

Interferometer-Based Calorimetric Measurements of Absorbed Dose to Water in External Beam Radiotherapy

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Calorimetry is often used to establish high-energy photon absorbed dose to water (ADW) standards as calorimeters directly measure the energy imparted to the water by the radiation. Current calorimeters use thermistors to establish national standards but there is the possibility of systematic errors because thermistors overheat due to their low heat capacity. For this reason, there has been increasing interest on alternative temperature measurement techniques, especially those that does not require a mechanical probe. Interferometer-based thermometry is a technique that exploits the temperature dependence of the refractive index of water and provides an alternative method for temperature measurement in radiation calorimetry. An appealing advantage of the use of interferometry for radiation calorimetry is the capability of obtaining 2D or 3D temperature/dose distributions. The use of interferometer-based ADW measurements has been limited by the low resolution of the measurements and optimized setups with higher accuracy and precision are necessary to enable measurements at clinically relevant dose rates.

A calorimeter for thermistor-based ADW measurements was developed to provide a reference for comparison and measure thermal drifts and noise in a water phantom. Additionally, the instrument was used to measure ADW from a 6MV photon beam from a medical linear accelerator.

A Michelson-type interferometer was built, characterized, and used to measure ADW within the dose range of interest for external beam radiotherapy. Residual thermal drifts were accounted for by using a three-steps measurement protocol. Interferometer and phantom temperature fluctuations were minimized by means of passive thermal control, leading to increased fringe pattern stability. The interferometer characterization included phase shift measurements to determine the accuracy and precision of the interferometer within the environmental conditions of a room housing a linear accelerator. The interferometer was used to measure ADW in a water-filled glass phantom, irradiated with a 6MV photon beam. The estimated type-A, $k=1$ uncertainty in the associated doses was 0.3Gy, which is an order of magnitude lower than previously published interferometer-based ADW measurements.

This work presented the first absolute ADW measurements using interferometry in the dose range of linac-based radiotherapy and represents a significant step towards standards-level measurements using this technique.