Optical readout Micromegas for monitoring medical pencil scanning proton beams and radiotherapy gamma ray

Cong Liu[a,b,1], Chao Shan[c,d,1], Zhiyong Zhang[a,b,*]

a. State Key Laboratory of Particle and Electronics, University of Science and Technology of China, Hefei 230026, China

b. Department of Modern Physics, University of Science and Technology of China, Hefei 230026, China

c. School of Nuclear Science an Technology, University of Science and Technology of China, Hefei 230026, China

d. Hefei Ion Medical Center, the First Affiliated Hospital of USTC, Division of Life Sciences and Medicine, University of Science and Technology of China, Hefei 230026, China

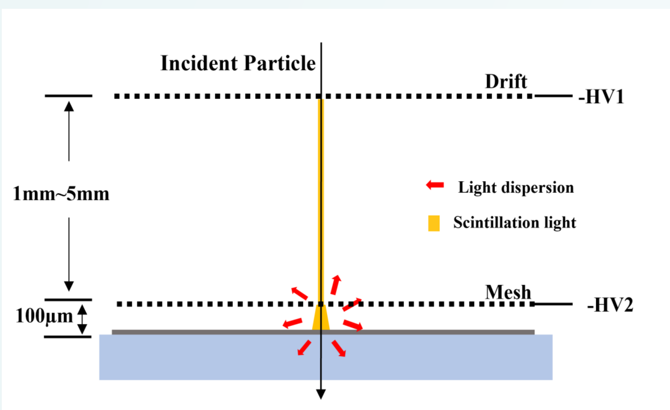
Abstract: Micro-pattern gaseous detectors (MPGDs), when integrated with optical imaging sensors, have been proven to effectively and accurately capture radiation beam information. To address the challenges of monitoring the dose and profile of medical pencil proton beams, which have a high density of greater than 10^9 Hz/cm^2, an optical readout micro-mesh gaseous structure (ORM) was proposed. A Micromegas prototype was manufactured with a glass substrate coated with transparent indium tin oxide as the detector anode. Its effective area is 25 cm × 25 cm. The ORM was firstly characterized with an Iron-55 X-ray source (^{55}Fe) and a silver target X-ray tube individually, high gain greater than 10^4, and spatial resolution of 400 μm (10% MTF) were achieved. The prototype was then tested with the medical pencil proton beams. The evaluation revealed linear dose responses exceeding 99% (R-squared value) for both single-point and nine-point beam spots at various beam energies and doses. The size and center position deviation of the nine-point spot measurement were within 0.35 mm and 1 mm, respectively, indicating the good potential of this method for MPPB spot quality assurance. The prototype also conducted radiotherapy gamma ray testing, and it allows for more accurate measurement of rising edges. In addition, by adding appropriate conversion layers, ORM is expected to be extended to monitor other types of high-throughput beams.

Introduction

- Proton therapy beam quality assurance
- The Optical Readout Micromegas system
- Proton beam and radiotherapy gamma test
- Conclusions

Proton therapy beam qulity assurance

Proton therapy (PT) utilizing high-precision scanning proton beams offers an innovative treatment approach by delivering a high dose of radiation to the tumor while minimizing exposure to surrounding healthy tissue and organs. PT must be carefully investigated. This process is called beam quality assurance (QA) and is essential to ensure the safe delivery of treatment to patients. Optical readout MPGD, which provides a feasible large-area and high-precision measurement for high-density proton beams when combined with a photon camera. In this study, an ORM prototype and a CMOS camera are used to conduct the QA study for proton beams.



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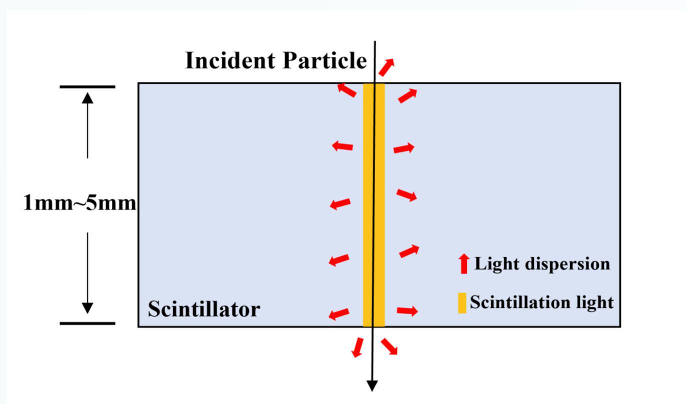
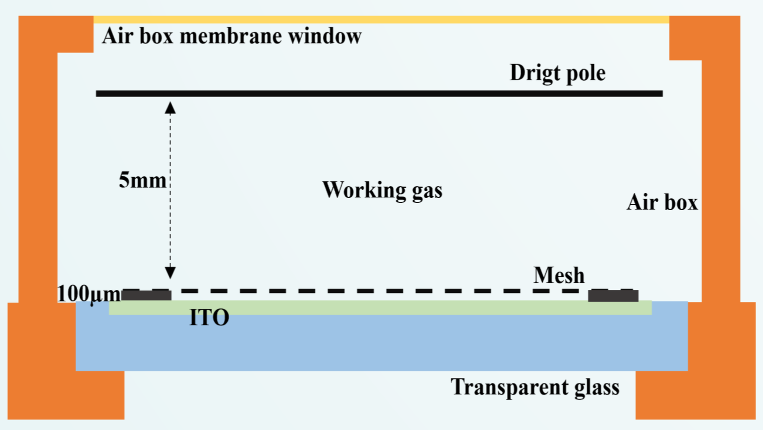


(b)

Fig 1. (a) ORM luminescence principle. (b) Scintillation luminescence principle.

The Optical Readout Micromegas system

In order to collect fluorescent light within the avalanche region, 100 mm × 100 mm, 3 mm thick transparent glass is employed to replace the traditional PCB anode board in the Micromegas. As shown in Fig 2(a), a 185 nm thick indium tin oxide (ITO) conductive film, with an overall resistance of 8-10 Ω and 83% light transmittance, was coated onto glass via vacuum magnetron sputtering technology.



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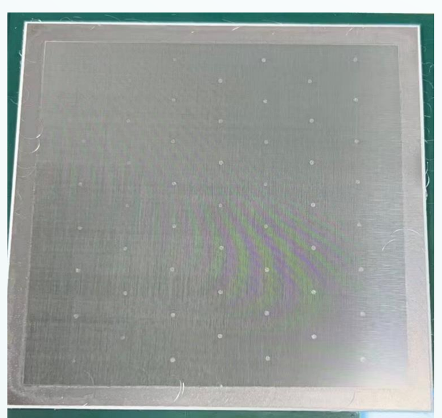

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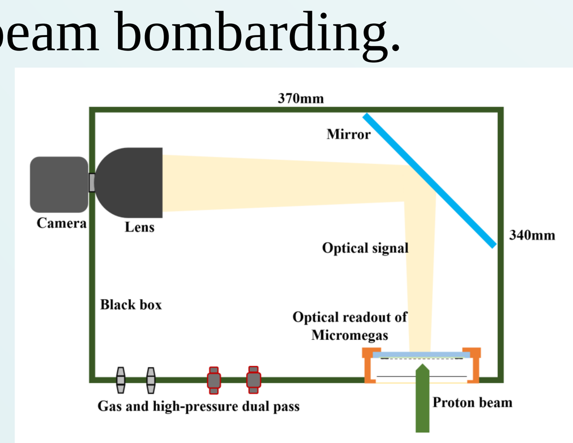
Fig 2. (a) Conceptual design, (b) photo of the avalanche structure.

As shown in Fig 3 (a), when the proton beams penetrate through the Micromegas, the fluorescence light produced in the avalanche region is reflected by a 45° mirror to prevent damage to the CMOS chip from proton beam bombarding.



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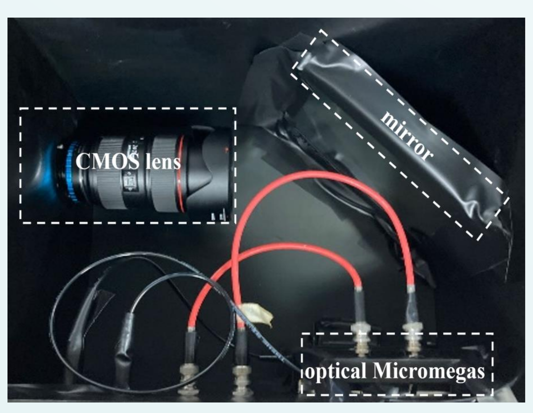

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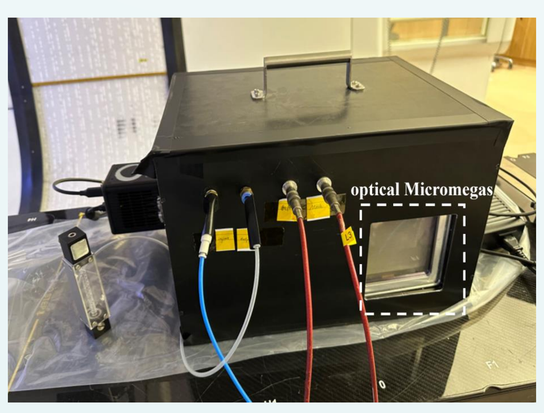


(c)

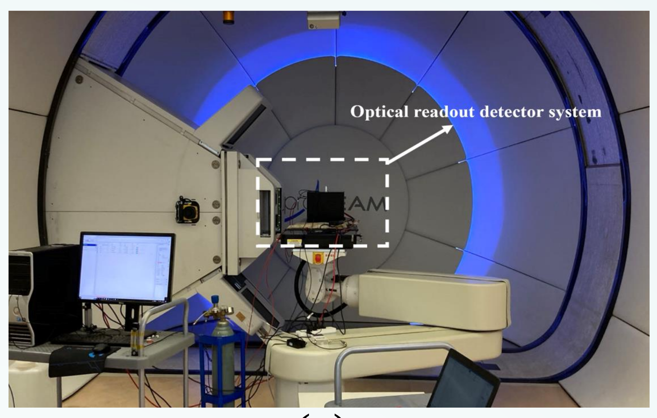
Fig 3. (a) Schematic design diagram, (b) internal photograph (c) and external photograph of the ORM system.

Conclusion

- An ORM prototype was manufactured with ITO glass.
- The prototype was tested with the MPPB and Gamma beam.
- The linear dose responses exceeding 99% for both single-point and nine-point beam spots. The size and center position deviation of the nine-point spot measurement were within 0.35 mm and 1 mm.
- This plan is expected to have more medical detection capabilities.

Proton beam and radiotherapy gamma test

The ORM system underwent proton beam tests at the treatment terminal of the proton therapy and radiotherapy gamma system to evaluate its QA performance.



(a)

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Fig 4. (a) Proton beam test for the ORM system. (b) Radiotherapy gamma test.

To evaluate the linear response of the ORM system to proton beam doses, tests were conducted using both single-point and nine-point MPPBs with various doses under different beam energies. The R² values of the brightness responses to proton beams with varying energies consistently exceeded 99.5%.

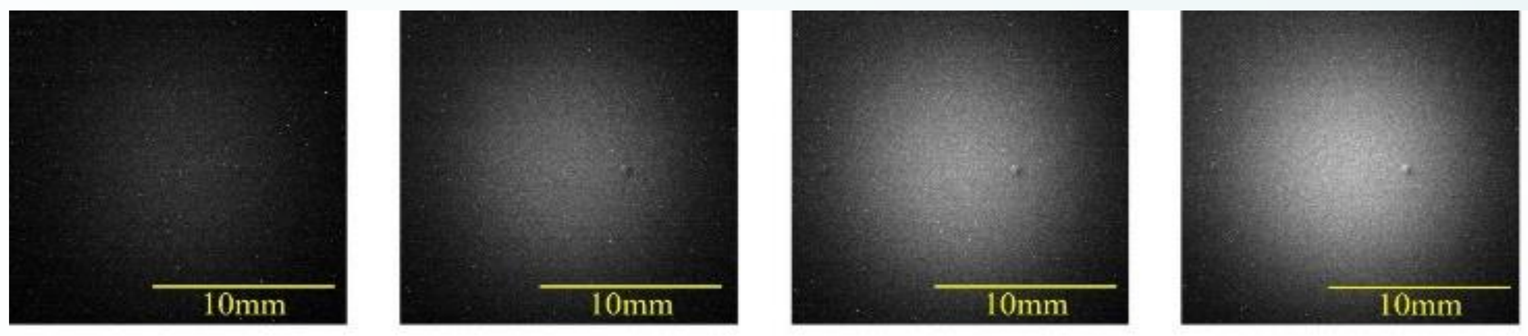
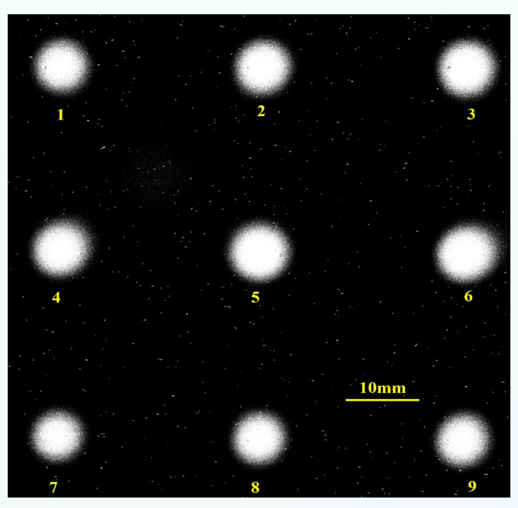


Fig 5. Imaging images of single proton beam spots at 20MU , 40MU, 60MU, 80MU.

The dose linearity response for the nine-point MPPB was subsequently evaluated. In this evaluation, the scanning beams were configured to emit in a 3×3 matrix distribution with a spacing of 30 millimeters between beams. Then the ORM finished the gamma test.



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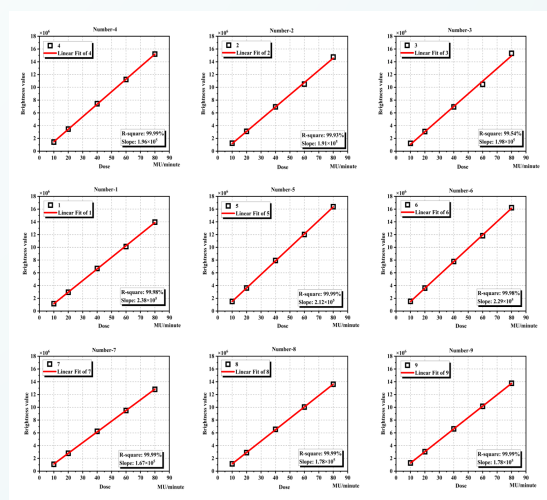

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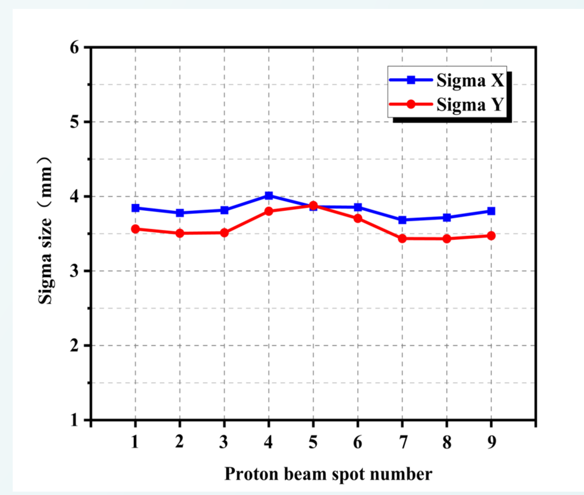

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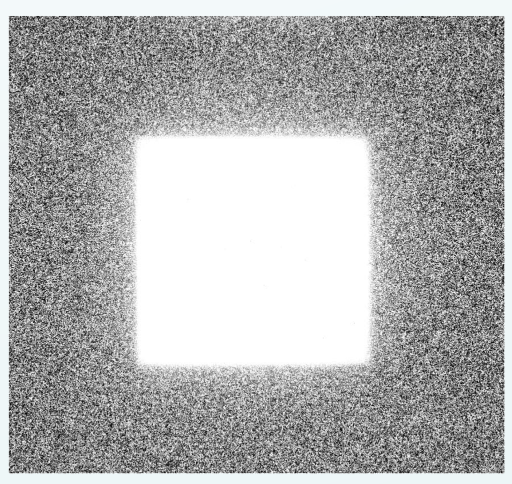

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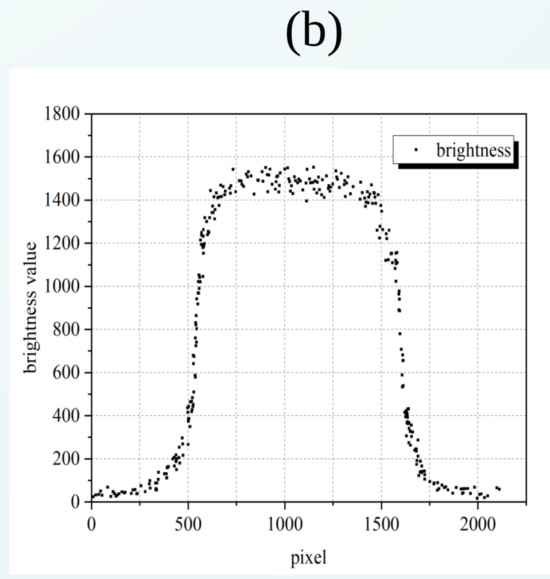

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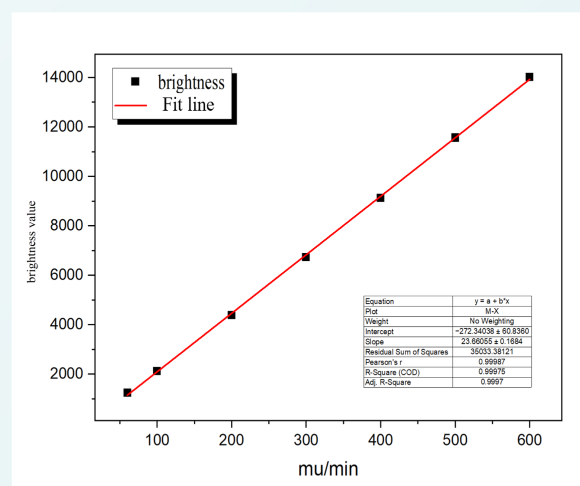

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Figure 6. (a) The brightness plots of the nine-point MPPB. (b) Dose linearity response for the nine-point MPPB. (c) Sigma size of the nine-point proton beam. (d) The photo of gamma test. (e) Gamma beam spot analysis. (f) Gamma brightness response analysis.

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