Modelling the source and multislit collimator geometry and their influence on MRT microbeam profiles

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Rationale and objectives

Monte Carlo simulation was used to investigate the influence of the source and multislit collimator (MSC) geometry on the profiles of MRT microbeams in Microbeam Radiation Therapy (MRT).

Methods

Monte Carlo (MC) simulation is the computational study of radiation particle transport in matter. A common assumption made in previous Monte Carlo studies is that the array of MRT microbeams emerging from the MSC are all identical and rectangular in shape. Due to the inefficiency of simulating a small detector volume tens of meters from a synchrotron source, which would require lengthy simulation times, earlier MC studies have started the transport of rectangular microbeams on the phantom surface. These short-cuts fail to account for any divergence of the beam from the distributed synchrotron source to the MSC (a distance of approximately 33 metres on the ESRF ID-17 medical beamline) and geometrical effects that may arise from the radiation transport through the MSC device. This paper investigates the effect of these factors on the microbeam profiles emerging from a MSC device consisting of two overlapping identical tungsten stacks. Simulations were performed with the MC PENELOPE, a coupled electron-photon transport code, which was chosen for its accurate low-energy electron and photon cross-sections. The modelling of the synchrotron source and MSC geometry was based on the MRT setup employed on the ESRF ID-17 medical beamline.

Results

The PENELOPE simulation results in Figure 1 show the influence of beam divergence and modelling of the MSC device on the MRT microbeam profiles. The figure on the left is the MC simulation of an array of 21 microbeams emerging from the MSC device, where *Cbeam* is the central microbeam profile and *L1, L3, L5, L10beam* correspond to profiles 1, 3, 5 and 10 microbeams to the left of centre and vice versa for *R1, R3, R5, R10beam* (when viewed along the direction of the beam). The reduction in intensity of microbeams to the right of centre (R1 to R10beam) can be explained by the geometrical relationship of the two overlapping stacks in the MSC device and their subsequent affect on the radiation transport. The influence of the beam divergence and modelling of the source geometry on the central microbeam profile is illustrated in the figure on the right, where *'MSC Pt'* and *'MSC Circ'* correspond to a point source and circular distributed source, respectively, at 33m behind the modelled MSC device. Both of these MSC profiles have steeper penumbral regions than the *'No MSC'* profile which was obtained with no modelling of the MSC device (i.e. a rectangular microbeam was started on the surface of the phantom). The sharper penumbra obtained with the more realistic circular source illustrates the effect that source geometry has on the beam divergence, and hence, the microbeam profiles emerging from the MSC device.

Conclusion

The shape of microbeam profiles are affected by the geometry of the synchrotron source and the MSC device, particulary those on the right side of the array and furthest from the centre. Thus, the common assumption made in earlier MC studies that an array of MRT microbeams are rectangular is an inaccurate assumption as it neglects the effect of beam divergence by failing to accurately model the geometry of the source and MSC device.