Experiment Report Form

The double page inside this form is to be filled in by all users or groups of users who have had access to beam time for measurements at the ESRF.

Once completed, the report should be submitted electronically to the User Office via the User Portal:

https://wwws.esrf.fr/misapps/SMISWebClient/protected/welcome.do

Reports supporting requests for additional beam time

Reports can be submitted independently of new proposals – it is necessary simply to indicate the number of the report(s) supporting a new proposal on the proposal form.

The Review Committees reserve the right to reject new proposals from groups who have not reported on the use of beam time allocated previously.

Reports on experiments relating to long term projects

Proposers awarded beam time for a long term project are required to submit an interim report at the end of each year, irrespective of the number of shifts of beam time they have used.

Published papers

All users must give proper credit to ESRF staff members and proper mention to ESRF facilities which were essential for the results described in any ensuing publication. Further, they are obliged to send to the Joint ESRF/ ILL library the complete reference and the abstract of all papers appearing in print, and resulting from the use of the ESRF.

Should you wish to make more general comments on the experiment, please note them on the User Evaluation Form, and send both the Report and the Evaluation Form to the User Office.

Deadlines for submission of Experimental Reports

- 1st March for experiments carried out up until June of the previous year;
- 1st September for experiments carried out up until January of the same year.

Instructions for preparing your Report

- fill in a separate form for each project or series of measurements.
- type your report, in English.
- include the reference number of the proposal to which the report refers.
- make sure that the text, tables and figures fit into the space available.
- if your work is published or is in press, you may prefer to paste in the abstract, and add full reference details. If the abstract is in a language other than English, please include an English translation.

ESRF	**Experiment title:** X-Ray Microbeam characterisation of high-precision silicon dosimeters for Microbeam Radiation Therapy (MRT) by means 2D position resolved scan	**Experiment number**: MI-1198
Beamline: ID17	**Date of experiment**: from: 22/11/2014 to: 25/12/2014	**Date of report**: 24/02/2015
Shifts: 9	**Local contact(s)**: Herwig Requardt	*Received at ESRF:*

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Report:

The aim of the experiment was to characterise a set of novel silicon detectors designed to be used as beam monitors during treatments in the Micro-beam Radiation Therapy (MRT) at ID17. Because of the very high dose delivered to the patient (up to 20 kGy), it is crucial to have reliable beam monitoring devices in order to stop the treatment in case of any beam abnormalities. Silicon detectors are a promising candidates due to their high dynamic range and real time operation. The task of these devices will be to monitor the micro-beam array. A strip arrangement was implemented to monitor each single micro peak in the array.

Samples description and experiment preparation:

A set of custom designed 10µm thick silicon strip detectors were fabricated at SINTEF MiNaLab in Oslo, Norway. In order to identify the optimal sensors design, strips of different lengths and pitches were implemented. Due to the extreme high dose rate at ID17, the shorter strip lenghts were favoured for this experiment (5, 50, 100µm). The standard layout for a strip sensor with an inter-strip pitch of 100µm where the strip is 50µm long, is shown in Fig. 1.a. A strip sensor with a variable pitch was also implemented. The section with a lower pitch between strip increases the spatial sampling in each micro-peak (Fig. 1.b), while every single strip was sufficient to monitor the area between the micro-peaks. The active volume of each single strip was limited by using "steering-rings" that surround each sensitive element. The surface passivation layers were carefully designed to limit radiation damage. The ultra thin property of these sensors also limits the beam perturbation. Sensors were glued and wire-bonded to custom designed printed circuit boards (designed by CMRP, Australia) (Fig.1c). A digital multi-channel readout system provided by CMRP was used for the data readout. The masurement setup was mounted in a shielding box fixed onto an x, y, z positioning system controlled by stepper motors, available at ID17 (Fig.1d).

Experimental technique and results:

Each sensor was intially tested in broad beam conditions in order to find the best configuration of the readout system parameters. In particular, scans were performed for constant Wiggler gap sizes while tuning the gain and the integration time of the readout system to avoid the saturation of the electronics. Once the devices were properly configured with respect to the expected operating conditions, scans with a single 50µm wide micro-beam were performed. A micro-beam was scanned across one sensitive element of the detector in steps of 10µm to record its shape (the current was recorded as a function of position using a Keithley electromer).

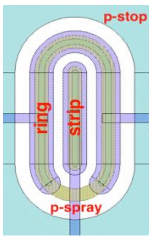

Fig. 1.a

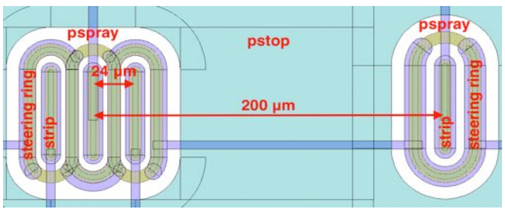

Fig. 1.b

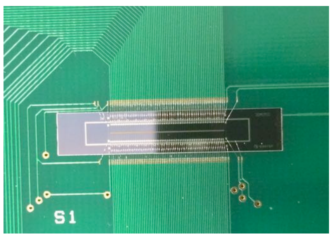

Fig. 1.c

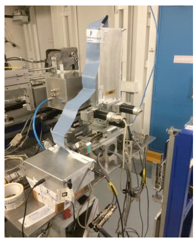

Fig. 1.d

Sensor ID	Strip length [μm]	Strip pitch [um]	Bias voltage [V]	Resistivity [Ohm cm]	Beam type	Wiggler GAP[mm]	Integration time [us]	Readout range
A2-L050-CL15	50	100 (constant)	0.67	5	1 micro beam	24.8	14	7
A2-L050-CL15	50	100 (constant)	0.67	5	25 micro beams	24.8	14	7
A2-L005-CL16	5	100 (constant)	0.67	100	25 micro beams	24.8	14	4
A9-L050-VAR03	50	200/24 (variable)	0.67	100	49 micro beams	24.8	14	6

Table 1. Summary of the key parameters for the measurements discussed in this report

The rest of the measurements were performed with an array of 50μm wide micro-beams spaced by 400μm in a condition as close as possible to those used in clinical trials (i.e. full beam intensity, Wiggler GAP set to 24.8mm, 25 or 49 micro-beams per array).

Table 1 summarises the device characteristics and the beam conditions that were used for a subset of the acquired data. Two bulk resistivities (5 and 100 Ωcm) and two strip lengths (5 and 50 μm) were used. The benchmark sensor configuration for this study is 50μm strip length, 100μm constant pitch, fabricated on a 5Ωcm silicon wafer, which is sensor A2-L050-CL15. After the initial calibration, a scan using a single micro-beam was performed. The result of this mesurement is shown in Fig. 2. The center of the scanned sensitive element locates at around x=210μm along the x-axis. The maximum current recorded by the electrometer is below 120nA. This is sufficiently low to avoid the saturation in the readout in the later measurements. The Full Width at Half Maximum (FWHM) of the measured micro-peak was 50.37μm, perfectly matching the nominal micro-beam width of 50μm.

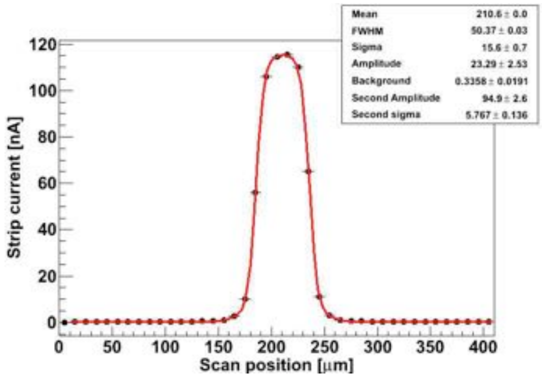

Fig. 2

Once the experimental setup and the basic functionalities of the benchmark sensor were verified, measurements using the multi-channel readout system were carried out with the same sensor, aiming at measuring the profile of an entire micro-beam array (Fig. 3.a). The profile was generaly as expected with two observations. Firstly, a noisy channel occurred in ch #116. Secondly, lower intensity was measured both sides away from the centre of the beam. This effect was caused by the beam divergence. The calculated divergence between each micro-beam of the array at the measurement point is roughly 1μm, resulting in the pitch between each micro-beam to be about 1μm wider than close to the collimator (400 m). On the contrary, the sensitive elements of the sensors have a fixed pitch of 100μm regardless of its position. Since sensitive elements of the sensors have a fixed pitch of 100μm, they were misaligned with the micro-peaks away from the centre. This issue can be corrected by positioning the sensor as close as possible to the Multi Slit Collimator (MSC) generating the array of micro-beams, which is unfortunately not an option at present. It is important to notice that no signal was visible in the channels between the peaks (valley regions). In order to see signal in the valleys it would be necessary to increase the gain of the readout. However, this would cause the remaining channels to saturate. The same measurement was performed on a sensor with a shorter strip length (5μm), in order to understand if a lower signal coming from a smaller active volume, would permit the observation of signal in the valley regions. Unfortunately, this was not the case as can be observed in Fig. 3.b for sensors A2-L005-CL16. The profile is similar to the previous one although less signal reduction is visible on the sides, most likely due to a better alignement between the sensor and the beam array.

The third sensor geometry to be tested was the one with the variable strip pitch. A result for device A9-L050-VAR03 is reported in Fig. 3.c. In this case, the sensor alignment was easier due to the availability of 3 measurement points from the three different strips for each micro-beam; a central one and two adjacent ones. For the reported measurements, the alignement occurred on channel 70. Once again the profile is not flat but, in this case, no reduction of signal was observed due to the fact that the micropeaks will be measured by one of the three strips even if the beam is misaligned with the entire set. Averaging the signal from the 3 adjacent strips could be one possible solution for a more precise beam profile reconstruction.

The experimental activities performed at ID17 were very succesful. Precautions and recommendations of improvements for the proposed beam monitoring system for MRT have been identified in this test: (i) the impact of the silicon resistivity is lower than expected and standard high resistivity material of high quality can be used; (ii) shorter strip lengths are more suitable for the high beam intensity at ID17; (iii) the channel spacing in the sensor must be chosen after its physical location in the beamline is decided, (iv) non-uniform tuning of the readout gains could allow measurements in the valley regions. A new batch of devices has already been designed following the recommendations observed in this experiment. New sensors will be ready by autumn 2015 for further testing at ID17.

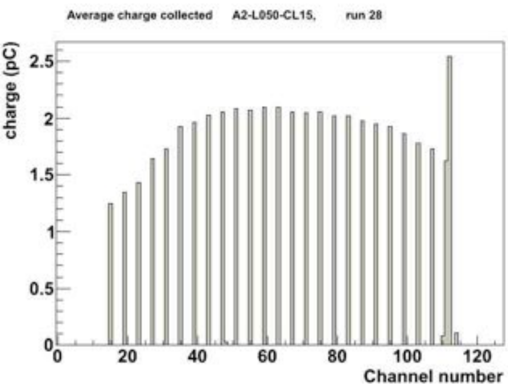

Fig. 3.a

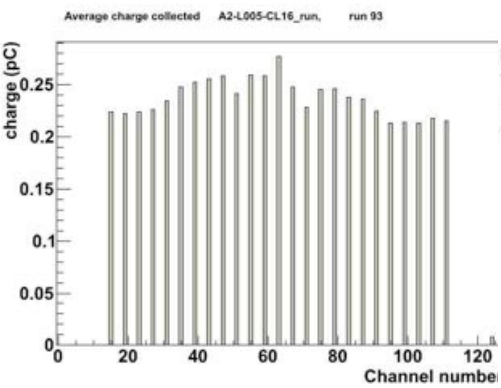

Fig. 3.b

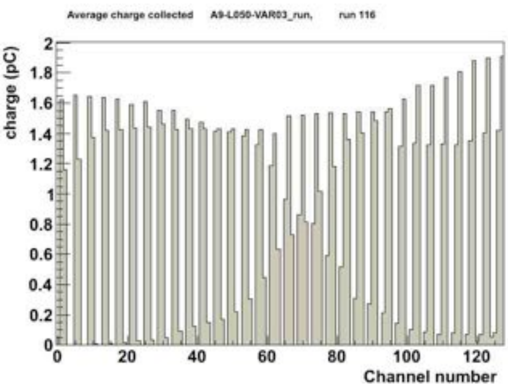

Fig. 3.c