Experimental observation of coupling between physically separated planar waveguides utilising tilted Bragg grating structures

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***Abstract*— We demonstrate a novel optical device used to couple light from one channel waveguide to another 100 µm away. An investigation into the blaze angle of the tilted gratings used to couple light into the cladding modes is presented.**

Keywords- tilted Bragg gratings; direct UV writing.

I. Introduction

Tilted Bragg gratings have been implemented in fiber and planar waveguide geometries [1], allowing increased filtering functionality [2], for sensing and wavelength specificity over equivalent non-tilted grating devices. Pairs of Bragg gratings in the same waveguide have also been demonstrated, further increasing the scope of the grating-based sensor for both refractive index and spectral applications [3,4].

We propose a novel geometry of tilted Bragg grating device, taking advantage of the higher index core photosensitive slab waveguide used in the production of direct UV written waveguides and Bragg gratings. The slab waveguide section between a pair of identical channel waveguides with tilted Bragg gratings allows coupling between waveguides separated by 100 µm, a distance much greater than would normally occur for evanescent coupling used in conventional directional couplers. We investigate the effect of the blaze angle of the tilted gratings on the spectral features observed.

II. Fabrication and Characterization

The waveguides were fabricated in a silica-on-silicon platform. An under-clad of thick thermal oxide (~15 µm) was grown on a silicon wafer. The core layer, with a refractive index of 1.4551, was deposited via flame hydrolysis deposition (FHD), and doped with germanium for photosensitivity and boron for refractive index control. A cladding layer was deposited post-consolidation, with phosphorus and boron dopants used to achieve a refractive index contrast of 0.010 between core and cladding.

The direct grating writing (DGW) technique [5] was used to inscribe waveguides and tilted Bragg gratings into the photosensitive core layer. The output from a frequency doubled 488 nm argon-ion laser was passed through an acousto-optic modulator before incidence on a 50:50 beam splitter. The photosensitive sample core was placed within the focus of the two interfering UV beams and translated at speed to create waveguiding regions. In order to create grating structures, the sample translation speed and modulation of the UV beam are controlled to create the periodic grating profile. To create tilted Bragg gratings, a rotational stage system was used, and waveguides and gratings written at the appropriate angle. The photosensitive reaction causes an increase in refractive index of around 0.005 in the ~5 µm wide waveguide region.

The fabricated components consist of 2 parallel waveguides separated by 100 µm. The width of each waveguide was ~5 µm. Each pair contains gratings which are 3 mm long, with central wavelength 1550.4 nm and identical blaze angles. The gratings were written with varying degrees of blaze angle, between 5 ° and 45 °. The gratings were written parallel to one another, to observe perpendicular coupling between the waveguides. The region between the two channel waveguides acts as a slab waveguide, vertically confining the propagating light.

Characterization of the sample was performed using the fiberized output of an EDFA ASE source.

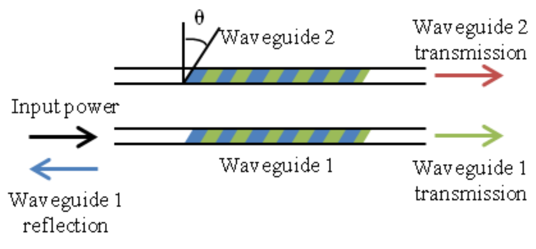

Figure 1. Schematic of fabricated device. Arrows show collection of light: blue is the reflected spectrum from waveguide 1, green is the transmitted spectrum from the waveguide 1, red is the transmitted spectrum from waveguide 2. Light is launched into waveguide along the direction of the black arrow.

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The output passed through a circulator, fiber in-line polarizer and polarization maintaining pigtail to the input at waveguide 1. The reflected spectrum from the gratings was obtained by observing the output of the circulator on an optical spectrum analyzer (OSA). In order to obtain the transmission spectrum, a second PM pigtail was used to collect the output spectrum from the waveguide under observation.

III. Results and Discussion

The measured spectrum from the device is shown in Fig. 2. In this case, we show the device written with a blaze angle of 5 degrees. The purple line shows the reflected spectrum of the tilted Bragg grating. The reflection from the grating is expected to be significant, due to the small blaze angle of the grating. This is corroborated by the large transmission dip (23 dB) observed in the transmission of the same waveguide (black). However, at the output of waveguide 2, we observe a non-zero transmission spectrum (red). A broad transmission is measured, with transmission dips indicative of cladding modes observed.

The presence of the broad transmission (~50 nm) at the output of waveguide 2 indicates that light is being coupled between the two waveguides over the 100 µm slab waveguiding region between. The relatively large distance between the waveguides indicates this is not an evanescent coupling effect; similar waveguides fabricated with normal incidence Bragg gratings stop coupling when separated by a distance of more than 20 µm. The coupling between the waveguides is due to the presence of the tilted Bragg gratings within the waveguide, allowing coupling to the cladding modes in the region between the waveguides, and coupling to the core modes of waveguide 2 to achieve the observed transmission.

Fig. 3 shows the collected spectra from a device with 10° blaze angle. A smaller transmission dip is observed at the output of waveguide 1, and the cladding modes at the output of waveguide 2 are not so well defined. This is due to changes in the coupling mechanism between the core and cladding modes of the waveguides for increased angle [1].

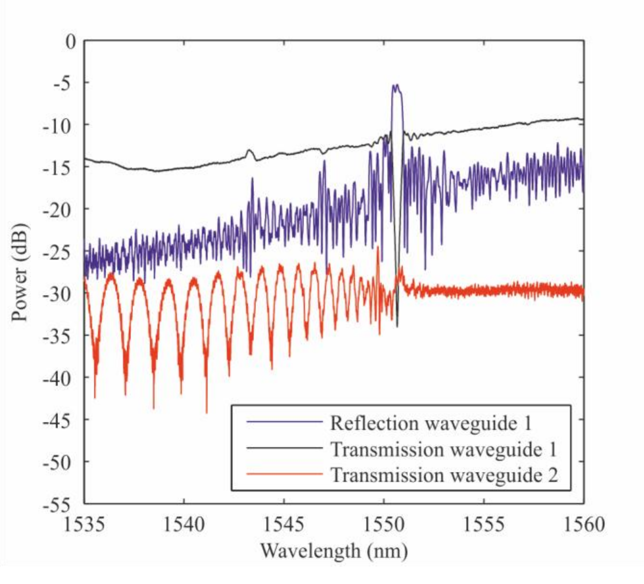

Figure 2. Measured spectrum from the device with 5 ° blaze angle. The reflected spectrum from waveguide 1 is shown in purple, the transmitted spectrum from waveguide 1 is shown in black, and the transmitted spectrum from waveguide 2 in red.

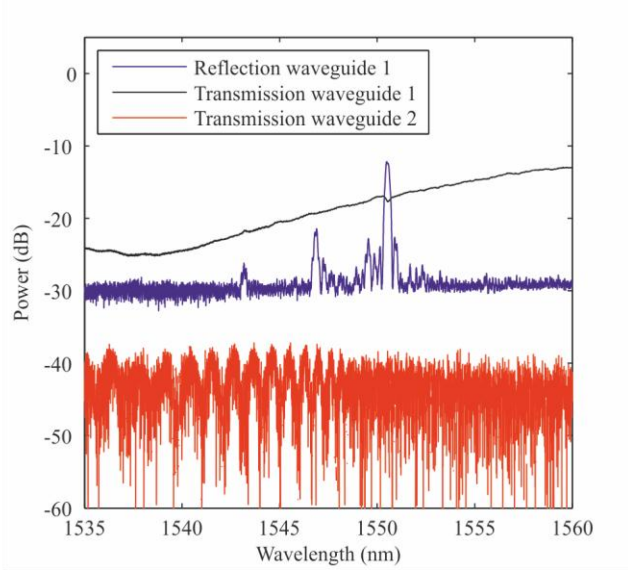

Figure 3. Measured spectrum from the device with 10 ° blaze angle.

These first non-optimized trial devices have relatively low coupling (0.5 %) and so are not suitable for any type of add-drop function, but offer a potential route for spectral monitoring with the advantage of separated output ports.

IV. Conclusions

We have implemented a waveguide design which allows coupling between two physically separated channel waveguides. Making changes to the blaze angle of the gratings changes the extent to which light propagates through the slab waveguide region between the two defined channel waveguides. The device has potential uses in sensing applications, and further investigation will take place into the limitations of the scheme. We will present theoretical analysis of the coupled mode behavior of the device, using a Cauchy integral method [2], alongside further advances of the experimental design and results.

References

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