



Contribution ID: 170

Type: Oral presentation

Patient position verification in ion beam therapy using pencil beam radiography

Monday, 4 July 2011 15:15 (20 minutes)

The basic rationale for radiation therapy using ion beams is its high local precision of dose deposition. Due to the steep gradients in dose distribution precise knowledge of the patient's position and potential tumor displacement becomes even more important than in conventional therapy using photon beams. Therefore accurate patient positioning prior and during beam application is a crucial part of the therapy.

The current standard position verification procedure uses X-ray based imaging before each beam application assuming the patient to remain in his position. During irradiation there is no possibility to monitor the patient position or organ movement. The aim of this study is to investigate the possibility of verifying the position of a fiducial marker during therapy with a narrow pencil beam. This method may be much faster than X-ray imaging and irradiates only very little tissue.

Some modern ion therapy facilities like the Heidelberg Ion Therapy Center (HIT), where our measurements were carried out, use scanning pencil beams to apply dose. Exploiting them for imaging allows to solely irradiate regions of interest in the patient's body, e.g. tissue containing medical seeds or bony structures. This can be done quickly in turn with therapeutical beam application.

Due to the high atomic number, metal markers provide much higher contrast than organic structures. For our measurements we used segmented gold and NiTi seeds of sizes up to $3 \times 1 \text{ mm}^2$ embedded in a cuboid PMMA phantom. To image the residual beam we used the Perkin Elmer RID256-L flat panel detector. It has a pixel pitch of $800 \mu\text{m}$ and provides an active area of $20 \times 20 \text{ cm}^2$.

Measurements showed that 10^4 particles of a 300 MeV/u carbon ion beam suffice to make the seed's position visible at different material depths with an uncertainty of 1 mm. While the dose is similar to an X-ray image, the irradiated volume is very much reduced.

In this work it was shown that imaging of seeds and landmarks by ion pencil beams and a flat panel detector is technically feasible. We are currently working on a comparison of the results with measurements performed using the Timepix detector, developed by the Medipix collaboration, where we expect even better performance due to the smaller pixel pitch and the possibility to distinct particles. Using this detector would in principle allow to reduce the dose considerably.

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Session Classification: Applications I

Track Classification: Applications