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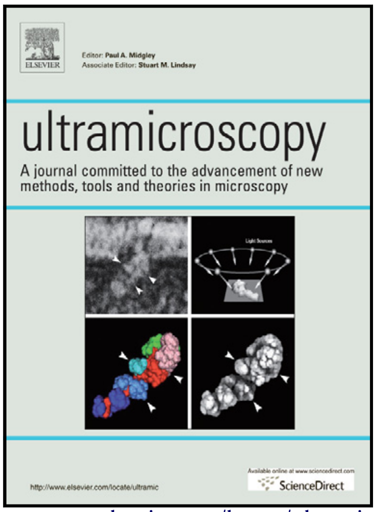

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Characterization of an indirect X-ray imaging detector by simulation and experiment

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Abstract

We describe a comprehensive model of a commercial indirect X-ray imaging detector that accurately predicts the detector point spread function and its dependence on X-ray energy. The model was validated by measurements using monochromatic synchrotron radiation and extended to polychromatic X-ray sources. Our approach can be used to predict the performance of an imaging detector and can be used to optimize imaging experiments with broad-band X-ray sources.

Keywords: Indirect imaging X-ray detector, point spread function, experiment validation, polychromatic source

1. Introduction

A common indirect X-ray detection imaging system employs a scintillator to convert an X-ray distribution to visible light distribution that is imaged by a lens system and digital camera. Such systems are useful over a broad X-ray energy range and their application in industrial and scientific imaging is widespread [1, 2]. The scintillator and its coupling to the objective lens strongly influence X-ray detection efficiency and imaging performance, which is characterized by quality parameters such as contrast, spatial resolution, and noise [3, 4].

Our work is directed towards optimizing the spatial resolution of detection systems used for tomographic imaging with laboratory X-ray sources. These sources have the advantage of widespread availability, low cost and relatively high X-ray energy. On the other hand, they are generally not bright enough to be used for imaging applications with a monochromator. Therefore, it is necessary to consider how the spatial resolution of the detection system depends on the X-ray energy across the source spectrum.

The spatial resolution dependence on composition, microstructure and shape of scintillators has been extensively studied by experiment [5] and simulation [6]. However, to our knowledge, modeling of the combined effect of the scintillator and the objective lens coupled to it as part of the full imaging system has not been reported. In this work we have studied a commercial indirect imaging detector supplied by Xradia, USA, as part of a micro X-ray computed tomography apparatus. We model the point spread function (PSF) of the detector in terms of X-ray photon energy dependent scintillator processes and the coupling of the scintillator to the

visible light detector. The results from an experimental study of these effects using a monochromatic X-ray source in the energy range 7 keV to 21 keV were used to validate the model. We also show that the validated model can be extended to accurately estimate the PSF of the detector when using a polychromatic laboratory X-ray source. The results obtained will allow modeling and thereby optimization of the detector system for particular experimental configurations and imaging applications.

2. Simulation

We consider an incident X-ray pencil beam normally incident on a CsI(Tl) scintillator separated from an objective lens by air. For an indirect imaging system the relevant physical processes can be described in terms of the interaction of X-rays that result in emission of optical photons, absorption and scattering of emitted optical photons within the scintillator and their interaction at the scintillator boundary, and, finally, imaging and detection of the optical photons by a lens-coupled charge-coupled device camera (CCD). The