Calibration of X-ray Imaging Devices for Accurate Intensity Measurement

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Historically, X-ray imaging has been used to determine geometric and qualitative intensity information, such as tooth damage or star luminosity. For many endeavors, including astronomy, non-destructive testing, medicine, and plasma physics, the ability to measure accurately the X-ray intensity in a specific energy interval has become more important. But the metrology for these measurements, namely the traceability to an internationally accepted standard, is not well developed. Over the past five years, National Security Technologies, LLC (NSTec) has built up several laboratories and developed X-ray sources to cover measurements in the energy range from 50 eV to 115 keV. These sources are primarily devoted to calibrating diagnostics and their components that are used for various plasma studies, mainly for the Lawrence Livermore National Laboratory (LLNL) and particularly the National Ignition Facility (NIF).

NSTec's X-ray sources are diode type and diode/fluorescer combinations. The detector types utilize energy dispersive measurement and total flux measurement. Calibrating the detectors is the key to the accurate calibration of our X-ray sources, and therefore calibrating the imaging devices using the sources. We have developed calibration techniques for the detectors using radioactive sources that are traceable to the National Institute of Standards and Technology (NIST). The German synchrotron at Physikalische Technische Bundestalt (PTB) is used to calibrate silicon photodiodes over the energy range from 50 eV to 60 keV. We are working with NIST through their National Voluntary Laboratory Accreditation Program (NVLAP) in order to achieve accreditation for the NSTec calibration facility.

The quantum efficiency averaged over all pixels, the camera counts per photon per pixel, and response variation across the sensor have been measured for several types of imaging devices. The instrumentation required to accomplish the calibrations is described. X-ray energies ranged from 720 eV to 22.5 keV. The X-ray sources produce narrow energy bands, allowing us to determine the properties as a function of X-ray energy. Some cameras were also operated in the single photon mode during calibration (sufficiently low intensity so that the photons do not overlap on the sensor) and the measurement of counts per photon is compared to the average counts per photon. There were several types of CCD (charge coupled device) sensors, a CID (charge induced device) type camera, and an X-ray microscope imager using a scintillator/CCD combination. Most devices were cooled but one operated at room temperature. These two camera types differ significantly in some of their properties that affect the accuracy of X-ray intensity measurements. All cameras discussed here are silicon based. The measurements of quantum efficiency variation with X-ray energy are compared to models for the sensor structure. Cameras that are not back-thinned are compared to those that are.

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