Use of Simulation in the Development of Next-generation Measurement Standards for Radiation Dosimetry

Ronald E. Tosh and Heather Chen-Mayer
NIST, Gaithersburg, MD 20899

Introduction: Calibration of field instruments used in radiation treatment clinics is currently traceable to NIST primary standards via protocols involving static, flat-field radiation beams. By contrast, radiation beams prescribed for treating cancer incorporate temporal and spatial modulation strategies in order to maximize dose to the tumor while sparing healthy tissue. Such beams often produce significant dose gradients over the active volume of clinical radiation detectors, thereby introducing systematic errors into the resulting dose measurements. Various strategies have evolved to address this problem, one of which is to design newer primary standards that can calibrate accurately in so-called non-standard beams.

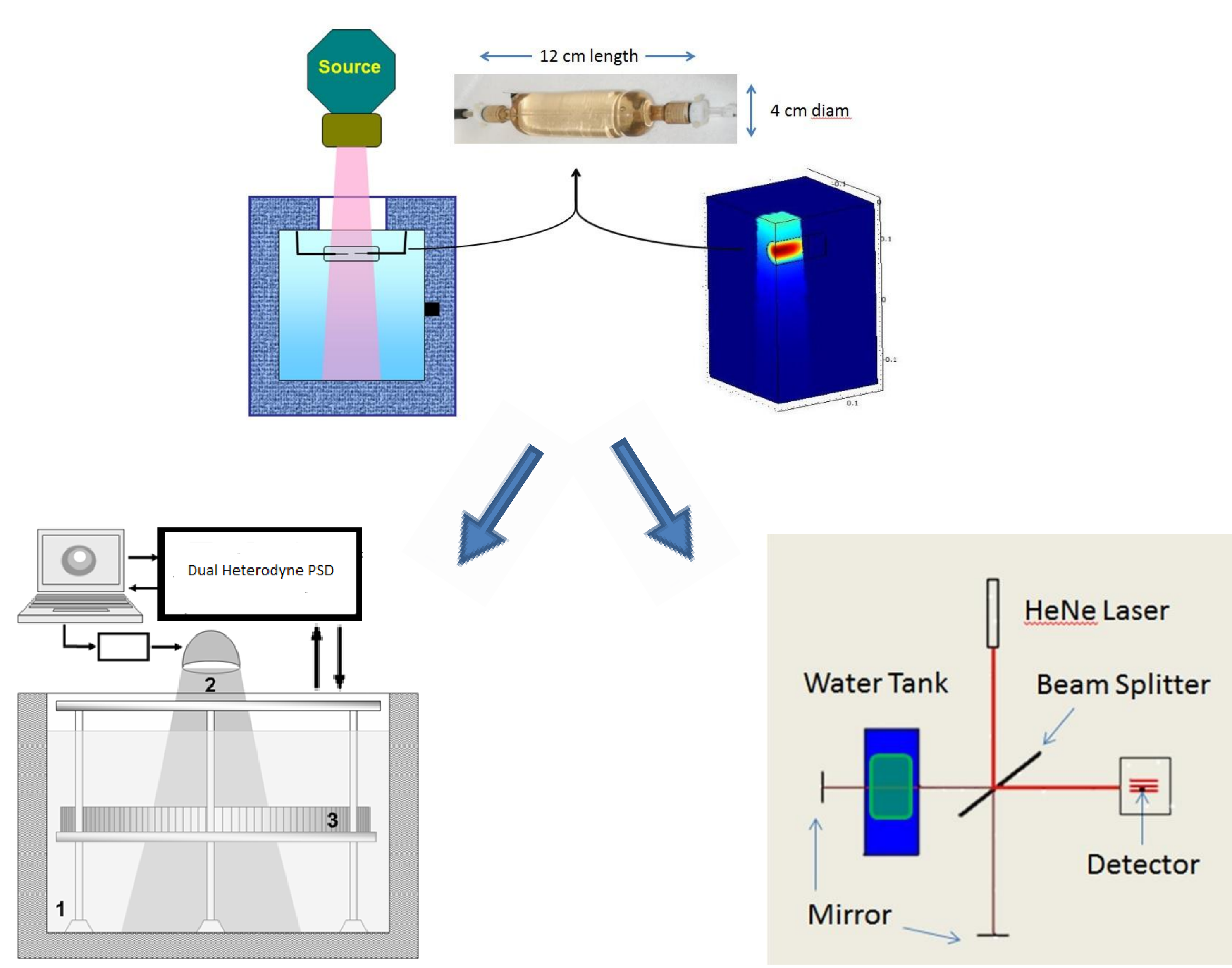

Figure 1. Present-day calorimetric system for radiation dosimetry (above) compared with newer, remote-sensing calorimetric prototypes based on ultrasonic time-of-flight (left) and optical interferometry (right).

Computational Methods: Calorimetry standards described above measure dose to water, and must correct for spurious effects due to heat transfer in the water, an example of which is shown in the upper part of Figure 1 (where large thermal gradients, evident near the temperature sensor, have been studied using COMSOL). More recently, COMSOL Heat Transfer Module, via conjugate heat transfer physics, has been used to design Joule heating sources for testing of new calorimeter concepts based on ultrasonic time-of-flight (Fig. 2) and optical interferometry and to model spurious heating of water by probe radiations (Fig. 3).

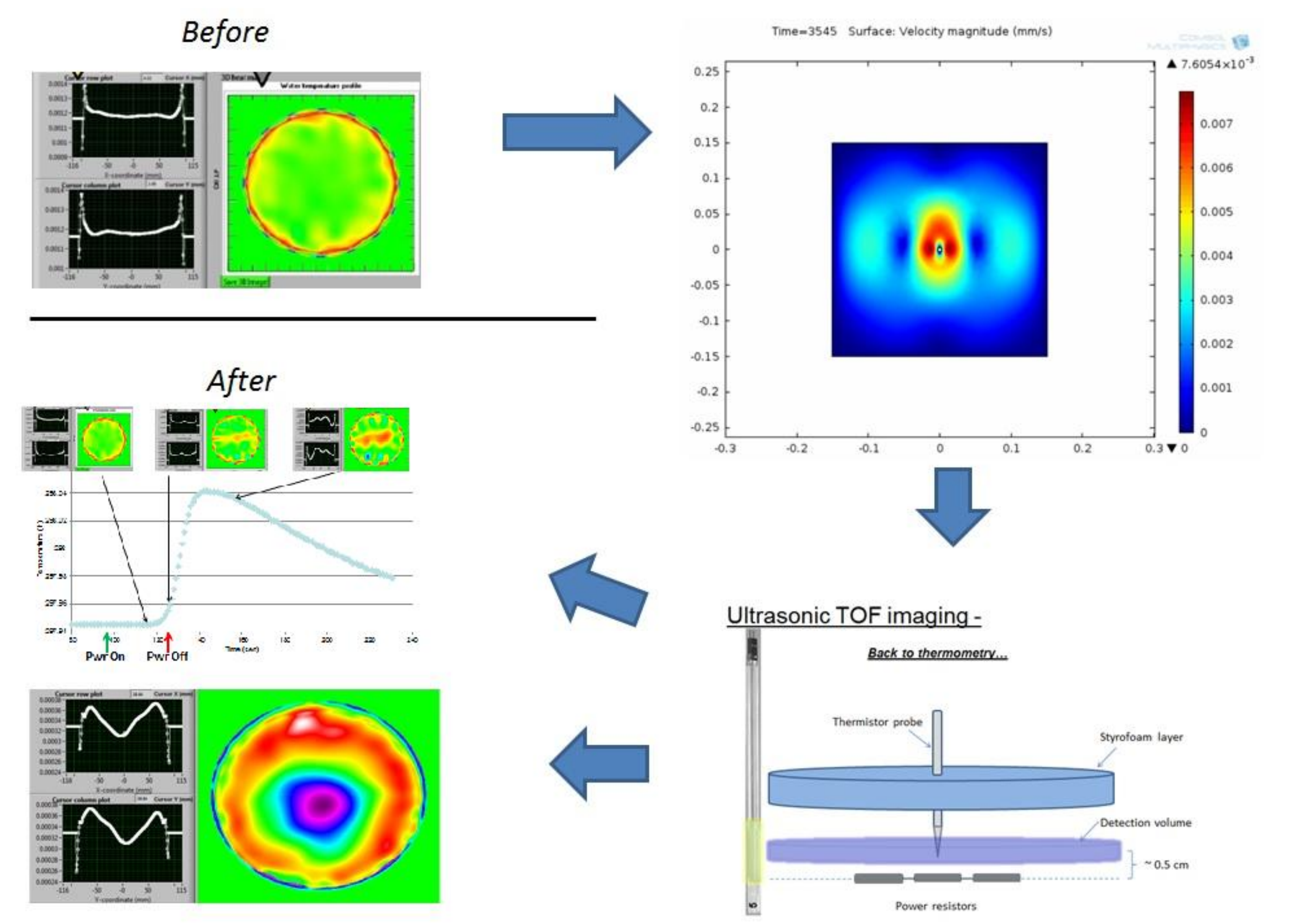

Figure 2. Failed initial tests with an ultrasonic array in a radiation beam (upper left) eventually resulted in success (lower left) after COMSOL was used to design a suitable Joule heating source for testing (intermediate steps) in which convection would be negligible.

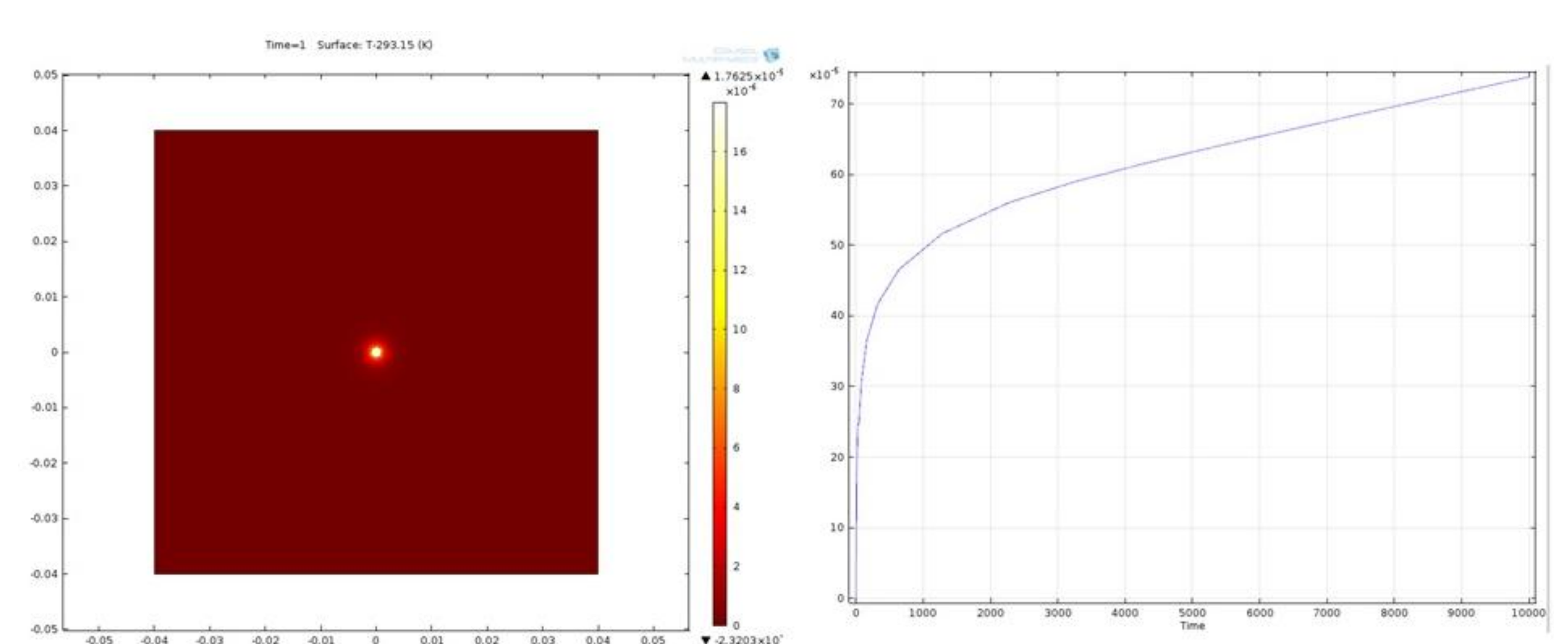

Figure 3. Quick study of spurious heating of water by laser radiation in an interferometric setup for doing high precision thermometry of water heated by radiotherapy beams.

Conclusions: Subtle thermal effects arise when using non-ionizing radiation as a probe of heat in water due to therapy-level ionizing radiation. Challenges to design and verification of new primary-standard concepts for realizing absorbed dose to water from non-standard beams in open phantoms, based on such remote-sensing techniques, are being met by use of simulations involving conjugate heat transfer tools available in the COMSOL Heat Transfer Module.

Excerpt from the Proceedings of the 2013 COMSOL Conference in Boston