近場光學及光子晶體之若干問題研究

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摘　　要

本論文是在理論的基礎上探討電磁波(光波)在近場環境下與散射體之交互作用，以及在光子晶體中不同介面間之傳輸行為。研究內容包含兩大領域：近場光學與光子晶體。

本文討論之重點著重在（一）光纖探針的優化設計。（二）固態浸入式透鏡光儲存系統之改良。（三）傳統波導與不同光子晶體波導間介面傳輸效率的提昇設計。

在近場光學領域裏，我們研究了一系列半波長尺度下孔徑之通光效率及場型分佈特性,提出光纖探針的優化設計程序以達成縮小光斑之目的。另外我們研究固態浸入式半球狀透鏡附加局部鍍鋁膜優化探針之光學儲存系統，提出了如何實現高密度光儲存之最佳化設計。

在光子晶體領域裏，我們針對如何提昇傳統波導與平面型光子晶體波導兩端之傳輸效率問題，我們設計的目的著重在簡單、高效率、小型化、製造誤差之容忍度高且易與光積體電路匹配。我們先以平面波展開法從包覆在二氧化矽基材中之二維正方晶格圓柱及三角晶格圓柱結構探討不同幾何形狀下之能帶結構，找出真正的傳輸模態，並輔以時域有限差分法設計出高效率傳輸的光積體傳輸電路,接著再探討光子晶體平板(slab)的三維計算情形，並比較兩者之間的差異，此外異質波導的傳輸效率之提昇，我們亦有專章討論。

The study of some problems in near-field optics and photonic crystals

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ABSTRACT

In this dissertation, we have undertaken a theoretical approach to the complex problem of modeling the flow of electromagnetic waves in near field optics and photonic crystals. Our focus is to address the feasibility of using the exciting phenomena of near field optics and photonic band gaps (PBG) in actual applications, such as the near field optic probe design and solid immersion lens (SIL) probe system used in high density storage process in near field zone, and the transmission efficiency between silica waveguide (SWG) and planar photonic crystal waveguide (PPCWG) in two dimensional (2D) and three dimensional (3 D) calculation versions. We start by providing analytical derivations of the computational electromagnetic methods used in our work. We also present a detailed explanation of the physics underlying each approach, as well as a comparative study of each problem addressed in this dissertation. Basically, this dissertation can be separated into two parts. The first part, we present the analysis and applications of the interaction phenomena between light waves and scatters (e.g. optical fiber, sample and SIL probe system) in the near field zone using 3D finite difference time domain (FDTD) method. In the second part, the high efficiency coupling techniques between SWG and PPCWGs are proposed using both plane wave expansion (PWE) and FDTD method. In the first part, there are two issues to be investigated. The first issue we have studied is a series using the FDTD method to get more insight in the near field distribution of subwavelength aperture with sample interactions and fiber probes are numerically investigated. Besides, the FDTD design of field enhancing NSOM probe is illustrated and gives a suggestion for fabricating an optimal probe. The second issue of the first part is a SIL combined with near field probes which are conic dielectric probe and local metallic coating one are designed for optical recording by means of a 3D FDTD method to gain more insight in the near field distribution. We investigate the optical properties of near field distributions between the SIL-probe and recording-layers. A promising idea for fabricating a new type of the SIL-probe system was proposed. As regards the part 2, we report high efficiency coupling techniques between SWG and PPCWGs using optimal configurations which can remarkably enhance the coupling efficiency at the entrance and exit terminals of PPCWGs. From simulations, we find that the transmission efficiency reaches up to 90%. Moreover, the suggested structures possess other advantages, such as the shortness taper, the ease of fabrication and its low cost. It is anticipated that the proposed structures might feasibly apply to the integrated optical circuits compatibility. Also, a comparison between the 2D devise and 3D slab version is given. Besides, we present an efficient mode coupling technique between silica SWGs and a planar photonic crystal heterostructure waveguide (PPCHWG).

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Abbreviation

NSOM	： near field scanning optical microscopy
SIL	： solid immersion lens
2D	：two dimension
3D	：three dimension
FDTD	：finite difference time domain method
PWE	：plane wave expansion
TM	：transverse electric
TE	：transverse magnetic
PC	：photonic crystal
PPC	：planar photonic crystal
WG	：waveguide
PCS	：photonic crystal slab
IOC	：integral optics circuit
PPCHWG	Planar photonic crystal heterostructure waveguide