EUROPEAN SYNCHROTRON RADIATION FACILITY

INSTALLATION EUROPEENNE DE RAYONNEMENT SYNCHROTRON

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

Deadlines for submission of Experimental Reports

Experimental reports must be submitted within the period of 3 months after the end of the experiment.

Experiment Report supporting a new proposal ("relevant report")

If you are submitting a proposal for a new project, or to continue a project for which you have previously been allocated beam time, you must submit a report on each of your previous measurement(s):

- even on those carried out close to the proposal submission deadline (it can be a *"preliminary report"),*
- even for experiments whose scientific area is different form the scientific area of the new proposal,
- carried out on CRG beamlines.

You must then register the report(s) as "relevant report(s)" in the new application form for beam time.

Deadlines for submitting a report supporting a new proposal

- 1st March Proposal Round - **5th March**
- 10th September Proposal Round - **13th September**

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.

Instructions for preparing your Report

- fill in a separate form for each project or series of measurements.
- type your report in English.
- include the experiment number 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:** Determination of valley dose in an anthropomorphic head phantom using 3-D optical CT imaging of radiosensitive samples	**Experiment number**: MD-1182
Beamline:	**Date of experiment**: from: 26/11/2018 to: 27/11/2018	**Date of report**: 27/02/2019
Shifts:	**Local contact(s)**: Herwig Requardt	*Received at ESRF:*

Names and affiliations of applicants (* indicates experimentalists):

Simon J Doran*, Institute of Cancer Research

Report:

BACKGROUND

Previous experiments using the PRESAGE® dosimeter, as reported in [1-4] have demonstrated the ability of PRESAGE® to record high-resolution maps of radiation dose from synchrotron microbeams. However, as illustrated in [4], it has so far proved difficult to obtain data with high enough spatial resolution to make an accurate measurement of the peak-to-valley dose ratio (PVDR). The aim of this experiment was to determine whether alternative methods of scanning the PRESAGE® samples would lead to improved data.

Sadly, during the period between the original submission of the proposal and the time of the experiment, one of the key collaborators, Elke Brauer-Krisch, passed away. This meant that additional aims of the experiment, in particular the direct comparison of the 3-D dosimetry with the TPS and the use of advanced plans with up to 5 ports were not possible. Work at ESRF was performed in collaboration with Paolo Pellicioli.

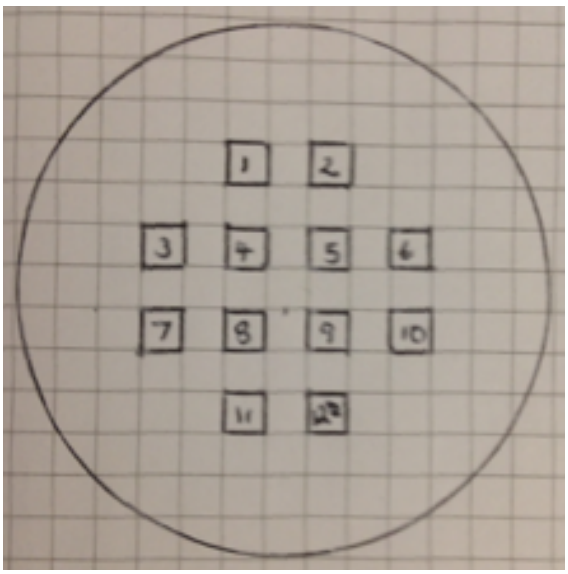
MATERIALS AND METHODS

Radiochromic film (MD-V3, Ashland) was placed at a depth of 2 cm in a phantom of water equivalent material and used to calibrate the beam, using standard techniques.

Three different sizes of PRESAGE® sample (cylinders of diameter 4 mm, 22 mm and 60 mm, respectively), originating from three different batches, were supplied by the manufacturer (Heuris Pharma, Skillman, NJ). The following irradiations were performed.

Pattern 1

The 60 mm sample was used to perform a calibration and linearity test using a method similar to that reported in [2], but with a test pattern consisting of twelve square irradiated regions (see Figure 1), rather than the seven irradiated previously. The same pattern was reduced in size and then applied to one of the 22 mm samples mounted inside a stack of 55 × 62 mm^2 Perspex slabs with 22 mm diameter holes.

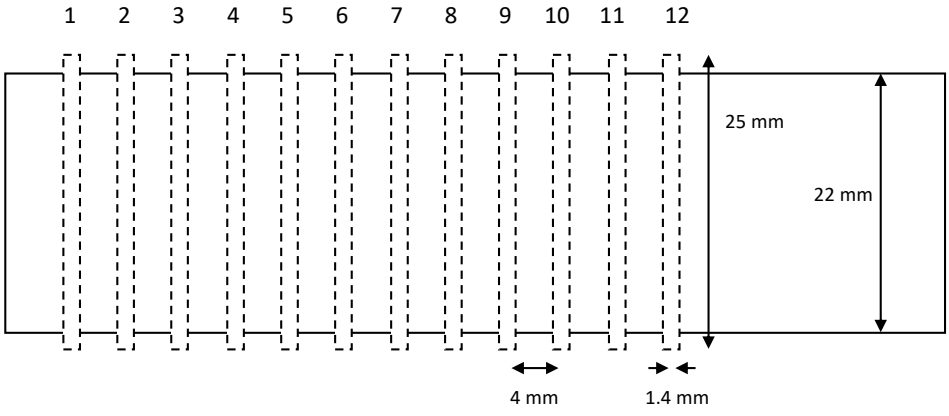


Position	Nominal dose / Gy
1	10
2	5
3	20
4	50
5	30
6	40
7	75
8	100
9	10
10	150
11	200
12	50

Figure 1: Test pattern irradiated in both the 60 mm and 22 mm samples. Note how the 10 and 50 Gy doses are repeated to assess whether there is a positional bias in the readings.

Pattern 2

A problem observed with previous measurements (both calibration samples and microbeam measurements) was that samples irradiated axially as above are exposed along their entire length and there is not a sufficient portion of unirradiated dosimeter to obtain a good background measurement. Furthermore, recent research [5] has demonstrated that dosimetry at the external edges of PRESAGE® samples may be compromised, not only by optical artefacts, but also a variable radiochromic response to radiation. In order to obtain a more reliable baseline reading, for calculating the valley dose, we investigated a different type of irradiation pattern, with the sample mounted inside the Perspex assembly described above and the synchrotron beam entering the sample perpendicular to the axis of symmetry (see Figure 2).



Position	Nominal dose / Gy
1	10
2	5
3	20
4	50
5	30
6	40
7	75
8	100
9	10
10	150
11	200
12	50

Figure 2: Test pattern irradiated in both the 22 mm samples. The solid rectangle is a side view of the cylindrical PRESAGE® sample and the dotted boxes represent the 25 × 1.4 mm^2 fields that were irradiated transversely.

Pattern 3

22 mm diameter samples were mounted as above and exposed to a 20 × 20 mm^2 field of microplanar beams with FWHM 50 microns and centre-to-centre distance 400 microns. Two different orientations were considered, with the microplanes either parallel or perpendicular to the axis of rotation of the cylindrical

samples. A further irradiation with microbeams parallel to the axis of symmetry was performed with the sample mounted in the “Christopher” head phantom.

Pattern 4
A two-port irradiation was given with the same parameters as above and microbeams incident both parallel and perpendicular to the axis of rotation.

Pattern 5
22 mm samples were drilled each with one 4 mm holes, into each of which was placed a 4 mm cylindrical PRESAGE® sample. These assemblies were irradiated with the microbeam field as above, in such a way as to expose only one half of the sample. The aim was to enable accurate, within-plane measurements of the dosimeter background.

Optical CT scanning of the samples was conducted using a modified version of the scanner described in [4]. A new facility is now available, allowing the wavelength of the light interrogating the sample to be varied. It is well known that the spectrum of the radiochromic response of PRESAGE® has a maximum value at $\lambda = 630$ nm, which is the normal scan wavelength and that this response diminishes rapidly for lower and higher wavelengths. However, we aimed to determine whether the poorer optical response at shorter wavelengths was compensated by a better spatial resolution, which might allow us to obtain improved estimates of PVDR.

RESULTS
Although many of the samples have now been optically scanned, analysis of the very large datasets is not yet complete. An initial analysis of projection data from sample 26B22/3, one of the 22 mm samples irradiated with Pattern 3 gave the results shown in Figure 3. Microbeams are clearly visualised in 3(a) and the corresponding profile through the centre of the sample is seen in 3(b). The calculated FWHM is 61 μm, which is very similar to the value obtained in [4], rather then the nominal 50 μm. However, this is likely to represent an overestimate, as the projection occurs over the entire 22 mm width of the sample and imperfect alignment of the camera would tend to broaden the peak. This may also explain the shape of the valley region.

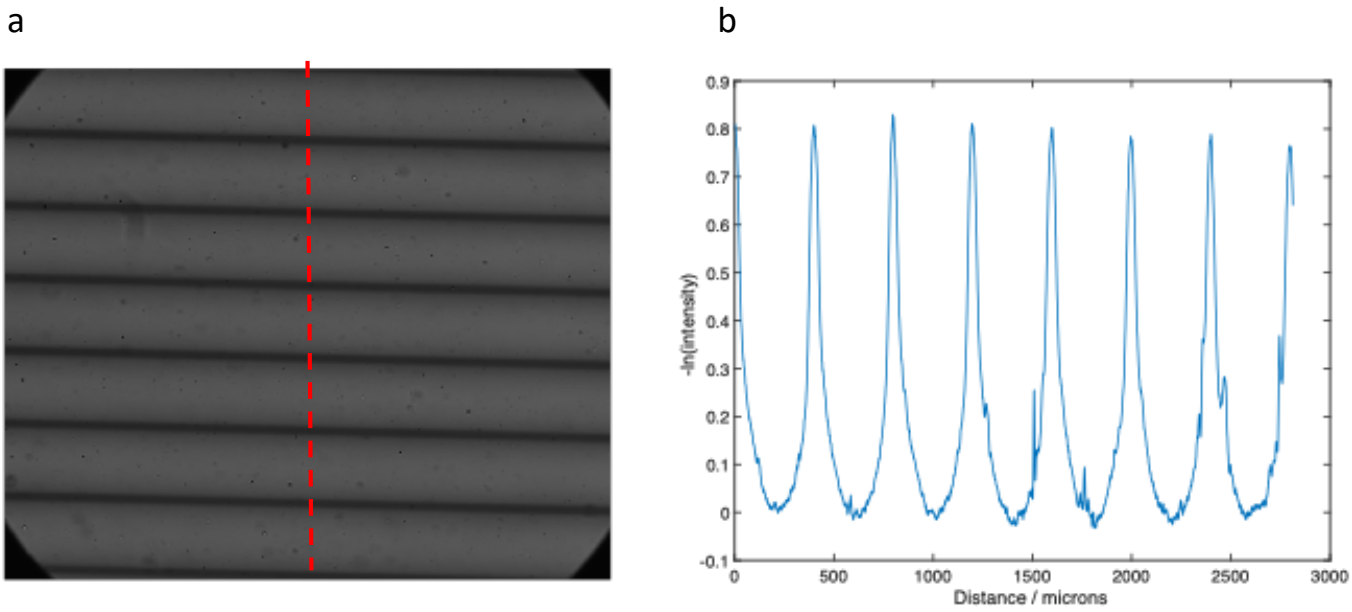


Figure 3: (a) Projection through small region of 22 mm sample. (b) profile along dashed line in (a).

PRELIMINARY CONCLUSION

Irradiation proceeded successfully and we have acquired a number of optical CT datasets. We have demonstrated visualisation of the microbeams, but data analysis is at too early a stage to reach a firm conclusion concerning the main question of the experiment, i.e., whether optical CT is able to make accurate measurements of PVDR.

REFERENCES

[1] E. Bräuer-Krisch, J.-F. Adam, E. Alagoz, S. Bartzsch, J. Crosbie, C. DeWagter, A. Dipuglia, M. Donzelli, S. Doran and P. Fournier 2015 *Physica Medica* **31** 568-583
[2] S. J. Doran, a. T. Abdul Rahman, E. Bräuer-Krisch, T. Brochard, J. Adamovics, A. Nisbet and D. Bradley 2013 *Physics in medicine and biology* **58** 6279-97
[3] S. J. Doran, T. Brochard, J. Adamovics, N. Krstajic and E. Bräuer-Krisch 2010 *Physics in medicine and biology* **55** 1531-1547
[4] C. M. McErlean, E. Bräuer-Krisch, J. Adamovics and S. J. Doran 2015 *Physics in Medicine & Biology* **61** 320
[5] F. Costa, S. Doran, J. Adamovics, S. Nill, I. Hanson and O. Uwe 2018 Characterization of small PRESAGE® samples for measurements near the dosimeter edges