Fiber-in-line Optical Transceiver Structure Using Silicon V-groove and Tilted-Fiber Gratings

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ABSTRACT

A novel fiber-in-line optical transceiver structure by focusing the outgoing radiation from a tilted and chirped fiber Bragg grating is proposed. The chirped gratings with 45^o tilted angle is designed for an optimum input coupling at 1.55μm and a FDTD method is used for analysis. Experimental results on beam focusing are shown. We expect this novel design can be used for a low-cost receiver in the bi-directional fiber-in-line optical transceiver.

Keywords: tilted and chirped, beam focusing, fiber Bragg grating, optical transceiver.

1. INTRODUCTION

There have been strong demands for the cost-reduction of optical transceivers in the optical access systems. Up to now, TO-can based BiDi(bidirectional) or triplexer type TRxs have been commonly used.[1][2] Even though the packaging technologies related with TO-can based TRxs have been enhanced, the conventional packaging techniques have limitations basically in cost-reduction due to expensive laser welding process and active alignment process.

Recently, many researchers have focused upon the PLC-based TRxs technology.[3][4][5] This technology utilizes the well-established silicon V-groove technology, silica or polymer waveguide technology, and the surface mounting of LD/PD technology. All processes can be semi-automated and make it possible to provide low-cost transceivers. However, the alignment procedures between PLC waveguides and fiber-butt are time-consuming and lead to additional high cost.[6][7] Furthermore, because of the poor reliability caused by epoxy degradation and large temperature sensitivity, the packaging cost of PLC-based TRxs is somewhat higher than that of conventional TO-can based on TRxs so far.

In this paper, we propose fiber-in-line type optical transceiver using a silicon V-groove and a tilted-fiber gratings. The chirped and tilted fiber Bragg grating(FBG) structure makes it possible to use a passive alignment between PD and fiber efficiently by focusing the radiation beam from fiber core to side without any focusing lens.[8][9][10][11][12][13] The chirped gratings with 45^o tilted angle is designed for an optimum input coupling at 1.55μm. A FDTD technique is used for analysis of coupling efficiency and focal length. To fabricate our proposed device, a fiber with a tilted grating and angled tip is mounted into a silicon V-groove. An LD and a PD are mounted on the silicon surface over the V-groove. Basic experimental results on beam focusing are shown.

In our novel structure, there is no active alignment requirement between waveguide and fiber-butt. Therefore, low propagation loss in in-line-fiber, fabrication step reduction, and enhanced reliability are expected, which result in cost reduction. We expect this novel design can be used for a low-cost receiver in the bi-directional fiber-in-line optical transceiver.

2. DESIGN OF FIBER IN-LINE OPTICAL TRANSCEIVER

2.1 Proposal of fiber in-line transceiver

The configuration of the proposed fiber in-line transceiver scheme is shown in Fig.[1] as follows. This schematic configuration could be useful for WDM PON. The optical Tx part consists of angled fiber end which is fabricated by polishing work and the transmitter is normally made of 1.31um Fabry-Perot laser, while Rx part receive the light which have single wavelength through down stream line. To enhance the performance, fiber end of Tx part is coated with anti-reflection thin film material such as Al or Au.

We tried to horizontally couple LD beam to fiber in this experience, but in future, we will make an attempt the vertical coupling as there is 1.31 VCSEL chip, which flip chip processing are available.

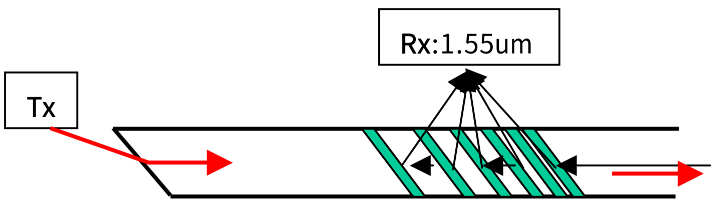

Fig.[1] Configuration of the proposed fiber in-line transceiver scheme

2.2 Design and analysis of tilted-chirped grating

Tilted fiber Bragg grating caused a part of the optical signal to be coupled out of the optical fiber through the fiber cladding. A photo detector is provided generally alongside the grating to collect and detect of the out-coupled optical signal. If there is the need for fast speed detection, detecting area of PD is to be small in proportion to optical signal modulation speed. In this case, chirped grating with tilted structure, which make the beam spot be small, is very useful. Dynamics of chirped grating can be understood as the interaction of vector sum between photon and momentum of grating structure. As the beam has single wavelength, the chirped FBG change the direction of beam according to the locations of grating with the help of interaction between photon and grating momentum. Figure [1] is the schematic of tilted chirped grating.

2.3 Simulation results

The 1.55um beam focusing to receiver was simulated. For the most part, chirped Bragg grating has used in broadening the spectrum width, played an important role in chromatic dispersion compensation of optical transmission system. Figure [2] is spectrum when chirp coefficient, α, is given as following formula;

$$\Lambda(z) = \Lambda_0 + \alpha\left(\frac{z}{L} - \frac{1}{2}\right)$$

Where Λ_0 is grating period at grating center, and α is the chirp coefficient.

Chirp coefficients are respectively given by 0(regular period), 0.001, 0.005, and 0.1 as it is gradually increased. As shown, spectrum width is wider and peak power is decreased as chirp coefficient is larger than regular period Bragg grating.

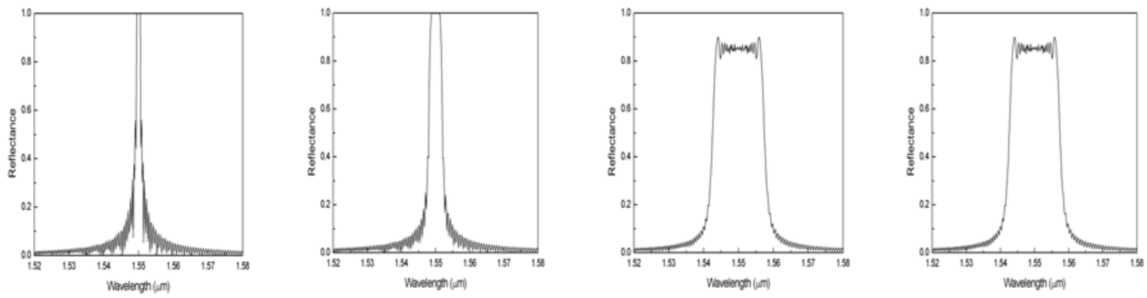

Fig. [2] The spectrum characteristics as chirp coefficient is variable.

The practical simulation is evaluated by software based on the well-known finite-difference time-domain(FDTD) method.

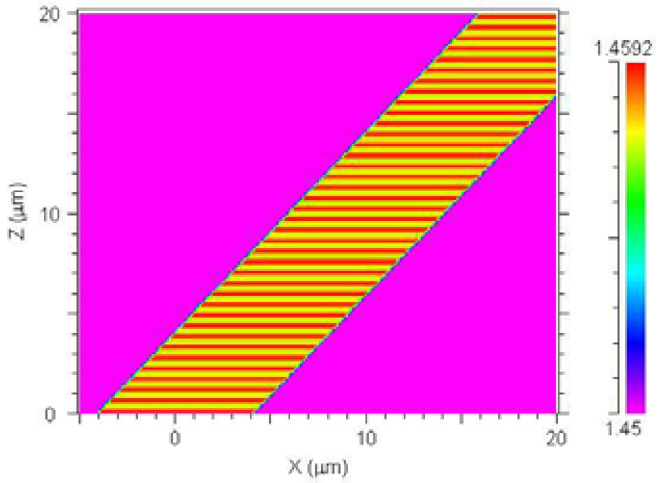

Fig. [3-1] 2-D view of grating part

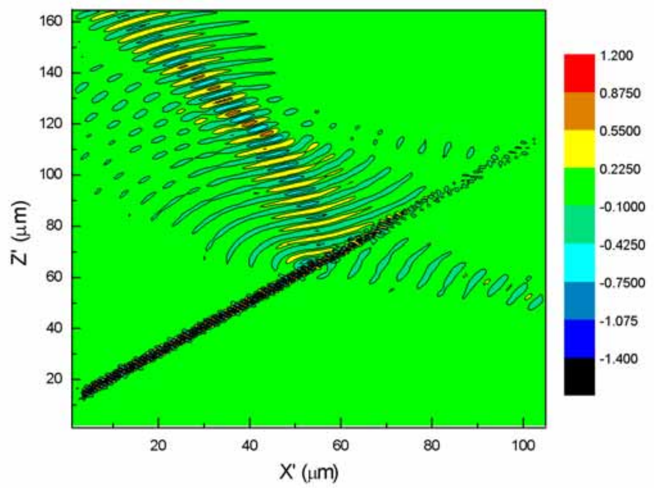

Fig. [3-2] Simulation results for tilted chirped Bragg grating

Figure [3-1] shows the grating part of waveguide with 45^{o} tilted. Figure [3-2] is the FDTD simulation result which shows the shape of beam radiating from fiber side and focusing to a certain spot. Simulation is achieved at 1.55um for tilted and chirped grating. As a result, the focal length and size is controlled by changing the period of grating. The focal length is around tens um and the size of focus is adjustable by changing chirp parameters.

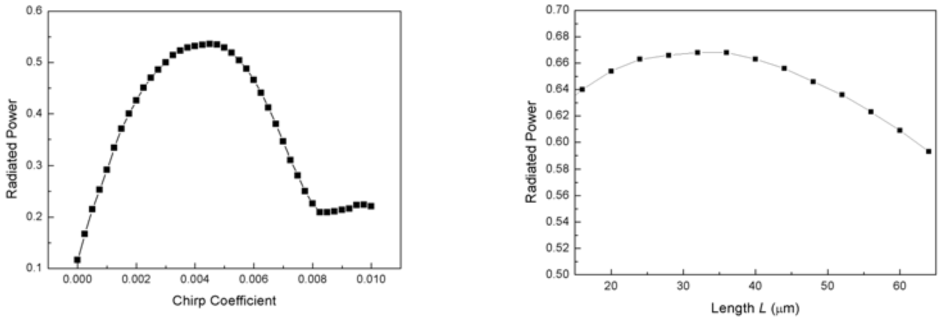

Fig. [4] Radiated power according to chirp coefficient and focal length

If the receiver is located y axis, the cylindrical lens effect according to x axis due to cylindrical shape of fiber and another lens effect according to z axis due to chirp gratings are expected.

3. EXPERIMENTAL RESULTS

3.1 Beam focusing effect by chirped grating

The experiment was done to test beam focusing without any measure such as lens system. The 1.55um wavelength beam is used for receiver while 1.31um used for transmission in WDM PON. The 1.55um beam easily is focused to PD using tilted and chirped FBG as a result.

Fig [5]. is the experimental result of beam focusing by chirped grating. The chirping rate is 5nm/cm and has 1533~1554nm bandwidth. The beam focusing shape, power, and profile were measured and analyzed. The beam shape is obtained by Far Field Pattern(FFP) analyzer(Model: Hamamatsu, A3267-12), whereas, we found that there is no light in the opposite direction of side part of tilted fiber grating. The grating is 1cm long and shows the beam focusing following the direction of length.

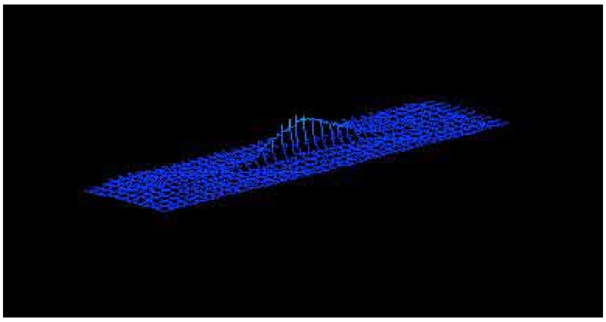

Fig. [5] Beam measured with FFP analyzer

The study on the uniform focal length according to the x, y axis is still going on . Also, the application to the TRx platform is already being suggested.

3.2 Fabrication process

A V-groove is fabricated by silicon wet-etching process. The depth of V-groove is designed to 400um. Tilted and chirped gratings are made by high power UV Excimer laser on a Ge-doped fiber. UV sensitive fiber is treated by soaking into H_2 gas under 100atm, 100^{o}C for 3 days. The excimer laser's power is 25kV(472mJ) and exposure time is about 10min, pulse repetition rate is 10Hz.

The fiber is inserted into a V-groove. An LD with a wavelength of 1.31um is mounted by a flip-chip process on the silicon surface as following Fig.[6]. A PD with a wavelength of 1.55um is mounted over the each top of tilted gratings on the silicon surface.

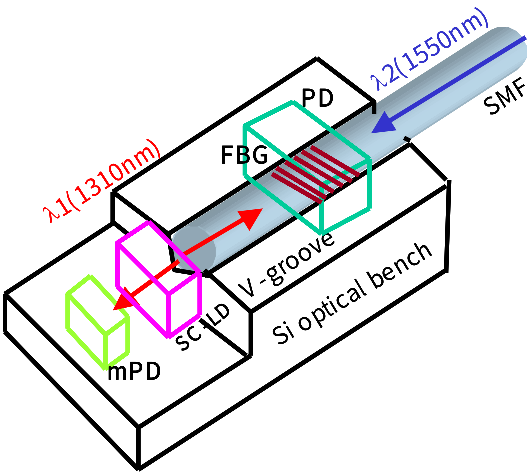

Fig. [6] Schematic configuration of fiber in-line transceiver for WDM PON system

After fabricating, we measure the LI curve for the laser diode. The main reduction of light power is considered due to the poor coupling efficiency between LD and angled tip. Also, we are measuring the BER performance at the bit-rate of 155Mbps.

4. CONCLUSION

In conclusion, we proposed and demonstrated a novel fiber-in-line optical transceiver structure using a silicon V-groove and a tilted chirped fiber Bragg grating. In our structure, a PD is integrated directly into a fiber with a tilted chirped grating and an LD is butt-coupled on a silicon V-groove. The tilted and chirped fiber grating is designed at an angle of 45^o for the optimum input coupling and analyzed with FDTD technique. The maximum performance of outgoing radiation is designed into a chirped fiber with a chirp coefficient 0.004 at a distance 34μm from fiber. The experimental results of beam focusing at the wavelength of 1.55μm are shown.

Our first fabrication shows the poor coupling efficiency of PD into the fiber. We are now improving the coupling efficiency with the angle adjustment and surface roughness control. Also, we are measuring the BER performance of the integrated PD. We expect this novel design can be used for a low-cost receiver in the bi-directional fiber-in-line optical transceiver.

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