EUROPEAN SYNCHROTRON RADIATION FACILITY

INSTALLATION EUROPEENNE DE RAYONNEMENT SYNCHROTRON

ESRF

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 using the **Electronic Report Submission Application:**

http://193.49.43.2:8080/smis/servlet/UserUtils?start

Reports supporting requests for additional beam time

Reports can now 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:** Experimental measurement of peak-to-valley dose ratios in X-ray micro-beam therapy using 3-D optical computed tomography	**Experiment number**: MD-439
Beamline:	**Date of experiment**: from: 8 November 2009 to: 9 November 2009	**Date of report**: 31 Aug 2010
Shifts:	**Local contact(s)**: Elke Bräuer-Krisch	*Received at ESRF:*

Names and affiliations of applicants (* indicates experimentalists):

Simon J Doran*, University of Surrey and Institute of Cancer Research

David A Bradley*, University of Surrey

A. T. Abdul Rahman, University of Surrey

Report:

This work has given rise to three extended (5-page) conference proceedings, which will be published in the Journal of Physics Conference Series (Institute of Physics Publishing, Bristol, UK). Full publications are currently in preparation. The material was presented at IC3DDose 2010, The 6th International Conference on 3D Dosimetry, Hilton Head Island, SC (23-26 August, 2010). The first two articles were directly related to the subject of MD-439, whilst the third made additional use the calibration cuvette samples that were irradiated during the course of MD-439. Results obtained from the experiment were also included in a review article by Bräuer-Krisch *et al.*

p. 413 of Preliminary IC3DDose 2010 abstract book

Verification of synchrotron microbeam radiation therapy using a purpose-built optical CT microscope

A. T. Abdul Rahman[1], Elke Bräuer-Krisch[2], Thierry Brochard[2], John Adamovics[3], David Bradley[1], Simon Doran[1,4]

[1]Department of Physics, University of Surrey, Guildford, UK
[2]European Synchrotron Radiation Facility, Grenoble, France
[3]Rider University, Lawrenceville, NJ, USA
[4]CRUK and EPSRC Cancer Imaging Centre, Institute of Cancer Research, Sutton, UK
Simon.Doran@icr.ac.uk

Abstract. This study presents an investigation of the use of 3-D dosimetry using optical computed tomography to provide verification of synchrotron microbeam radiation therapy (MRT). MRT is based on the remarkable tolerance of normal tissues to high doses of radiation when this dose is constrained to very narrow beams. At beamline ID17 of the European Synchrotron Radiation Facility, pre-clinical radiation therapy is delivered using an array of parallel microbeams of x-rays generated by a synchrotron-wiggler source. Measurement of the dose distribution around these microbeams requires a dosimeter with high spatial

resolution, and the radiochromic plastic dosimeter PRESAGE™, used in conjunction with optical CT, is highly appropriate for this task. Two solid cylinders of 9.7 mm diameter PRESAGE™ were irradiated to create quality-assurance phantoms for the optical CT microscope using the dose-painting facilities at ID17. Images were analysed to ascertain the scanner linearity over the range 8 – 35 Gy and modulation-transfer function (MTF). With the initial scanner settings, MTF was found to be greater than 30% at 12 line pairs/mm and around 8% at 20.8 line pairs/mm, thus allowing individual lines of width 24 μm to be visualised. A further 9.7 mm PRESAGETM sample was irradiated with a typical array of microbeams of FWHM 50 μm and centre-to-centre distance 400 μm. Results demonstrate how optical CT dosimetry may be capable (after further analysis) of making quantitative measurements of the peak-to-valley ratio of the microbeams. Finally, two samples of diameters 9.7 and 22 mm were irradiated from four directions using a typical MRT "cross-firing" pattern, and then imaged at two different image resolutions. The results show how optical CT dosimetry is able both to visualise the planned dose distribution and identify an incorrect treatment delivery.

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Creation of sophisticated test objects for quality assurance of optical computed tomography scanners

A. T. Abdul Rahman[1], Elke Bräuer-Krisch[2], Thierry Brochard[2], John Adamovics[3], Steve Clowes[1], David Bradley[1], Simon Doran[1,4]

[1]Department of Physics, University of Surrey, Guildford, Surrey, UK
[2]European Synchrotron Radiation Facility, Grenoble, France
[3]Rider University, Lawrenceville, NJ, USA
[4]CRUK and EPSRC Cancer Imaging Centre, Institute of Cancer Research, Sutton, UK
Simon.Doran@icr.ac.uk

Abstract. Optical computed tomography (CT) shows great potential for radiation therapy dose verification in 3D. However, an effective quality assurance regime for the various scanners currently available still remains to be developed. We show how the favourable properties of the PRESAGETM radiochromic polymer may be exploited to create highly sophisticated QA phantoms. Five 60 mm-diameter cylindrical PRESAGETM samples were irradiated using the x-ray microbeam radiation therapy facility on the ID17 biomedical beamline at the European Synchrotron Radiation Facility. Samples were then imaged on the University of Surrey parallel-beam optical CT scanner and were designed to allow a variety of tests to be performed, including linearity, MTF (three independent measurements) and an assessment of geometric distortion. A small sample of these results is presented. It is clear that, although the method produces extremely high quality test objects, it is not practical on a routine basis, because of its reliance of a highly specialised radiation source. Hence, we investigated a second possibility. Two PRESAGETM samples were illuminated with ultraviolet light of wavelength 365 nm, using cheap masks created by laser-printing patterns onto overhead projector acetate sheets. There was good correlation between optical density (OD) measured by the CT scanner and the expected UV "dose" delivered. The results are highly encouraging and a proposal is made for a scanner test regime based on calibrated and well characterised PRESAGETM samples.

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An investigation of the response of the radiochromic dosimeter PRESAGETM to irradiation by 62 MeV protons

Shamsa Al Nowais[1], Andrzej Kacperek[2], John N H Brunt[2], John Adamovics[3], Andrew Nisbet[1,4] and Simon J Doran[1,5]

1 Department of Physics, University of Surrey, Guildford, Surrey, UK
2 Douglas Cyclotron, Clatterbridge Centre for Oncology NHS Trust, Wirral, UK
3 Heuris Pharma, Skillman, NJ, USA
4 Royal Surrey County Hospital, Guildford, Surrey, UK
5 CRUK and EPSRC Cancer Imaging Centre, Institute of Cancer Research, Sutton,
Surrey, UK
Simon.Doran@icr.ac.uk

Abstract. Measurements of the 62 MeV proton beam at the Clatterbridge Centre for Oncology using the radiosensitive plastic PRESAGETM have previously shown a dependence of the dosimeter sensitivity (dose-

response slope) on the linear energy transfer (LET) of the ionizing particles. This work focuses on a possible explanation in terms of track structure theory (TST). Experimental measurements of highly irradiated PRESAGETM samples established the *D*37 parameter of the theory to be of the order of 1000 Gy. Initial attempts at applying the theory showed good agreement of the theoretical and experimental values of relative effectiveness, but more work is needed to verify the model and understand its different parameters.

Potential High Resolution Dosimeters For MRT
AIP Conf. Proc. -- July 23, 2010 -- Volume 1266, pp. 89-97
6TH INTERNATIONAL CONFERENCE ON MEDICAL APPLICATIONS OF SYNCHROTRON RADIATION; doi:10.1063/1.3478205

Microbeam Radiation Therapy (MRT) uses highly collimated, quasi-parallel arrays of X-ray microbeams of 50–600 keV, produced by 2nd and 3rd generation synchrotron sources, such as the National Synchrotron Light Source (NSLS) in the U.S., and the European Synchrotron Radiation Facility (ESRF) in France, respectively. High dose rates are necessary to deliver therapeutic doses in microscopic volumes, to avoid spreading of the microbeams by cardiosynchronous movement of the tissues. A small beam divergence and a filtered white beam spectrum in the energy range between 30 and 250 keV results in the advantage of steep dose gradients with a sharper penumbra than that produced in conventional radiotherapy. MRT research over the past 20 years has allowed a vast number of results from preclinical trials on different animal models, including mice, rats, piglets and rabbits. Microbeams in the range between 10 and 100 micron width show an unprecedented sparing of normal radiosensitive tissues as well as preferential damage to malignant tumor tissues. Typically, MRT uses arrays of narrow (~25–100 micron-wide) microplanar beams separated by wider (100–400 microns centre-to-centre, c-t-c) microplanar spaces. We note that thicker microbeams of 0.1–0.68 mm used by investigators at the NSLS are still called microbeams, although some invesigators in the community prefer to call them minibeams. This report, however, limits it discussion to 25–100 μm microbeams. Peak entrance doses of several hundreds of Gy are surprisingly well tolerated by normal tissues. High resolution dosimetry has been developed over the last two decades, but typical dose ranges are adapted to dose delivery in conventional Radiation Therapy (RT). Spatial resolution in the sub-millimetric range has been achieved, which is currently required for quality assurance measurements in Gamma-knife RT. Most typical commercially available detectors are not suitable for MRT applications at a dose rate of 16000 Gy/s, micron resolution and a dose range over several orders of magnitude. This paper will give an overview of all dosimeters tested in the past at the ESRF with their advantages and drawbacks. These detectors comprise: Ionization chambers, Alanine Dosimeters, MOSFET detectors, Gafchromic® films, Radiochromic polymers, TLDs, Polymer gels, Fluorescent Nuclear Track Detectors (Al2O3:C, Mg single crystal detectors), OSL detectors and Floating Gate-based dosimetry system. The aim of such a comparison shall help with a decision on which of these approaches is most suitable for high resolution dose measurements in MRT. The principle of these detectors will be presented including a comparison for some dosimeters exposed with the same irradiation geometry, namely a 1×1 cm5 field size with microbeam exposures at the surface, 0.1 cm and 1 cm in depth of a PMMA phantom. For these test exposures, the most relevant irradiation parameters for future clinical trials have been chosen: 50 micron FWHM and 400 micron c-t-c distance. The experimental data are compared with Monte Carlo calculations.