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Exploring novel radiotherapy techniques with Monte Carlo simulation and measurement

Heidi Nettelbeck

A thesis submitted in fulfilment of the

requirements for the award of the degree

Doctor of Philosophy

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School of Engineering Physics

University of Wollongong

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Thesis supervisors: Doctor George J. Takacs and Professor Anatoly B. Rosenfeld

ABSTRACT

This work is the first comprehensive investigation of potential changes in the radio-biological effectiveness of clinical photon beams caused by a redistribution of electrons in a magnetic field. It is also a fundamental study of both the influence of magnetic fields on the peak-to-valley dose ratio of microbeams and the accuracy of theoretical modelling for dose planning in Microbeam Radiation Therapy (MRT).

The application of a strong transverse magnetic field to a volume undergoing irradiation by a photon beam can produce localised regions of dose enhancement and dose reduction. Results from Monte Carlo PENELOPE simulation show regions of enhancement and reduction of as much as 111% and 77% respectively for magnetic fields of 1 to 100 T applied to Co^{60}, 6, 10, 15, and 24 MV photon beams. The dose redistribution is shown to occur predominantly through an alteration in the lower energy electron population, which may correspond to a change in the relative biological effectiveness.

In MRT, an experimental and theoretical investigation of the influence of transverse and longitudinal magnetic fields on the lateral dose profile and peak-to-valley dose ratio (PVDR) of microbeams is presented. Results show that longitudinal magnetic fields greater than 10 T are needed to produce an effect. Strong transverse magnetic fields, on the other hand, have no influence on microbeam profiles. The radiation response of the edge-on MOSFET and its ability to measure dose profiles of monoenergetic and polyenergetic microbeams are also investigated.

Simulations investigating the dependence of microbeam dose profiles on the accuracy of beamline modelling (i.e. synchrotron source, multislit collimator, and beam divergence) are also presented. Results show the asymmetric collimator construction is responsible for a 10% variation in the full-width at half-maximum of microbeams which affects the PVDR. Modelling the distributed source and beam divergence increases the penumbral dose by almost 30%. The influence of the collimator alignment, interaction medium, and the height of scoring regions on the PVDR are also investigated.

CERTIFICATION

I, Heidi Nettelbeck, declare that this thesis, submitted in fulfilment of the requirements for the award of Doctor of Philosophy, in School of Engineering Physics, University of Wollongong, is wholly my own work unless otherwise referenced or acknowledged. The document has not been submitted for qualifications at any other academic institution.

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Heidi Nettelbeck

April 14, 2009

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