Application of the Multiple Image Radiography Method to Breast Imaging

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Abstract. The Multiple Image Radiography (MIR) method is new imaging modality that extends the capability of conventional absorption based radiography by adding the additional contrast mechanisms of x-ray refraction and ultra-small angle scatter. In order to design a clinically based MIR system, the MIR specific x-ray properties in breast tissue must be analyzed to determine which are diagnostically useful. Developing MIR as an imaging modality also requires developing new phantoms that incorporate x-ray refraction and ultra-small angle scatter in addition to traditional x-ray absorption. Three breast cancer specimens were imaged using MIR to demonstrate its MIR specific x-ray properties. An uncompressed anthropomorphic breast phantom with an imbedded low absorption contrast acrylic sphere was imaged to provide a physical model of how the unique properties of MIR can be utilized to improve upon conventional mammography and illustrate how these can be used to design a clinically useful imaging system.

1 Introduction

The Multiple Image Radiography (MIR) method is a new imaging modality able to generate images based on an object's x-ray absorption, refraction, and ultra-small angle scatter [1, 2]. MIR is an improvement of a previously described method called Diffraction Enhanced Imaging (DEI) [3-11]. DEI utilizes the Bragg peak of perfect crystal diffraction to convert angular changes into intensity changes, providing a large change in intensity for a small change in angle. The use of DEI for breast imaging

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was first described by Pisano et al [12], and has been shown in multiple subsequent studies to generate improved contrast when compared to conventional radiography[13-15]. Previous studies investigating DEI specific contrast mechanisms in breast tissue have demonstrated considerable gains in contrast, up to 33 fold when compared to a conventional radiograph [16, 17]. MIR improves upon DEI by providing an ultra-small angle scatter image, produces more accurate absorption and refraction images, and has been shown to have good noise performance from photon limited data [2]. All DEI and MIR experiments to date have been performed using a synchrotron, which provides high flux x-rays over a wide energy range. The requirement of a monochromatic, collimated x-ray beam incident on the sample or object makes the design of a non-synchrotron based DEI or MIR system an engineering challenge. Initial studies using MIR with photon-limited data indicates that this method would be useful when using non-synchrotron x-ray sources.

2 Multiple Image Radiography

A detailed mathematical description of the MIR method has been presented previously by Wernick et al [1, 2]. MIR uses the reflectivity curve of a silicon analyzer crystal, presented in Figure 1, to generate parametric images representing the x-ray absorption, refraction, and ultra-small angle scatter of an object. For example, if the intrinsic rocking curve of a background region is used as a reference, then changes that decrease the area under the curve can be interpreted as x-ray absorption since photon absorption will decrease the maximum intensity. For a purely refractive event, the centroid of the rocking curve will be shifted, but the width and height of the rocking curve will remain constant. Interactions that lead to ultra-small angle scattering will scatter photons across the angular distribution of the rocking curve, causing the rocking curve to widen. Assuming that photons are not scattered outside the acceptance window of the rocking curve, scattering events will not affect the area under the curve. MIR analyzes these events and calculates the contributions of each on a pixel by pixel basis, producing three separate images from the same data set.

3 Experimental DEI Setup at the National Synchrotron Light Source

Experiments were carried out using the X15A beamline at the National Synchrotron Light Source (NSLS), Brookhaven National Laboratory, Upton, New York. A complete description of the DEI system at the NSLS has been previously described by Zhong et al [18]. In order to understand the parameters being analyzed, a brief description of the system is in order. The bending magnet source at the X15A beamline produces high flux x-rays from 10 to 60 keV. A double crystal silicon monochromator is used to select a particular energy from the incident x-ray beam. MIR images are obtained by placing a silicon analyzer crystal behind the object which is tuned to select a particular angle. The analyzer can be thought of as an angular notch filter with a resolution on the order of tenths of microradians, which facilitates the measurement of x-ray refraction and ultra-small angle scatter. Individual images