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# Development of simple proton CT system with novel MCS correction methods

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Proton therapy is an advanced cancer therapy that features energy loss of protons, known as the Bragg peak. Owing to high concentration of the radiation dose, the proton range in a patient's body, characterized by the water equivalent length (WEL), must be accurately determined for safe and effective proton therapy. Current treatment planning is based on X-ray CT images, which might cause uncertainty and/or be inaccurate because of the different energy loss processes between protons and X-rays. A more accurate estimate of the WEL is obtained if the proton itself is used for CT imaging. We develop a novel but simple, real-time proton CT system comprising an X-ray scintillator sheet and EM-CCD camera. Since protons lose energy when passing through a subject like a patient's body or phantoms, different light output corresponding to proton energy loss, is anticipated within a screen sheet, which can be imaged by the EM-CCD camera. Experiments were performed using this technique with 70-MeV and 200-MeV proton beams. Further, we examined two different beam types, broad and narrow beams, which mimic the passive scattering and spot scanning systems generally used in clinical treatment. In all cases, blurring of images caused by multiple Coulomb scattering (MCS) was significant, prompting us to develop various correction methods. One such technique involves changing the distance between the phantom and screen to estimate the proton CT image at the phantom in situ for the broad beam. Deviation from an incident beam profile is corrected as being due to MCS for the narrow beam. We successfully obtain clear images with little MCS effect by applying these correction methods. Moreover, we confirm that the WEL values estimated from the acquired CT images are in good agreement with true values for Polymethyl methacrylate (PMMA), isopropyl alcohol, and Vaseline within 1$\sigma$ uncertainty.

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