X-ray Grating-based Imaging — Waves Work Wonderfully

Current x-ray imaging is of critical for clinical and pre-clinical applications but it is fundamentally restricted by the attenuation mechanism. X-ray grating-based imaging represents outstanding opportunities and major challenges, especially for tomography utilizing the wave nature of x-rays for superior tissue contrast at minimal radiation dose. Our general hypothesis is that 2D grating-based imaging can be developed to produce better projective/ and tomographic images of biomedical interest than 1D grating-based techniques. The overall goal is to develop the first of its kind 2D-grating-based imaging system for mouse and breast imaging.

and G2 gratings, gold electroplating, followed by coating in epoxy and bonding to a frame for mechanical stability [23].

2.2. Theory of 2D Talbot interferometry

In this section, we present the mathematical theory for the setup in the previous section.

2.2.1. Talbot effect under plane wave illumination

Talbot effect of 2D grating was first analyzed in [24]. The treatment was refined further in the following years. We consider the case of a 2D grating G1 illuminated coherently by a unit-amplitude plane-wave X-rays $\exp(ikz)$ of wavelength λ where $k = 2\pi/\lambda$ is the wave number, though the case of Gaussian beams can also be investigated [25]. The optical axis is parallel to the z-axis. The 2D grating G1 on the xy-plane at $z = 0$ is of periods p_x and p_y in the x- and y-directions, respectively. The complex transmittance function of G1 is given by the following Fourier series:

$$T_1(x,y) = \sum_{m,n} a_{m,n} \exp\left(\frac{i2\pi mx}{p_x}\right)\exp\left(\frac{i2\pi ny}{p_y}\right). \quad (2)$$

We assume that gratings are infinitely extended in this preliminary study. Under a paraxial approximation, the wave field at a distance z behind the grating G1 is, by the Fresnel-Kirchhoff diffraction formula [25–27],

$$E(x,y,z) = \exp(ikz)\sum_{m,n}\beta_{m,n}(z)\exp\left(\frac{i2\pi mx}{p_x} + \frac{i2\pi ny}{p_y}\right), \quad (3)$$

where

$$\beta_{m,n}(z) = a_{m,n}\exp\left(-\frac{i\pi\lambda m^2 z}{p_x^2} - \frac{i\pi\lambda n^2 z}{p_y^2}\right). \quad (4)$$

The intensity of the wave field is given by

$$I(x,y,z) = |E(x,y,z)|^2 = \sum_{m,n}\rho_{m,n}(z)\exp\left(\frac{i2\pi mx}{p_x} + \frac{i2\pi ny}{p_y}\right), \quad (5)$$

where

$$\rho_{m,n}(z) = \sum_{m',n'}\beta_{m+m',n+n'}(z)\overline{\beta_{m',n'}(z)} \quad (6)$$

Let the periods p_x and p_y be of a rational ratio in the following sense:

$$p_x = Mp, \qquad p_y = Np, \quad (7)$$

for some positive numbers M, N, and p, where M and N are integers. Let

$$Z_T = \frac{2M^2N^2p^2}{\lambda}. \quad (8)$$

Paper by Our Team

Jiang M, Wyatt CL, Wang G: X-ray phase-contrast imaging with three 2D gratings. To appear in International Journal of Biomedical Imaging, 2007 (First paper on 2D grating-based x-ray imaging theory)