Synchrontron

Water equivalent PRESAGE® for synchrotron radiation therapy dosimetry:
Gagliardi, F.M., Day, L., Poole, C.M., Franich, R.D., Geso, M.
(2018) Medical Physics, 45 (3), pp. 1255-1265.

Synchrotron Radiation Therapy techniques are currently being trialed and commissioned at synchrotrons around the world. The patient treatment planning systems (TPS) developed for these treatments use simulated data of the synchrotron x-ray beam to produce the dosimetry in the treatment plan. The purpose of this study was to investigate a water equivalent PRESAGE® dosimeter capable of 3D dosimetry over an energy range suitable for synchrotron x-ray beams. Methods: Water equivalent PRESAGE® dosimeters were fabricated with a radiological effective atomic number similar to water over an energy range of 10 keV to 10 MeV. The dosimeters were irradiated at various energies, scanned using optical CT (OCT) scanning and compared to ion chamber measurements. Percentage depth dose and beam profiles of the synchrotron beam were compared to Monte Carlo (MC) model simulations. Results: The PDD profiles of the water equivalent PRESAGE® agreed with ion chamber measurements and MC calculations within 2% for all keV energies investigated. The PRESAGE® also showed good agreement to the MC model for depths below 5 mm of the synchrotron beam where ion chamber data do not exist. The spatial resolution of the OCT was not sufficient to accurately measure the penumbra of the synchrotron beams compared to MC calculations or EBT3 film; however, the water equivalent PRESAGE® was able to verify dose profile characteristics of the MC model. Conclusions: The radiological response of a water equivalent PRESAGE® dosimeter has been validated for synchrotron x-ray beam energies along with the ability to independently verify dose distributions of a MC model.

Assessment of optical CT as a future QA tool for synchrotron x-ray microbeam therapy
McErlean, C.M., Bräuer-Krisch, E., Adamovics, J., Doran, S.J.
(2015) Physics in Medicine and Biology, 61 (1), pp. 320-337

Synchrotron microbeam radiation therapy (MRT) is an advanced form of radiotherapy for which it is extremely difficult to provide adequate quality assurance. This may delay or limit its clinical uptake, particularly in the paediatric patient populations for whom it could be especially suitable. This study investigates the extent to which new developments in 3D dosimetry using optical computed tomography (CT) can visualise MRT dose distributions, and assesses what further developments are necessary before fully quantitative 3D measurements can be achieved. Two

experiments are reported. In the first cylindrical samples of the radiochromic polymer PRESAGE® were irradiated with different complex MRT geometries including multiport treatments of collimated 'pencil' beams, interlaced microplanar arrays and a multiport treatment using an anthropomorphic head phantom. Samples were scanned using transmission optical CT. In the second experiment, optical CT measurements of the biologically important peak-to-valley dose ratio (PVDR) were compared with expected values from Monte Carlo simulations. The depth-of-field (DOF) of the optical CT system was characterised using a knife-edge method and the possibility of spatial resolution improvement through deconvolution of a measured point spread function (PSF) was investigated. 3D datasets from the first experiment revealed excellent visualisation of the 50 µm beams and various discrepancies from the planned delivery dose were found. The optical CT PVDR measurements were found to be consistently 30% of the expected Monte Carlo values and deconvolution of the microbeam profiles was found to lead to increased noise. The reason for the underestimation of the PVDR by optical CT was attributed to lack of spatial resolution, supported by the results of the DOF characterisation. Solutions are suggested for the outstanding challenges and the data are shown already to be useful in identifying potential treatment anomalies.

High resolution 3D imaging of synchrotron generated microbeams

Gagliardi, F.M., Cornelius, I., Blencowe, A., Franich, R.D., Geso, M.
(2015) Medical Physics, 42 (12), pp. 6973-6986

Purpose: Microbeam radiation therapy (MRT) techniques are under investigation at synchrotrons worldwide. Favourable outcomes from animal and cell culture studies have proven the efficacy of MRT. The aim of MRT researchers currently is to progress to human clinical trials in the near future. The purpose of this study was to demonstrate the high resolution and 3D imaging of synchrotron generated microbeams in PRESAGER dosimeters using laser fluorescence confocal microscopy. Methods:Water equivalent PRESAGER dosimeters were fabricated and irradiated with microbeams on the Imaging and Medical Beamline at the Australian Synchrotron. Microbeam arrays comprised of microbeams 25-50 µm wide with 200 or 400 µm peak-to-peak spacing were delivered as single, cross-fire, multidirectional, and interspersed arrays. Imaging of the dosimeters was performed using a NIKON A1 laser fluorescence confocal microscope. Results: The spatial fractionation of the MRT beams was clearly visible in 2D and up to 9 mm in depth. Individual microbeams were easily resolved with the full width at half maximum of microbeams measured on images with resolutions of as low as 0.09 µm/pixel. Profiles obtained demonstrated the change of the peak-to-valley dose ratio for interspersed MRT microbeam arrays and subtle variations in the sample positioning by the sample stage goniometer were measured. Conclusions: Laser fluorescence confocal microscopy of MRT irradiated PRESAGER dosimeters has been validated in this study as a high resolution imaging tool for the independent spatial and geometrical verification of MRT beam delivery.

Ultra-high resolution optical CT dosimetry for the visualisation of synchrotron microbeam therapy doses
SJ Doran, AT Abdul Rahman, E Bräuer-Krisch, T Brochard ,J Adamovics
2013 *J. Phys.: Conf. Ser.* 444 012074

Optical CT is a method that can potentially provide both accurate dosimetry at high spatial resolution and 3-D visualization over a large field-of-view in a single dataset. The major factors limiting spatial resolution in previous studies are analysed here and it is shown that improvements in equipment specification can overcome many of these. The need for ultra-high spatial resolution in the verification of microbeam radiation therapy verification is demonstrated and example images of a PRESAGE® sample are presented.

Evaluating the peak-to-valley dose ratio of Synchrontron Microbeams using PRESAGE fluorescence
N Annabell, N Yagi, K Umetani, C Wong and M Geso
J. of Synchrotron Radiation 19(3) 332-339 (2012)
Synchrotron-generated microbeam radiotherapy holds great promise for future treatment, but the high dose gradients present conventional dosimetry with a challenge. Measuring the important peak-to-valley dose ratio (PVDR) of a microbeam-collimated synchrotron source requires both a dosimeter and an analysis method capable of exceptional spatial resolution. The PVDR is of great interest since it is the limiting factor for potential application of the microbeam radiation therapy technique clinically for its tissue-sparing properties (i.e. the valley dose should be below the tolerance of normal tissue). In this work a new method of measuring the dose response of PRESAGE dosimeters is introduced using the fluorescence from a 638 nm laser on a confocal laser-scanning microscope. This fluorescent microscopy method produces dosimetry data at a pixel size as low as 78 nm, giving a much better spatial resolution than optical computed tomography, which is normally used for scanning PRESAGE dosimeters. Using this technique the PVDR of the BL28B2 microbeam at the SPring-8 synchrotron in Japan is estimated to be approximately 52:1 at a depth of 2.5 mm. The PVDR was also estimated with EBT2 GAFchromic films as 30.5:1 at the surface in order to compare the PRESAGE fluorescent results with a more established dosimetry system. This estimation is in good agreement with previously measured ratios using other dosimeters and Monte Carlo simulations. This means that it is possible to use PRESAGE dosimeters with confocal microscopy for the determination of PVDR.

An investigation of the potential of optical computed tomography for imaging of synchrotron-generated x-rays at high spatial resolution

By Doran Simon J; Brochard Thierry; Adamovics John; Krstajic Nikola; Brauer-Krisch Elke
From **Physics in medicine and biology** (2010), 55(5), 1531-47.
X-ray microbeam radiation therapy (MRT) is a novel form of treatment, currently in its preclinical stage, which uses microplanar x-ray beams from a synchrotron radiation source. It is important to perform accurate dosimetry on these microbeams, but, to date, there has been no accurate enough method available for making 3D dose measurements with isotropic, high spatial resolution to verify the results of Monte Carlo dose simulations. Here, we investigate the potential of optical computed tomography for satisfying these requirements.

Sophisticated test objects for the quality assurance of optical computed tomography scanners
A T Abdul Rahman, Elke Brauer-Krisch, Thierry Brochard, John Adamovics, S K Clowes, David Bradley and Simon J Doran,
Phys. Med. Biol. 56 (2011) 4177–4199
Five 60 mm diameter cylindrical PRESAGE samples were irradiated using the x-ray microbeam radiation therapy facility on the ID-17 biomedical beamline at the European Synchrotron Radiation Facility. Samples were then imaged on the University of Surrey parallel-beam optical CT scanner.

Creation of sophisticated test objects for quality assurance of optical computed tomography scanners
By Abdul Rahman, A. T.; Brauer-Krisch, Elke; Brochard, Thierry; Adamovics, John; Clowes, Steve; Bradley, David; Doran, Simon
From **Journal of Physics: Conference Series** (2010), 250
Optical computed tomog. (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 favorable properties of the PRESAGE radiochromic polymer may be exploited to create highly sophisticated QA phantoms. Five 60 mm-diam. cylindrical PRESAGE 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.