平面光學設計及其在顯示器上之應用

博士研究生：韋安琪　　　指導教授：謝漢萍教授

國立交通大學　　　光電工程研究所

摘　要

各式各樣的通訊產品與影音媒體不斷推陳出新，驅策著光電科技日新月異，而光學元件之需求量也與日俱增。然而傳統光學元件厚重的架構與精準的對位需求常造成設計者的困擾與使用者的不便。為改善上述問題，本論文研究平面積體化自由空間光學(Planar-integrated free-space optics, PIFSO)，簡稱平面光學（Planar Optics），以使光學元件合於輕巧化、薄型化之趨勢，並提升光學元件與系統整合之效能。

本論文以三種不同的平面光學元件為例，分別應用於變焦模組及平面顯示器(Flat Panel Display)等領域。本論文除了建構適切之元件模型以提升設計效率外，亦利用鑽石刀加工（Diamond Machining）、微機電系統(micro-electro-mechanical-system, MEMS)、壓印(Imprint)等製程技術，製作出高品質、低成本之平面光學元件。

本論文所提出的**平面變焦模組(Planar Zoom Module)**，係將變焦模組所需之自由空間光學元件(free-space optics)整合在基板的上下表面，因此可大幅縮減傳統變焦模組之體積。此外，藉由拋物面鏡之設計，此平面變焦模組應用於雷射光束之縮放時，還可大幅減少像差，達到高品質之光束整形。

有機發光二極體顯示器具有薄型、色飽和度佳、廣視角等優勢，但其出光效率不佳仍是問題。因此，本論文提出**多斜度增光層（Multi-zoned Light-enhancing Layer, MZ-LEL）**，藉由多斜度之結構來減低全內反射(Total

Internal Reflection, TIR)，以將原侷限於顯示面板中的光線導引出來，故可提升出光效率。本論文除提供有效之設計模型外，亦藉由鑽石刀加工、微機電製程、壓印等技術製作元件。實驗結果顯示，所設計的增光層將面板之光效率提升至 1.28 倍，且製程與模擬間的誤差由 50%大幅下降至 4%。

金屬線柵偏振片(Wire-grid Polarizer, WGP)搭配適當光學元件後，可用以回收再利用(recycling)偏振光，故具潛力取代現行之吸收式偏振片，而提升液晶顯示器之系統效率。然而，金屬線柵偏振片應用於顯示器時，須以拼貼方式(patching)來達到大面積之需求，此時拼貼間隙問題(seam effect)卻會減低偏振片的偏光效能。因此，本論文提出**光學分析模型以探討拼貼間隙問題**。該模型是根據間隙大小，適當地配合幾何光學(Geometric Optics)與嚴格耦合波理論(Rigorous Coupled Wave Analysis, RCWA)來計算消光比(extinction ratio)。此模型除了滿足分析時所需的能量守恆及收斂等要素外，在模擬速率與記憶體需求上也較具優勢，故可有效提高金屬線柵偏振片之設計效率。

論文中展現了平面光學元件於光電產業之應用潛力，並提供設計者更多的創意來源以研發更多高效能的光學元件；而平面光學設計與微機電製程及壓印技術之結合，亦將在未來高科技產業中呈現更多采多姿之應用。

Planar Optics and its Applications to Display

Doctoral Student: An-Chi Wei **Advisor: Dr. Han-Ping D. Shieh**

Department of Photonics and Institute of Electro-Optical Engineering,
National Chiao Tung University

Abstract

Various communication and multimedia products are fast renewed, driving the optoelectronics techniques to develop rapidly. However, conventional optics has the thick and heavy structure and requires precise alignment, thereby, restricting the design freedom and causing the inconvenience for users. To overcome the above issues, we investigated planar-integrated free-space optics (PIFSO), or called planar optics, for realizing compact optics and promoting the performance of system.

In this dissertation, we demonstrated three planar optical components as examples for zoom lens set and flat panel display applications. Besides effective optical models, available techniques, including diamond machining, micro-electro-mechanical systems (MEMS) technique and imprint, were exploited to realize high-quality and low-cost components.

The **planar zoom module (PZM)** integrates the free-space optics onto the surfaces of a transparent substrate. Then, the zoom lens system is miniaturized. In addition, when the PZM with paraboloid mirrors is utilized for laser beam scaling, the aberrations are shown to be minimized; as a result, the performance in beam shaping are improved.

Organic light-emitting diodes (OLEDs) possess many advantages, such as thin devices, good color gamut and wide viewing angle; yet, its out-coupling efficiency remains an issue. For suppressing the total internal reflection (TIR) and then

enhancing the light efficiency, a **multi-zoned Light-enhancing Layer (MZ-LEL)** is presented herein. In this study, not only the modeling accuracy of light-enhancing layer has been improved, but also the devices have been fabricated by the mentioned techniques. Experimentally, the MZ-LEL has enhanced the light efficiency of OLED panel by a gain factor of 1.28. Also, the discrepancy between the simulation and the experimental results was improved from 50% to 4%.

Wire-grid Polarizer (WGP) has the great potential to replace the conventional absorption polarizer for improving the system efficiency of liquid crystal displays (LCDs). However, when the WGP is applied to a display, the patching approach is required to produce the large size WGP; then, the effect of the seams between adjacent patches will degrade the polarization efficiency. Hence, we established a **model to analyze the seam effect**. The model applies geometric optics and rigorous coupled wave analysis (RCWA) to evaluate those seams much larger than the wavelength those nano-seams, respectively. Also, we proposed strategies to allow the calculations to satisfy the modeling criteria. As a result, the proposed modeling method has exhibited the superiority in simulation speed and memory requirement, leading to efficient design and analyses.

This thesis has successfully demonstrated the great potential of planar optics for opto-electrical applications. Along with the MEMS and the imprint techniques, various designs of planar optics shall be developed for novel applications in the near future.