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The characterisation of planar silicon pin diodes for use in proton therapy

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This thesis is presented as part of the requirements for the award of the Degree of:

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CERTIFICATION

I, Joel Poder, declare that this thesis, submitted in partial fulfilment of the requirements for the award of Master of Science – Research, in the Centre for Medical Radiation Physics, University of Wollongong is wholly my own work unless otherwise referenced or acknowledged. This document has not been submitted for qualifications at any other academic institution.

Joel Poder
28th June 2010

ABSTRACT

Many new techniques in the delivery of radiation therapy are being developed for the treatment of cancer. One of these new techniques, proton therapy is becoming increasingly popular due to the presence of the characteristic proton Bragg peak, which allows for better conformation of the dose to the tumour volume. The production of high LET secondary particles in the beam line and within the patient however could result in a significant contribution to the integral dose and diminish this potential advantage. Measured secondary particle doses from clinical proton facilities vary greatly; this is partly due to the differences in beam delivery methods at different centres and due also to the different methods used to measure this secondary particle dose.

The potential of quantification of this mixed particle dose can be achieved through practical and simple measurements of non-ionizing energy losses (NIEL) and ionizing energy losses (IEL). The suitable sensor for NIEL measurements is a silicon PIN diode, through the development of the silicon PIN diodes the possibility of the quantification and therefore significance of the dose delivered by the primary and secondary particles can be realised.

This thesis investigates the characterisation of the response of silicon PIN diodes for use in proton therapy, of particular interest is the in field forward bias response of the PIN diodes as well as their dependence on temperature and light.

Monte Carlo calculations are performed using the Geant4 platform to characterise the response of the silicon PIN diodes when placed in field during proton therapy. The forward bias response of the detector when placed in field was found to be dependent on protons only, with the neutron component of the response being negligible. This allows for the possibility of characterisation of the PIN diodes on the central axis of the beam.

The relative sensitivity of the PIN diodes to protons was found by dividing the forward bias response by the theoretical depth dose and it was found that the relative

sensitivity of the diode is independent of the phantom material and depends only on the initial energy of the primary proton beam.

Experiments are performed in order to characterise the response of the PIN diodes under various conditions. The effect on the forward bias response of the PIN diodes when exposed to visible light was examined by taking forward voltage measurements on each of the diodes both exposed and not exposed to visible light. It was found that the difference in forward bias voltage measurements with light incident on the diode and when light is blocked is no greater than the uncertainty involved in the measurement, using the dedicated forward bias voltage read – out system.

In order to investigate any change in forward bias voltage across the temperature range of interest each of the PIN diodes forward bias voltage is measured over a range from 25 - 35°C. The average temperature coefficient was found to be 0.75mV/°C at 1mA and 1.8mV/°C at 20mA. Considering that the variation in room temperature was expected to be minimal (< 1°C) the temperature of the diodes should differ very little over the several hours between pre and post irradiation read out.

The linearity of the current source in the read-out system is tested at current values of 1, 10, 15 and 20 mA over a wide range of resistances to ensure that the current remained constant over these values. A change in the linear relationship between voltage and resistance was observed in the 10, 15 and 20 mA characteristics. This change was attributed to the fact that the current source is no longer putting out a constant value, highlighting the limit of power in the forward bias voltage read-out device.

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