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Guided wave optics

Transmission type tunable wavelength filters based on polymer waveguide Bragg reflectors

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ABSTRACT

In WDM communication systems, a compact low-cost tunable wavelength filter is highly demanded. Polymeric Bragg reflector devices are suitable for this purpose because the large thermo-optic effect of the polymer enables widely tunable wavelength filters with simple device structure. To direct the filtered signal in the forward direction rather than the backward direction, a waveguide mirror device is integrated. A compact package was then achieved by attaching a fiber-connecting receptacle and a high-speed PD on each side of the chip. The tunable filter exhibited a tuning range of 14 nm, a 3-dB bandwidth of 0.45 nm, and a 15-dB bandwidth of 1.54 nm. The device exhibited a low polarization dependence of 0.08 nm, which is the first demonstration in polymeric tunable filters.

1. Introduction

Tunable optical wavelength filters are indispensable components in optical communication systems utilizing multiplexed wavelength signals [1,2]. Optical filters have been investigated based on thin film dielectric filters [3–5], Fabry–Perot cavity devices [6,7], and fiber Bragg gratings [8,9]. Thin film filters have the merits of thermal stability and good reproducibility but require high thermal tuning power and have a slow tuning speed. Fabry–Perot devices could produce a narrow bandwidth and low polarization dependence compared to thin film filters; however, mechanical instability and hysteresis degrade their overall long-term stability. Fiber grating devices are bulky and have a limited tuning range, but their reflection spectrum is close to the ideal wavelength filter.

Polymer waveguide Bragg grating devices were incorporated to produce widely tunable wavelength filters by virtue of their highly efficient refractive index tunability [10–12]. Simple direct refractive index tuning through the thermo-optic (TO) effect of polymer enables a wavelength tuning range greater than 30 nm, which is not available in Bragg reflectors based on any other material [13]. However, the signal of Bragg grating reflects back to the input port, and the circulator is necessary to separate the filtered wavelength signal. For the wavelength filter to be useful for WDM systems, a transmitting-type device rather than an ordinary reflecting-type Bragg reflector is anticipated for a low-cost compact package solution.

In this work, we propose a transmission-type tunable wavelength filter with an output port placed on the other side of the device, and we demonstrate a compact package without using the circulator device. A tunable Bragg reflector device is integrated along with a waveguide mirror device to change the propagation direction of the guided mode to the other side. In this way, we achieved a compact package with a fiber-connected receptacle and a high-speed photodetector module attached to each side of the Bragg reflector device. A wide tuning range, narrow bandwidth, and low polarization dependence are accomplished in this experiment.

2. Design and fabrication of the transmitting tunable wavelength filters

To direct the reflected signal from a polymeric Bragg reflector in the forward direction, as a simple practical method, a waveguide mirror device is incorporated. The device consists of a Bragg reflector, a Y-branch power divider, a tapered waveguide section, and a metallic mirror as shown in Fig. 1. When a certain wavelength is filtered and reflected back by the Bragg reflector, the reflected power is divided by the Y-branch. Half of reflected power propagates toward the mirror and the other propagates toward the input port. The circulator is not necessary to block the reflected light into the input port because there is an isolator normally included at the light source. When a confined light is reflected by the mirror, it will introduce a strong coupling to the higher order modes, and increases the reflection loss. The waveguide mirror

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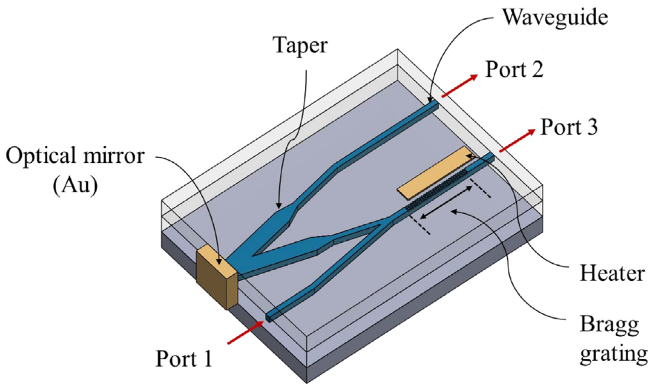

Fig. 1. Schematic diagram of transmitting-type tunable wavelength filters comprising polymeric Bragg reflection grating and metal mirror to reflect light in the forward direction.

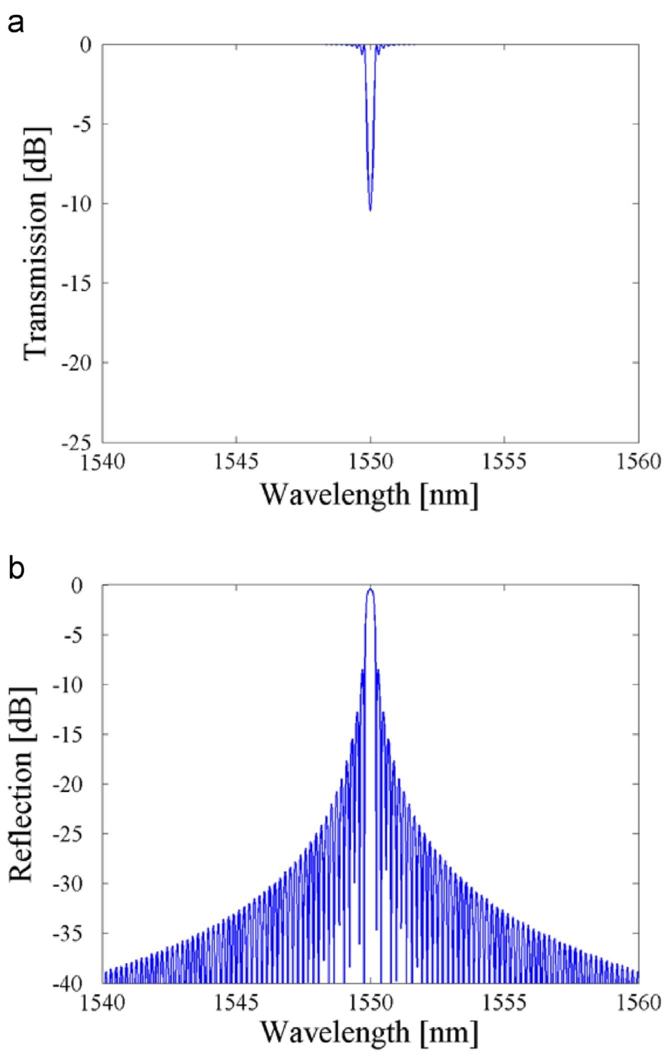

Fig. 2. Design results of the fifth-order Bragg grating for (a) transmission spectrum and (b) reflection spectrum.

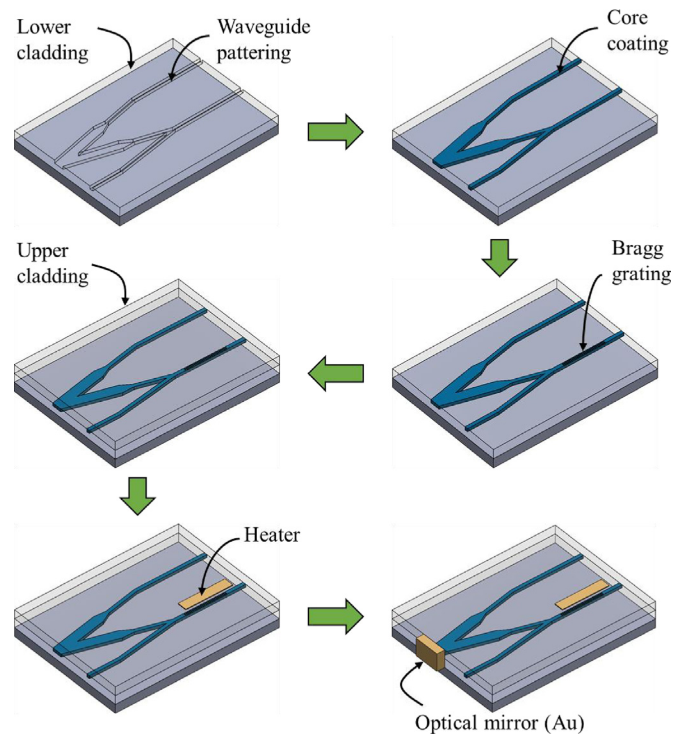

Fig. 3. Schematic fabrication procedures of polymer waveguide tunable wavelength filters.

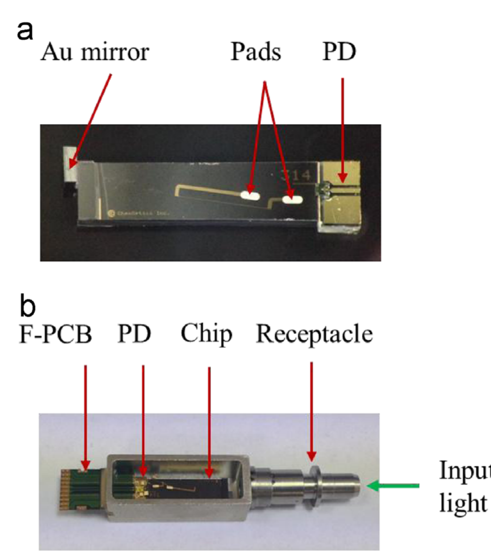

Fig. 4. Photographs of (a) the fabricated waveguide device chip and (b) the packaged device with a receptacle and a flexible PCB attached to each side of the transmitting tunable wavelength filter.

structure is designed to reduce the loss due to the higher order mode coupling. The width of waveguide is increased from 3 µm to 19 µm in a length of 1.2 mm, then the profile of fundamental mode is widen adiabatically. The wide profile single mode has narrow wave vector distribution, and it will be reflected by the mirror with a small divergence angle. In this way, higher order mode coupling by the mirror reflection is suppressed. The mirror attached to the edge of the device could then produce reflection loss less than 0.5 dB according to the beam propagation method simulation.

The signal reflected from the mirror propagates to the output side of the sample. The waveguide width is reduced to that of the ordinary single-mode waveguide. In this way, with no need for a circulator device, we can produce a transmitting-type wavelength filter with input and output ports separated on each side of the sample. On the input side, a receptacle device with a lens and fiber connector is attached, and a high-speed photodetector module will be aligned on the other side. The proposed device will have inherent excess loss of 6 dB owing to the Y-branch device and the Y-branch in the current device should be replaced with other