Charge Collection Mapping of a Novel Ultra-Thin Silicon Strip Detector for Hadrontherapy Beam Monitoring

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Context & Objectives

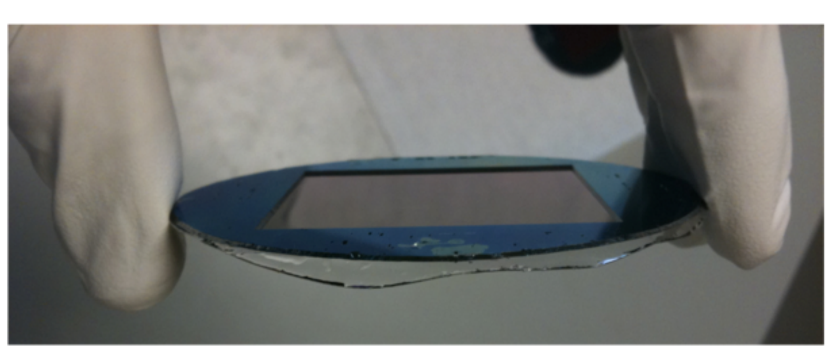
For precise treatment purposes in hadrontherapy, the particle beam has to be monitored in real time without being degraded. For the first time, silicon strip detectors have been fabricated over an area as large as 4.5cm x 4.5cm with ultra low thickness of 20µm. Ultra-thin detectors offer the following considerable advantages: a significantly reduced beam scattering [1], a higher radiation hardness [2] which leads to an improved detector lifetime, and a much better collection efficiency. In a previous work [3], the novel sensor has been described and a global macroscopic dosimetry characterization has been proposed.

The latter characterization provides practical information for the detector daily use however it does not help to improve the local microscopic knowledge of the sensor.

This work therefore presents a micrometric-accuracy charge collection characterization of this new generation of ultra-thin silicon strip detectors.

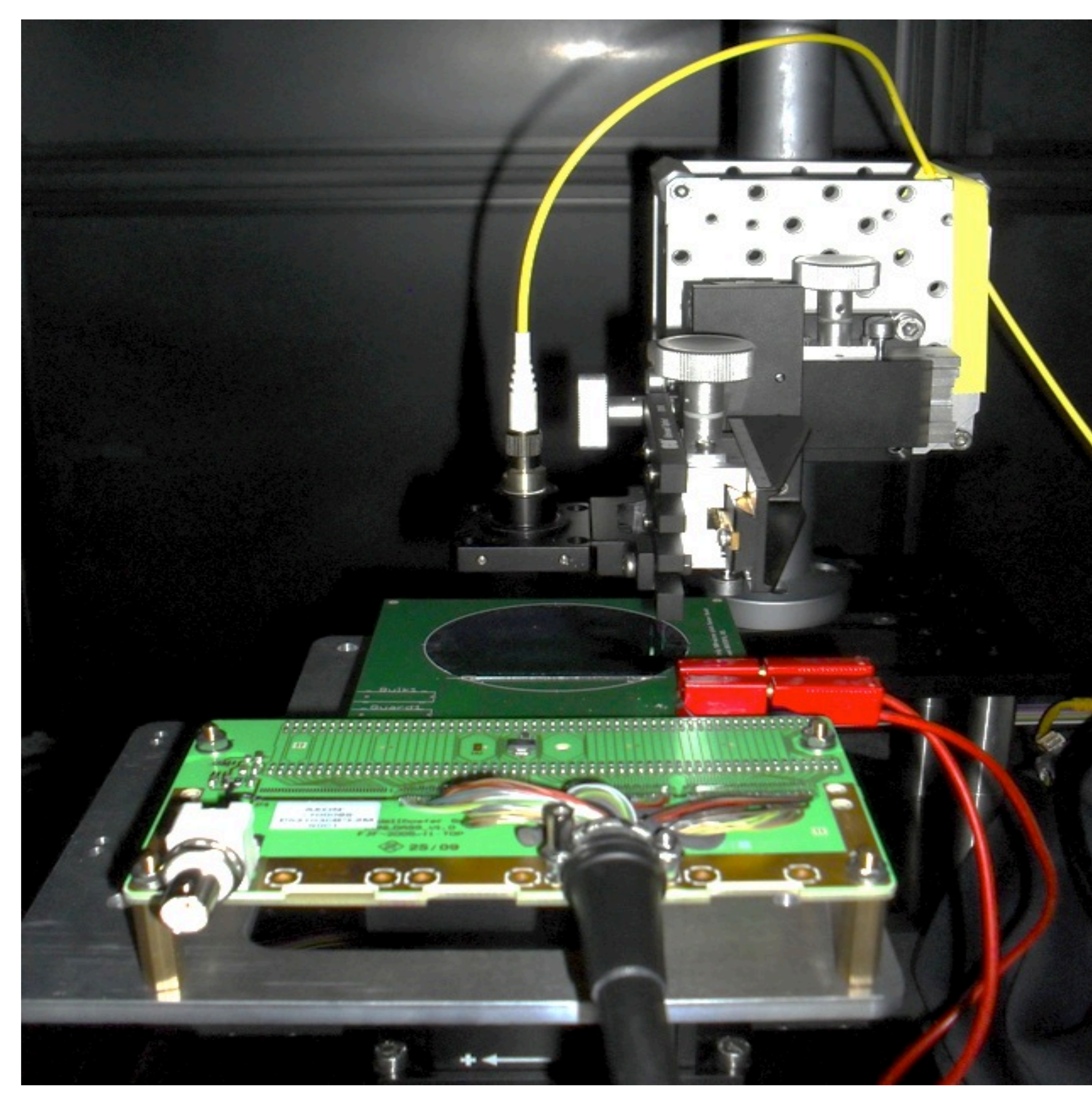
This study gives a much better knowledge of the inefficient areas of the sensor and allows therefore optimization for future designs.

Materials & Methods

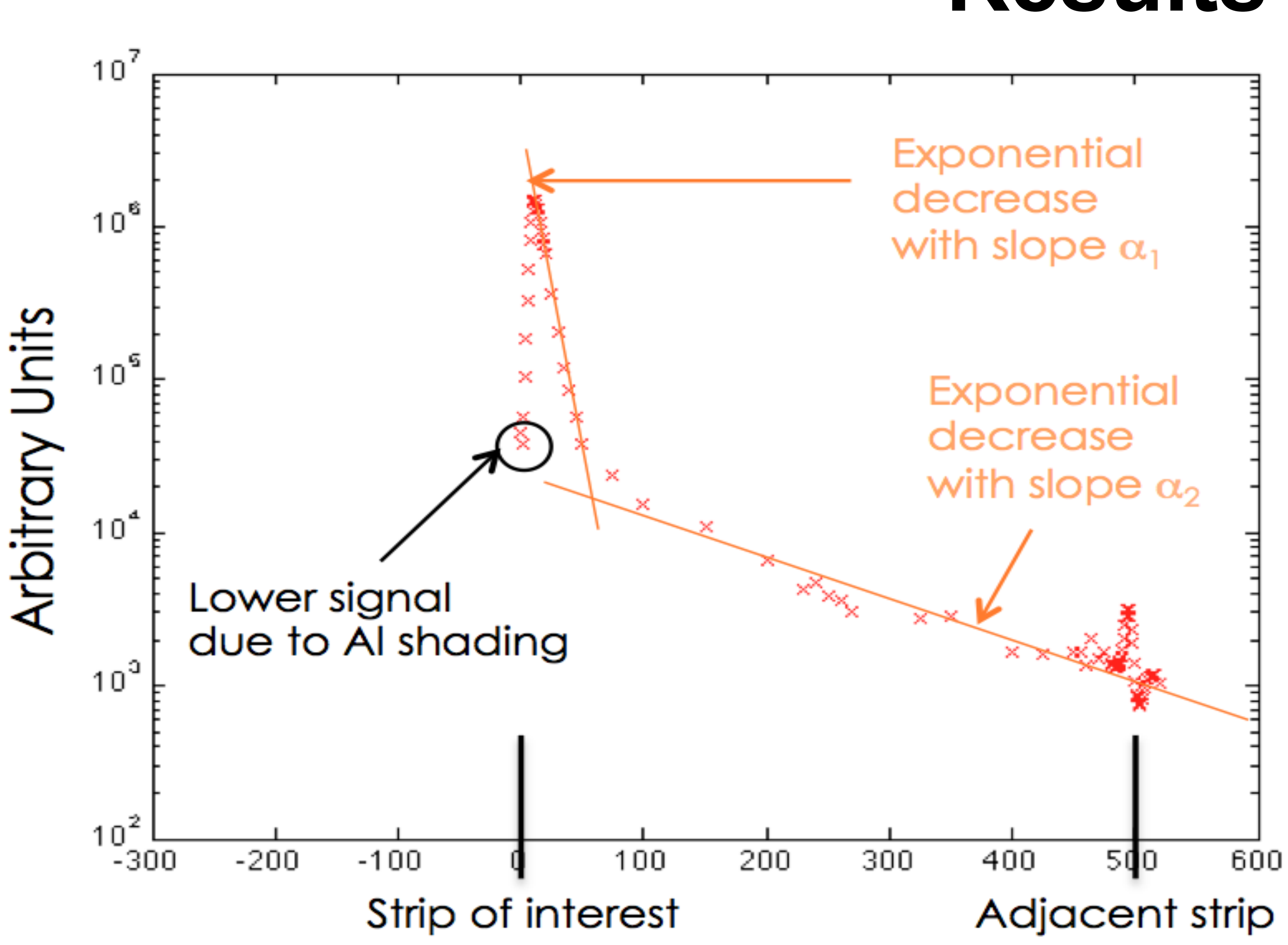


Number of strips	81
Pitch	500 µm
Width	20 µm
Depth	≈ 1 µm
Length	4 cm
Doping	10^{20} cm^{-3}

Above, the twenty-micron-thick sensor seen from the backside with the strips dimensions. The membrane surface is 4.5 x 4.5 cm^2. The wafer is boron pre-doped with resistivity of 10-30 Ω.cm.
The experimental setup is shown on the right : the sensor (wafer) is glued on the interface PCB which lies on the submicron resolution moving platform along X, Y and Z axes. The laser diode is fixed and emits 1060nm photons perpendicularly to the sensor surface.
The spot is gaussian-shaped and its size was set to minimum, i.e. a standard deviation of 7.5 microns.
The readout electronics is a current-to-frequency converter called « emXX » and developed by the company « Ion Beam Applications ». It biases the device at 3mV in reverse mode.



Results & Discussions



On the left, the figure shows the measured collected current (log-scale in arbitrary units) as a function of "X", position of the laser hit perpendicularly to strips on the sensor. Contrary to what can be expected, there are 2 diffusion lengths instead of one, meaning there are 2 effective minority carrier lifetimes (ELT). Close to the strip, diffusion length is about 8.5µm, i.e. ELT of 0.02µs. At about 50µm and further, the diffusion length increases till 105µm, i.e. ELT of 3µs.
Two major conclusions:
first, ELT is more than 150 times lower close to the implanted areas of the strips;
second, collection efficiency decreases by one order of magnitude in about 25µm. Consequently, the major part of the silicon between 2 adjacent strips is inefficient in terms of collection.

References

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[2] D. Menichelli et al., "Design and development of a silicon-segmented detector for 2D dose measurements in radiotherapy", Nucl. Instr. and Meth. A 583 (2007) 109-113
[3] M. Bouterfa et al., "Characterization of Ultra-Thin Silicon Strip Detectors for Hadrontherapy Beam Monitoring", submitted & accepted for [Proceedings of I2MTC2013, Minneapolis, USA, 2013]

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