Transactions of the Korean Nuclear Society Spring Meeting
Jeju, Korea, May 7-8, 2015

Talbot Carpet Simulation for X-ray grating interferometer

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1. Introduction

X-ray imaging has been developed in medical and industrial field such as diagnostics and NDT respectively. In this progress, X-ray grating interferometer is one of techniques make contrast higher of materials with low atomic number than conventional radiography.

Grating interferometer produces interference of X-ray called Talbot pattern with gratings manufactured in micro scale. Talbot pattern is self-images of phase grating which develops interference as beam splitter that is one of gratings consisted of interferometer. As the other gratings, there are source grating makes coherence and analyze grating is used to analyze interference onto detector.

Talbot carpet has been studied as the beam behavior which is distinguished with common X-ray imaging systems. It is helpful to understand grating interferometer and possible to expect beams' oscillation for designing theoretically.

In this study, Talbot carpet simulator has been developed to visualize the X-ray grating interference patterns in grating interferometer. We have simulated X-ray interference for a variety of simulations and demonstrated a few examples in this summary.

2. Basic simulation formula

2.1 Theory

X-ray performance of grating interferometer is presented wave function. X-ray produced from point source passes source grating and phase grating in the interferometer sequentially. Assuming the grating to be infinitely wide, and using the Fresnel-Kirchhoff diffraction integral in the paraxial approximation, the wave in front of the second grating is given by

$$\Psi_2\,(x_0, x_1, L_0) = \int t_1(x_1) e^{ik\sqrt{{L_0}^2+(x_1-x_0)^2}} e^{ik\sqrt{{L_1}^2+(x_2-x_1)^2}} dx_1$$

The intensity of wave field $I(x0,\, x1,\, L0)$ is

$$I(x_0, x_1, L_0) = \left|\Psi_2\,(x_0, x_1, L_0)\right|^2$$

2.2 Phase Object

The phase object is situated in front of phase grating to produce phase contrast and dark field image. Talbot pattern is deformed according to phase object compared with pattern in free domain. Phase shirt from object is written by

$$\Phi\left(x - \frac{n\lambda z}{d}, y\right) \approx \Phi(x, y) - \frac{n\lambda z}{d}\frac{\partial\Phi(x, y)}{\partial x}$$

3. Simulation results

3.1 Talbot Carpet

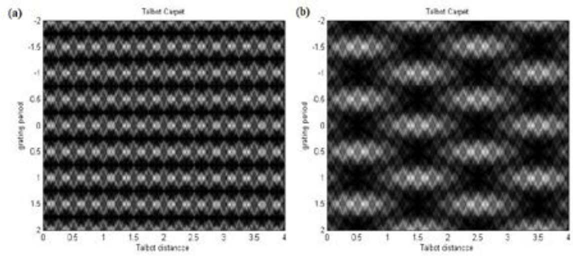
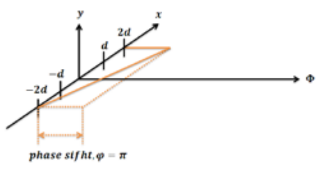
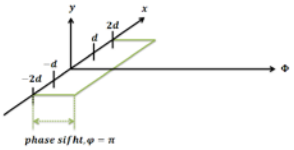
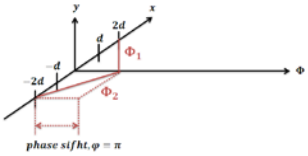
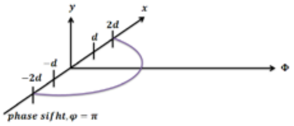


Fig 1. Talbot carpet, (a) pi phase shift simulation, (b) pi/2 phase shift simulation

3.2 Deformed Talbot Carpet by Phase Object

Table 1. Phase object conditions for Talbot carpet simulation

Type	Figure	Phase shift
Line		$\frac{\varphi}{4d}x + \frac{\varphi}{2}$

Rectangle		φ
Triangle		$-\frac{\varphi}{2d}x+\varphi$ $\frac{\varphi}{2d}x+\varphi$
Semicircle		$-\frac{\varphi^2 x}{4d^2\sqrt{\varphi^2-\varphi^2\cdot\frac{x^2}{4d^2}}}$

4. Conclusion

Talbot carpet is simulated well based on wave function in various conditions with basic parameters of grating interferometer and phase objects. We confirm pattern has periodicity produced by interference after pi and pi/2 phase grating and changes in the perpendicular direction to entrance face according to phase objects. It is needed to include much realistic conditions but could be standard information for design and study of grating interferometer.

REFERENCES

[1]Youngju Kim, Ohsung Oh, Jongyul Kim and Seung Wook Lee: Study on Talbot Pattern for Grating Interferometer, Korean Society Radiological Science, Vol.38, No.1, 2015