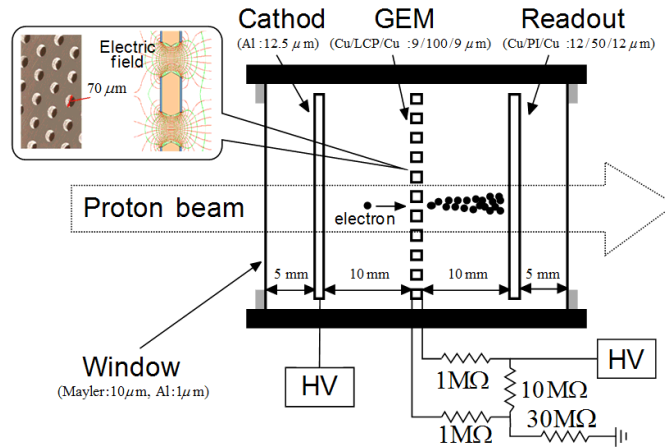3) Fuji Photo Film Co., Ltd.

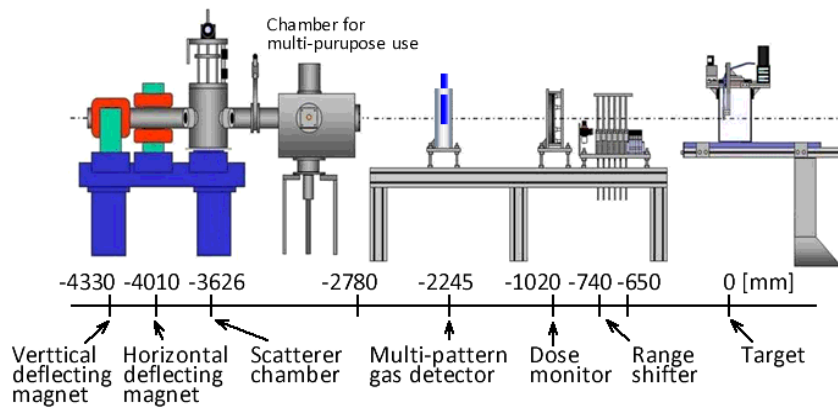Figure 1.　Multi-pattern gas detector based on GEM for measuring a 2D beam-intensity distribution.

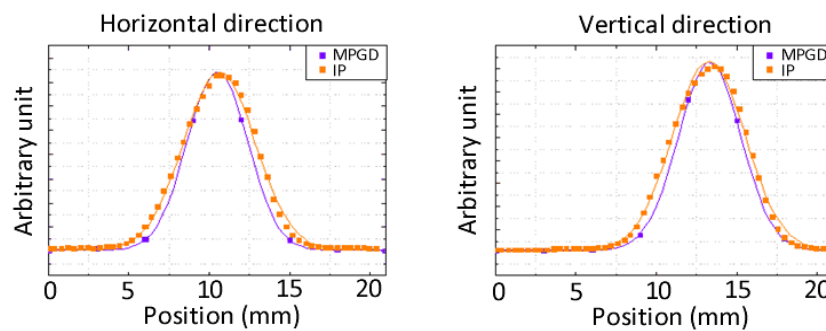Figure 2.　Experimental setup of the multi-pattern gas detector.

Figure 3.　Comparisons of measured lateral intensity-distributions of the incident proton beam between MPDG and IP.
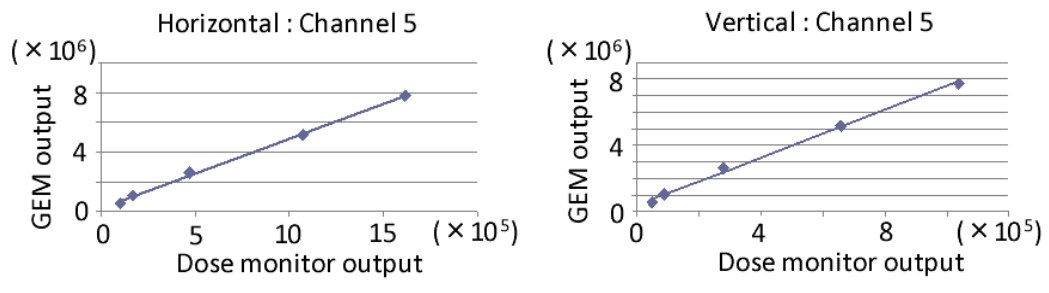
Figure 4.　Relationships between the MPDG output current and relative dose measured with the dose monitor placed behind the MPDG.