Physica Medica xxx (2016) xxx–xxx

Contents lists available at ScienceDirect

Physica Medica

journal homepage: http://www.physicamedica.com

Original paper

Multi-strip silicon sensors for beam array monitoring in micro-beam radiation therapy

E. Alagoz [a], E. Brauer-Krisch [b], A. Bravin [b], I. Cornelius [c], P. Fournier [c], T.E. Hansen [d], A. Kok [d], M. Lerch [c], E. Monakhov [e], J. Morse [b], N. Pacifico [a,*], M. Petasecca [c], M. Povoli [f], H. Requard [b], A.D. Rozenfeld [c], M. Salome [b], H. Sandaker [e], B. Stugu [a]

[a] Department of Physics and Technology, University of Bergen, Postboks 7803, N-5020 Bergen, Norway
[b] European Synchrotron Radiation Facility, 71 avenue des Martyrs, 38000 Grenoble, France
[c] Centre for Medical Radiation Physics, University of Wollongong, NSW 2522, Australia
[d] SINTEF MiNaLab, Department of Microsystems and Nanotechnology, Gaustadalléen 23 C, Oslo, Norway
[e] Department of Physics, University of Oslo, Postboks 1048 Blindern, 0316 Oslo, Norway
[f] Centre for Material Science and Nanotechnology, University of Oslo, Postboks 1048 Blindern, 0316 Oslo, Norway

A R T I C L E I N F O

Article history:
Received 4 May 2016
Received in Revised form 14 September 2016
Accepted 1 November 2016
Available online xxxx

Keywords:
Synchrotron radiation
Micro-beam radiation therapy
Silicon
Beam monitor

A B S T R A C T

We present here the latest results from tests performed at the ESRF ID17 and ID21 beamlines for the characterization of novel beam monitors for Microbeam Radiation Therapy (MRT), which is currently being implemented at ID17. MRT aims at treating solid tumors by exploiting an array of evenly spaced microbeams, having an energy spectrum distributed between 27 and 600 keV and peaking at 100 keV. Given the high instantaneous dose delivered (up to 20 kGy/s), the position and the intensity of the microbeams has to be precisely and instantly monitored. For this purpose, we developed dedicated silicon microstrip beam monitors. We have successfully characterized them, both with a microbeam array at ID17, and a submicron scanning beam at ID21. We present here the latest results obtained in recent tests along with an outlook on future developments.

© 2016 Associazione Italiana di Fisica Medica. Published by Elsevier Ltd. All rights reserved.

1. Introduction

Microbeam Radiation Therapy (MRT) [1–5] is a recent application of synchrotron radiation to the treatment of solid tumors. It is currently being implemented at CMRP (Australia) and ESRF (Grenoble), with ongoing tests on small-animal-models, which are advancing towards large-animal-models with a future outlook on human tests.

The technique relies on the different susceptibility of healthy and cancerous tissue to a micro-beam array. A tungsten collimator (multi-slit collimator) is used to create the micro-beam array typical of MRT, featuring high dose regions (peaks) and low dose regions (valleys). Each micro-beam (peak) has a width of a few tens of micron, and the spacing between micro-beams (valleys) can be varied between 100 and 400 μ m. This beam configuration allows healthy tissue to recover from radiation induced damage more efficiently than in standard uniform beam configurations. In order to maintain the radiation damage confined to the intended slices of tissue, the dose has to be delivered quickly, to avoid the displacement of the treated region due to cardiosynchronous movements. This requires extremely high dose rates, than can only be delivered at 3rd generation synchrotron radiation facilities, and a monitoring system (Patient Safety System – PSS) which can stop the beam in short time in case anomalies in its delivery are detected.

As a part of the PSS, we have developed an active beam monitoring system, employing the proven technology of silicon junction detectors. An array of silicon microstrips is deployed in the beam and constantly monitors its intensity and position. In order to avoid beam perturbations before the delivery to the patient, the sensors have to be extremely thin (down to 10 μm) and be engineered for an optimal resolution. We will describe the tested geometries and a custom readout system we have developed, based on the Texas Instruments AFE ASIC. In addition, we will present the results from two separate beam tests. The first experiment was carried out at the MRT beamline (ID17) in real MRT operating conditions, and was aimed at evaluating the performances of different sensor layouts. The second experiment was carried out at ID21 with a focused 7.2 keV X-ray beam, and was instead aimed at gathering in depth information on the charge collection dynamics and uniformity of the studied detectors.

* Corresponding author.
E-mail address: nicola.pacifico@cern.ch (N. Pacifico).

http://dx.doi.org/10.1016/j.ejmp.2016.11.005
1120-1797/© 2016 Associazione Italiana di Fisica Medica. Published by Elsevier Ltd. All rights reserved.

ARTICLE IN PRESS

2. Sensors

The sensors developed for the MRT have been manufactured at SINTEF MiNaLab (Oslo Norway) on 6 inches wafers of Float-Zone p-type bulk silicon. We designed several geometries for the arrangement of the n^+ junction implants. The active region of the sensor is thinned (etched) down to a thickness of 10 μm, in order to avoid perturbing the beam. The simplest geometry has 7 μm wide implants spaced by a constant pitch of 100 μm and is shown in Fig. 1a. The beam profile consists of peaks and valleys, and the pitch between each peak is normally set to 400μm. This geometry, when correctly aligned, allows to have information for both the peak and valley regions (one measurement on each peak and two in each valley). In order to avoid charge diffusion to neighboring strips, steering ring structures (connected together and also realized through n^+ implants) are surrounding the strip implants: only the charge generated within the ring will be collected by the main implant.

This geometry requires the microbeam pitch to be perfectly matched with the strip sensor pitch but, in earlier tests, we have observed a slight divergence of the beam that causes a higher measured pitch that, although not clinically significant, causes a noticeable modulation in the detected signal on the outer strips of the sensor (the strips on each side of the array). The pitch mismatch comes from the fact that the measurement position is further away from the multi-slit collimator than previously foreseen. Unfortunately as the beamline is currently set up for animal trials, no modifications are allowed. In order to overcome this issue, we have developed variable pitch sensors. In these detectors, three-strip islands (*triplets*), with a 24 μm interstrip spacing, are interspaced by single strips, the latter dedicated to the measurement of signal in the valleys. Single strips are spaced by half period, 200 μm in this case, from the center of each triplet. Each strip is surrounded by a steering ring as in the single strip sensors. The layout of these sensors is shown in Fig. 1b. The triplets allow to have the beam hitting the active region as long as the mismatch is contained within ~50 μm over the whole detector width. This approach, as already demonstrated in [7], provides a uniform sensitivity in our beam tests, even in the presence of a slight beam divergence. An additional reason for the variable pitch detector is to have multiple intensity measurements on the same peak without dramatically increasing the total number channels. By doing so, when the beam to sensor alignment is correct, each peak will be sampled three times while each valley will only be sampled once. A large number of geometrical variations are available on the wafer design. Different strip lengths were designed (10, 50, 100, 250 μm) to

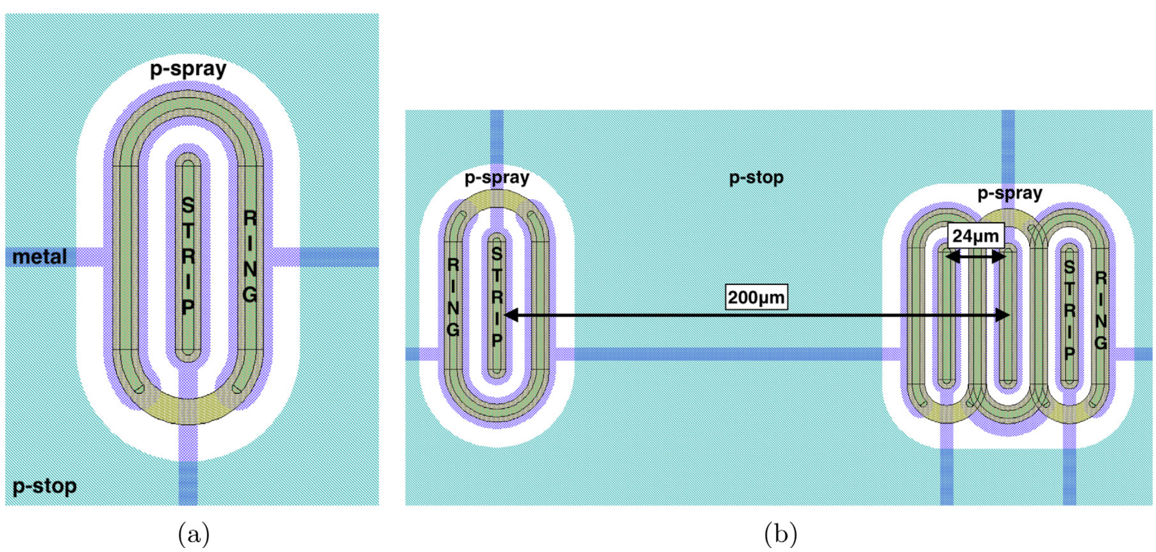

Fig. 1. Layout of 2 different geometries of MRT beam monitors. (a) Single strip, with enclosing steering ring. (b) Strip triplets with common steering ring.

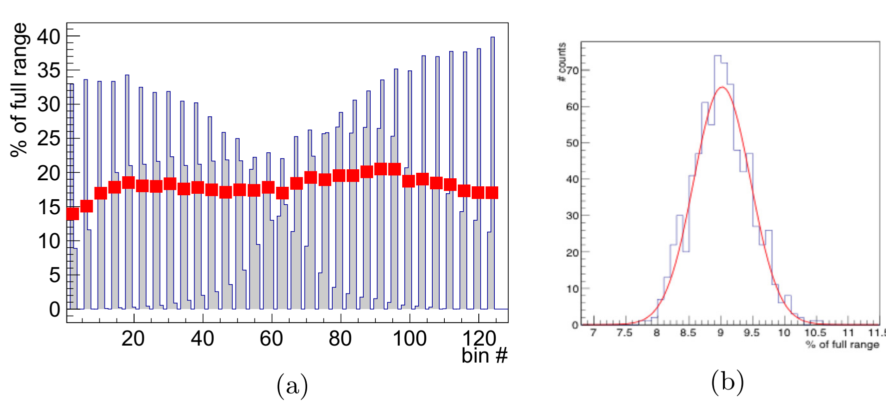

Fig. 2. (a) Charge collected over one beam extraction for a variable pitch sensor. Red dots show the centre of mass position and the average charge for each triplet. (b) The distribution of charge samples for a triplet channel, with a gaussian fit shown. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Please cite this article in press as: Alagoz E et al. Multi-strip silicon sensors for beam array monitoring in micro-beam radiation therapy. Phys. Med. (2016), http://dx.doi.org/10.1016/j.ejmp.2016.11.005

Download English Version:

https://daneshyari.com/en/article/5498670

Download Persian Version:

https://daneshyari.com/article/5498670

Daneshyari.com