PhD Thesis title: 'Digital Holographic Interferometry for Radiation Dosimetry'

Author: Alicia Cavan
Email: alicia.cavan@cdhb.health.nz
Institution: University of Canterbury
Supervisors: Associate Professor Juergen Meyer and Associate Professor Jon-Paul Wells
Graduation Date: 24 June 2015
Available on line: http://hdl.handle.net/10092/10465

ABSTRACT:

A novel optical calorimetry approach is proposed for the dosimetry of therapeutic radiation, based on the optical technique of Digital Holographic Interferometry (DHI). This detector determines the radiation absorbed dose to water by measurement of the refractive index variations arising from radiation induced temperature increases. The output consists of a time series of high resolution, two dimensional images of the spatial distribution of the projected dose map across the water sample. This absorbed dose to water is measured directly, independently of radiation type, dose rate and energy, and without perturbation of the beam. These are key features which make DHI a promising technique for radiation dosimetry.

A prototype DHI detector was developed, with the aim of providing proof-of-principle of the approach. The detector consists of an optical laser interferometer based on a lensless Fourier transform digital holography (LFTDH) system, and the associated mathematical reconstruction of the absorbed dose. The conceptual basis was introduced, and a full framework was established for the measurement and analysis of the results. Methods were developed for mathematical correction of the distortions introduced by heat diffusion within the system. Pilot studies of the dosimetry of a high dose rate Ir-192 brachytherapy source and a small field proton beam were conducted in order to investigate the dosimetric potential of the technique. Results were validated against independent models of the expected radiation dose distributions.

Initial measurements of absorbed dose demonstrated the ability of the DHI detector to resolve the minuscule temperature changes produced by radiation in water to within experimental uncertainty. Spatial resolution of approximately 0.03 mm/pixel was achieved, and the dose distribution around the brachytherapy source was accurately measured for short irradiation times, to within the experimental uncertainty. The experimental noise for the prototype detector was relatively large and combined with the occurrence of heat diffusion, means that the method is predominantly suitable for high dose rate applications.

The initial proof-of-principle results confirm that DHI dosimetry is a promising technique, with a range of potential benefits. Further development of the technique is warranted, to improve on the limitations of the current prototype. A comprehensive analysis of the system was conducted to determine key requirements for future development of the DHI detector to be a useful contribution to the dosimetric toolbox of a range of current and emerging applications. The sources of measurement uncertainty are considered, and methods suggested to mitigate these. Improvement of the signal-to-noise ratio, and further development of the heat transport corrections for high dose gradient regions are key areas of focus highlighted for future development.

References to author publications that relate specifically to the dissertation:

A. Cavan and J. Meyer, “Digital holographic interferometry: a novel optical calorimetry technique for radiation dosimetry,” Med. Phys. 41(1): 022102, 2014