國立交通大學

光電工程研究所

博 士 論 文

穿透式 X 光顯微鏡中的相位影像

Phase Imaging in Transmission X-ray Microscope

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摘　　要

X 光影像在生物以及醫療應用上有著非常重要的角色。而相位對比在高解析度的 X 光影像是一個很重要的工具，因為相位的對比較傳統的吸收造成的對比要能提高個二至三個數量級，並且非常有效的減少 X 光影像帶來的輻射劑量。相位對比在於我們目前注重的高解析度的細胞影像，以及其他軟物質有非常重要的貢獻。

這篇論文，最主要的目的是要在穿透式 X 光顯位鏡中發展相位對比的方法。利用同步輻射所提供的光源，我們所使用的穿透式 X 光顯微鏡(TXM)在吸收的對比下能夠達到具有數十奈米的解析度。對相位對比，我們使用發展出兩種不同的方式來觀察相位。第一種是利用光波傳遞的方式紀錄不同位置的繞射的條紋，第二種是利用 Zernike 的相位方法來觀察干涉的相位圖樣。第一種方法我們利用合併以往兩種分別使用在高解析度電子顯微鏡(TEM)的迭代方法(SCWP)，以及以往利用在低解析度 X 光影像的(TIE)方法來解出 X 光顯微鏡中的相位。第二種方法我們使用一個疊代的方式解 Zernike 的相位方法，並且可以只用一張影像解出相位的資訊。這個方法將可以應用在立體的相位對比斷層掃描(phase tomography)上。理論方法和實驗的結果都呈現在論文之內。此兩種方法，都可以應用在 X 光顯微鏡之內，並且有效的回覆相位資訊。此項技術將對三維高解析度的生物醫學影像帶來很大的貢獻。

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ABSTRACT

The phase imaging in X-ray is a powerful tool for non-destructive investigation at nanometer scale. The phase image enhances the contrast for 2 to 3 orders of magnitude higher then the absorption contrast at the hard x-ray region. Furthermore, with the high penetration deep, the phase imaging in hard x-ray is good for the soft material like a cell or bio-medical tissue.

This thesis describes the development of the x-ray phase imaging technique using transmission X-ray microscope (TXM) at a synchrotron source National Synchrotron Radiation Research Center (NSRRC). The TXM has the spatial resolution of several tens of nanometer by using absorption contrast. For phase contrast imaging, the combination method of transport of intensity equation (TIE) and self-consistent wave propagation (SCWP) is applied to retrieve the pure phase information and a resolution of tens of nanometer resolution at hard x-ray region is demonstrated experimentally. To realize the phase tomography, an iterative method (iterative phase retrieval for common path interferometer, IPR-CPI) to calculate the phase image from the Zernike phase contrast method is proposed. It is realized that by using only one x-ray image and a known structure of Zernike phase plate, the phase image can be retrieved and the new methodology was verified by both computer simulation and TXM experiment.

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The installation of TXM was a joint development for Xradia and NSRRC. I thank Dr. Fred Duewer, Dr. Michael Feser, Mr. Shashi Kamath and Dr. Andrei Tkachuk for sharing knowledge and experience during my visit in Xradia and the time for commissioning this machine at NSRRC. Special thanks are due to Dr. Wenbing Yun (雲文兵博士) who always encourages me to explore the new thinking in TXM.

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