國科會專題研究結案報告

波導結構光電元件及相關介觀材料結構研究 – 總計畫

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With non-collinear OPG on PPLN, we have theoretically predicted retracing behaviors of phase matching and experimentally demonstrated the generation of broadband signal and idler beams. The broadest signal spectrum covered the wavelength range from 1.66 through 1.96 μm. The corresponding idler wavelength ranged from 2.328 through 2.963 μm. Note that the OPG output bandwidth reported can be reduced if an OPO is implemented because of the propagation direction confinement of either signal or idler.

Also, we have numerically demonstrated the RB of QPM phase-matching curve, which are the key phenomena for broadband optical parametric processes. With QPM, vertical phase matching curves and hence broadband operations exist in collinear, non-collinear, and quasi-collinear configuration. Broadband operation is feasible only at the degenerate point in the collinear configuration with a specific pump wavelength, λ_{BC}. Such a constraint sets a significant limitation in application. Particularly, all the broadband signals of collinear phase-matched PPLN, PPKTP, PPKTA, PPLT, and QPM GaAs (the data are not discussed in this paper) are beyond the fiber communication wavelength range and biological window (650 – 1300 nm). With non-collinear or quasi-collinear phase matching configuration, the conditions and output signal ranges of broadband operation are much more flexible, particularly those useful for fiber communication and optical imaging of biological tissues.

The finite element method (FEM) has been an efficient numerical method for studying optical or dielectric waveguides. We have established an efficient and highly accurate three-dimensional full-vectorial finite element numerical model by introducing inhomogeneous elements to properly handle the boundary conditions at the interface between different dielectrics and at the corners of the dielectric structure. In this research we continue to explore the generalization and applications of the FEM theoretical analysis models. Using the established model, we study in detail field distribution near dielectric corner singularities of the dielectric waveguide, and examine its relation to the precision of the effective index calculation. To examine if the results obtained by the formulation in [11] alone is adequate to analyze the waveguide corners, we propose two additional formulations based on different approximation schemes for the corner singularities and obtain field profiles near the corners for comparison. We have investigated the differences in the calculated effective index between different numerical boundary conditions [12]. In this research we have also extended the FEM numerical model for treating optical waveguide structures involving anisotropic media. Moreover, operating characteristics of polished-type fiber-optic couplers with an intermediate liquid crystal layer have been studies.

Nonlinear optical loop mirrors (NOLM's) are useful for high speed signal processing and communications. Recently, we have implemented a monolithic all-semiconductor-optical-amplifier (SOA)

nonlinear loop device, showing efficient power-dependent switching. The configuration of this device is the same as an NOLM, including an SOA loop and a multimode-interference waveguide amplifier for closing the loop. In this study, we numerically simulate the device in the case of pulsed-signal operation. Simulations are conducted using a modified time-domain traveling-wave method. Relevant parameters are varied to evaluate their influences on the device performance.

子計畫四的研究主題有兩項，第一項主題為低度含氮的氮砷化銦材料成長技術的研究。由於合金能隙的彎曲效應，加氮可以同時降低晶格常數與能隙，能延伸元件的發光波長。本年度我們研究氮砷化銦塊材的成長與特性。我們發現隨著氮的加入，DXRD 變寬，而且電子濃度也變高。高電子濃度產生的 Burstein Moss Shift 使得氮砷化銦的吸收能量反而高於砷化銦。我們利用 Band Anti-crossing Model 以及砷化銦的三能帶 E-k 關係來推算氮砷化銦的能隙及 E-k 關係，並據以估計電子濃度所產生的 Burstein Moss Shift 以及 Band renormalization。藉著與實驗樣本吸收光譜的比對擬合，以獲取不同氮成份(x)下 Band Anti-crossing Model 的矩陣耦合參數 V_{NM}，並進一步求得其與氮成份的關係式中 $V_{NM} = C_{NM}\, x^{1/2}$ 的常數 $C_{NM} = 1.92$eV。這是首次對此種材料的測定值。經由分析，我們也求得不受 Burstein Moss effect 的原始能隙與氮成份的關係，其結果顯示氮的加入確實會產生能隙彎曲效應。第二個研究主題為含銻化合物半導體的分子束磊晶技術。我們使用 EPI 銻裂解 K-cell 研究成長銻化鎵與砷銻化銦及其量子井等結構。成長於 GaSb 基板的 GaSb 磊晶層經過成長溫度與 Sb/Ga 比的最佳化之後，其低溫 10K PL 雖仍有導電帶至 complex 的放光，但已經能夠觀察到 0.802eV 的 Bound Exciton 甚至 0.810eV 的 Free Exciton，與文獻的結果比較，顯示我們的磊晶品質已相當優良。

Related publications:

1. Nai-Hsiang Sun, Chih-Cheng Chou, Ming-Jen Chang, C. C. Yang, and Yean-Woei Kiang, "Analysis of Phase-matching Conditions in Flexural-wave Modulated Fiber Bragg Grating," accepted for publication in J. Lightwave Technology.
2. Yan-Ju Chiang, Likarn Wang, Wen-Fung Liu, and C. C. Yang, "Multipoint Temperature-independent Fiber-Bragg Grating Strain Sensing System Employing Optical Power Detection Scheme," accepted for publication in Applied Optics.
3. Chih-Wei Hsu, Chieh-Ting Chen, and C. C. Yang, "Retracing Behaviors and Broadband Generation Based on Quasi Phase-matched Optical Parametric Processes," accepted for publication in J. Optical Society of America.
4. Jyh-Yang Wang, Yean-Woei Kiang, and C. C. Yang, "Numerical Simulation on Pulsed Operation of an All-Semiconductor-Optical-Amplifier Nonlinear Loop Device," accepted by J. Lightwave Technology.
5. C. C. Yang, Yean-Woei Kiang, Jiun-Haw Lee, Jyh-Yang Wang, Horng-Shyang Chen, Chih-Wei Hsu, Ding-An Wang, and Chih-Chang Chen, "Nonlinear Optical Effects in Semiconductor Optical Amplifiers and Their Applications to All-optical Switching," SPIE Proceedings, Volume 4580, 2001. ***(invited)***
6. C. C. Yang, Chih-Nan Lin, Chung-Yih Tang, Yan-Ju Chiang, Yean-Woei Kiang, Chih-Cheng Chou, Nai-Hsiang Sun, Chih-An Wei, Wen-Fung Liu, I-Ming Liu, Lung-Wei Chung, and Ding-Wei Huang, "Flexural Waves on Fiber and Fiber Bragg Gratings for WDM Switching and Gain Equalization of Erbium-doped Fiber Amplifiers," SPIE Proceedings, Volume 4579, 2001. **(invited)**
7. Yan-Ju Chiang, Likarn Wang, Wen-Fung Liu, Horng-Shyang Chen, Chih-Wei Hsu, and C. C. Yang, "Temperature-

Insensitive Strain Measurement Using Two Fiber Bragg Gratings in a Power Detection Scheme," Optics Communications, Vol. 197, pp. 327-330, 2001.

8. Chih-Wei Hsu and C. C. Yang, "Broadband Optical Parametric Generation with Non-collinear Operation on Periodically Poled $LiNbO_3$," Optics Letters, Vol. 26, No. 18, pp.1412-1414, 2001.
9. Jiun-Haw Lee, Jyh-Yang Wang, C. C. Yang, and Yean-Woei Kiang, "All-Optical Switching Behaviors in an All-Semiconductor Nonlinear Loop Device," J. Optical Society of America B, Vol. 18, No. 9, pp. 1334-1341, 2001.
10. J. Q. Yao, X. Ding, J. Y. Qiao, C. C. Yang. I. J. Hsu, and C. W. Hsu, "Pump-Tuning Optical Parametric Oscillation and Sum-Frequency Mixing with KTP Pumped by a Ti:sapphire Laser," Optics Communication, Vol. 192, pp. 407-416, 2001.
11. D. U. Li and H. C. Chang, "An efficient full-vectorial finite-element modal analysis of dielectric waveguides incorporating inhomogeneous elements across dielectric discontinuities," *IEEE J. Quantum Electron.*, vol. 36, no. 11, pp. 1251-1261, 2000.
12. D. U. Li and H. C. Chang, "Full-vectorial finite element modal analysis of bounded and unbounded waveguides," *Proc. 2001 Asia-Pacific Microwave Conference*, vol. 1, pp. 376-379, Taipei, Taiwan, R.O.C., December 3-6, 2001.
13. Jyh-Yang Wang, Jiun-Haw Lee, Yean-Woei Kiang, and C. C. Yang, "Numerical Simulation on Pulsed Operation of an All-Semiconductor-Optical-Amplifier Nonlinear Loop Device," Journal of Lightwave Technology, Vol. 19, No. 11, November 2001.