Photonic crystal filter integrated with photodiodes

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Abstract—**We demonstrate the monolithic integration of photonic crystal waveguides, a photonic crystal demultiplexer, a conventional waveguide and photodiodes in InGaAsP-based material. The photonic crystal demultiplexer consists of hexagonally arranged air holes. The inputted light at the wavelengths of 1530nm and 1550nm can be separated by the demultiplexing system.**

Keywords-component; Photonic crystals; filter; photodiodes; waveguides

I. INTRODUCTION

The photonic bandgap (PBG) effect of PC provides the highly confined mode needed to be control the propagation of the light. Due to their nanometer feature size, the device packing density can be increased. PC-based devices are potentially integrated into a monothilic material with electronic devices which are in nanometer scale. Several PC devices have been developed such as directional couplers[1], ring resonators[2], hollow waveguides[3], laser[4], lenses[5], etc. To integrate these devices, the fabrication process including the conventional pthotolithography and the e-beam lithography should be utilized for the patterns of micrometer and nanometer scales, respectively. In this study, we realize the integrated nano-optics system consisting of a PC demultiplexer which separates the incoming light of the wavelengths at 1530nm and 1550nm, a PC taper coupler, PC waveguide as well as two photodiodes for the detection of the light.

II. DEVICE DESIGN AND FABRICATION

InGaAsP-based materials are chosen for the fabrication of the device to obtain high absorption efficiency at the operating wavelengths. The refractive index of the guiding material is designed to be higher than that of the cladding layer to obtain the vertical confinement in the input/output conventional slab waveguides. For the photodiodes, the partially p-doped photo-absorption layer is adopted to accelerate the diffusion of the electron form absorption layer to the depletion layer [6]. The PC demultiplexer is formed by periodically arranged air-holes in hexagonal lattice. The radius is chosen to be 0.33a. The normalized frequency of the complete photonic bandgap is between 0.2 and 0.3. The normalized frequency of 0.24 is chosen for the wavelength at 1.55μm. The corresponding lattice constant and radius of the air-holes are 0.375μm and 0.125μm, respectively. The corresponding photonic bandgap in wavelength is between 1.25μm and 1.875μm. This result confirms that the operating wavelengths at 1.53μm and 1.55μm are in the photonic bandgap. The sample is grown by metal-organic-chemical-vapor-deposition (MOCVD) on a semi-insulating InP substrate. The conventional waveguide and the photodiodes are fabricated by the conventional photolithography processes. The pattern of the PC region is defined onto the photoresist by electron-beam lithography. The inductively coupled plasma (ICP) etcher was used to transfer the PC patterns into the InGaAsP layers to form the PC waveguides and demultiplexer. PC taper couplers are used between the conventional waveguides and the PC waveguides to reduce the coupling loss. Figure 1 shows the scanning electron microscope images of the systems including the conventional waveguide, PC taper coupler, PC waveguides, PC demultiplexer and photodiodes

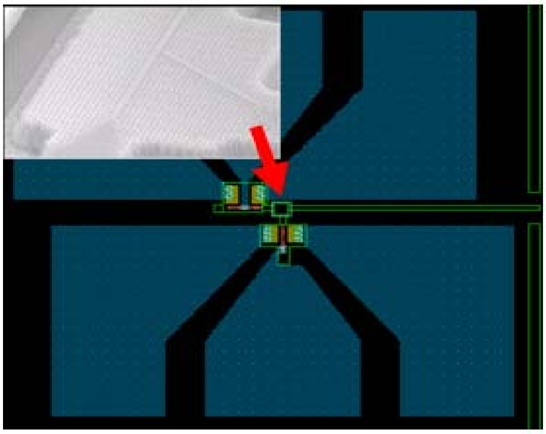

Figure 1. Layout of integrated nano-optics system. The inset is the PC demultiplexer.

III. MEASUREMENT RESULTS

A tunable semiconductor laser with its power of 0dBm is used as the light source. The input light is polarized in the TE mode. The wavelength of the input light is scanned from 1.52μm to 1.57μm. Figure 2 shows the measured photocurrent ratios between two photodiodes. From the measured result, we can observe that the PC demultiplexer can successfully separate the different wavelengths. The photocurrent ratio is 3.2 (5dB) and 3.8 (5.8dB) for the photodiodes of 1530nm and 1550nm, respectively.

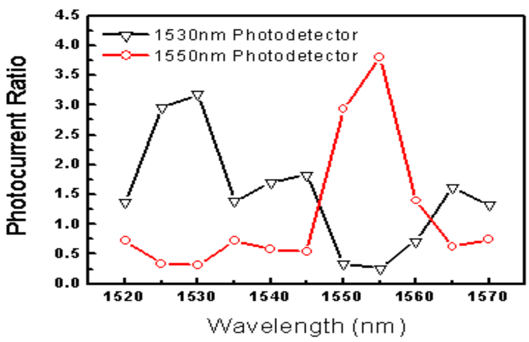

Figure 2. Response spectra measured from photodetectors.

The bandwidth of the photodiode is measured with a heterodyne beating system which the optical signal is generated by mixing two tunable lasers with different wavelength into a 3-dB coupler and through the lensed fiber with a diameter of 2.5μm. The result shows that the electric-bandwidth performance is achieved about 25GHz.

IV. Conclusions

In this work, we demonstrate an integrated nano-optics system consisting of conventional waveguide, PC taper coupler, PC waveguide, PC demultiplexer and partially p-doped photodetector. The results show that the system can separate the wavelengths at 1.53 and 1.55μm simultaneously for the wavelength division multiplexer application with a bandwidth of 25GHz. By introducing a PC laser source in the system, a complete optical communication system can be achieved in a chip for the application of optical computing.

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