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Dose Imaging Detectors for Radiotherapy Based on Gas Electron Multipliers

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In recent years there has been increased interest throughout the world in the use of proton radiation therapy for treatment of tumors. The new techniques in radiation therapy and widespread use of modern dynamic beam delivery systems demand new beam monitoring devices as well as accurate 2D dosimetry systems to verify the delivered dose distribution.
We are developing dose imaging detectors based on gas electron multiplier (GEM) with the goal of improving dose measurement linearity, position and timing resolution, and to ultimately allow pre-treatment verification of dose distributions and on-line monitoring of radiotherapy treatments employing scanning beam technology. A prototype 10×10 cm2 double-GEM detector is undergoing tests in the 205 MeV proton beam at IUCF, in electronic and optical readout modes. Preliminary results with electronic cross-strip readout demonstrate fast response (signal rise and fall time of <40 ns with X-ray and electron sources), single pixel (4 mm) position resolution, linearity up to dose rates of 50 Gy/min, and adequate representation of the Bragg peak.

Summary (Additional text describing your work. Can be pasted here or give an URL to a PDF document):

The new methods of beam delivery in charged particle therapy such as beam scanning and energy stacking are becoming increasingly in demand as more new clinical proton facilities include Intensity Modulated Proton Therapy (IMPT) in their specifications. Widespread use of modern dynamic beam delivery systems call for development of new real-time 2D beam monitoring devices and dosimetry systems with fast response, improved position resolution and high dose measurement linearity to verify the delivered dose distribution.
We report on the development of novel dose imaging detectors based on gas electron multiplier (GEM), employing either electronic segmented anode readout or optical readout with a CCD camera.
A prototype detector consists of aluminum housing with thin windows, continuously purged with Ar/CO2 or Ar/CF4 (depending on readout mode) gas mixture, with cascaded double-GEM amplification structure inside. 10×10 cm2 GEM foils with double-conical holes (50 μm inner diameter, 140 μm pitch) produced by Tech-Etch (Tech-Etch Corp, Plymouth, MA, USA) are mounted on Rexolite frames. For electronic readout tests, a crossed-strip readout electrode has been manufactured by Tech-Etch. This multi-layer electrode consists of 0.4 mm thick fiberglass substrate with etched 5 μm thick copper strips (bottom layer 340 μm wide Y-strips and top layer perpendicular 80 μm wide X-strips, both with 400 μm pitch), insulated with 50 μm thick Kapton strips. The series of strips are connected in groups of ten, forming 4 mm readout pixel size.
The detector has been tested with X–ray and electron sources, with 12x13 array of strips read out using NIM and CAMAC electronics and VME-based data acquisition system. Pulse height distributions of signals from single strips obtained with 5.9 keV 55Fe X-ray source show energy resolution of better than 30%, with the main peak and the Ar escape peak clearly separated. The charge collection efficiency of X-strips relative to Y-strips, measured with the same source, is 0.68±0.03. Tests to estimate the position resolution of the detector has been carried out with 90Sr electron source and 55Fe X-ray source. The detector was illuminated through 2.9 mm diameter aluminum collimator (estimated beam spot diameter at the detector's sensitive volume is ≈8 mm FWHM). With both sources, acquired peaks are ≈2 pixels FWHM wide, which indicates the position resolution close to one pixel (4 mm) as expected. For X-rays and electrons, signal rise and fall times of <40 ns have been observed with an oscilloscope.
The detector has been irradiated in a quasi-continuous 205 MeV proton beam of the Proton Dose Test Facility at IUCF. The beam from the cyclotron was spread out using a 2 mm thick copper scatterer to form a beam spot at the detector location of ˜50 mm FWHM. The dose delivery was monitored by a parallel plate ionization chamber located at the test facility beamline entrance. A Markus chamber model TN23343 mounted immediately behind the detector was used to measure the dose rate close to detector center. An array of 12x13 strips was read out using Multi-Channel Gated Integrator (MCGI) cards and a LabView data acquisition system. Integration time dependence, linearity in a broad dose rate range, spatial resolution and depth-dose response has been studied. Preliminary results indicate a linear strip signal response at dose rates of up to 50 Gy/min and single pixel (4 mm) spatial resolution. The Bragg peak underestimation was less than 18% relative to the

Markus chamber.
The tests of the detector in optical readout mode with transparent mesh anode and SBIG CCD camera are underway.

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