Experimental Measurement of Thermal Heating of Millimeter Sized Spheres using IR Imaging Subjected to Synchrotron X-Ray Beam with Comparison to Theoretical Predictions

M. Kazmierczak, R. Kumar, P. Gopalakrishnan and R. Banerjee

Department of Mechanical, Industrial and Nuclear Engineering, University of Cincinnati, Cincinnati, OH 45221-0072

The temperature rise of 1mm and 2mm glass spheres (sample) exposed to an intense X-ray beam (undulator ID sector 19 X-ray beam of the APS) is measured at high spatial resolution using an Indigo Systems Phoenix thermal imaging camera with a 4x magnification lens (method described in Snell et al., J. Synchrotron Rad., 14, 109-115 (2007)). The sample is cooled in a stream of nitrogen gas (i.e. cryostream) to prevent overheating and minimize thermal damage to the sample. The heat transfer, including external forced convection and internal heat conduction, was also theoretically modeled using CFD to predict the temperature variation throughout and on the sphere. The local surface temperature distribution from the experimental measurements and the numerical predictions are compared side-by-side and show good agreement, both qualitatively and quantitatively, for both sphere sizes and at the two different flow velocities tested using the adjusted beam flux. Over the last decade, sample cooling using cryostream N₂ gas cooling has been routinely used in the field of crystallography for macromolecular structural determination of biocrystals, but heretofore, actual local temperature measurements on small x-ray interrogated samples were unavailable.