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A Planar-waveguide 8-channel Arrayed Wavelength Division Multiplexing Coupler using Directional Coupler with Higher-order Mode cutting Filter for Waveguide Amplifier

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Abstract

We have developed a planar-waveguide 8-channel arrayed WDM coupler for EDWA application. The coupler is compact and can be directly connected to an EDWA chip. The insertion loss is less than 2.0 dB over the full C-band.

Introduction

The erbium-doped fiber amplifier (EDFA) has played a key role in the development of broadband fiber networks, which now span the globe. The challenge now is to reduce their size and cost. A candidate for meeting this challenge is the erbium-doped waveguide amplifier (EDWA) integrated with a wavelength division multiplexing (WDM) coupler [1,2]. However, it has two drawbacks: a large propagation loss for C-band signals and large crosstalk from the pump light to the signal light during demultiplexing, which degrades the noise figure (NF). We have thus taken a different approach and have developed an arrayed WDM coupler with high-Δ SiON waveguides, which are compact, have low loss and low crosstalk, and can be directly connected to an EDWA chip.

Design

As shown in Figs. 1 (a) and (b), our WDM coupler consists of a spot-size converter (SSC) for Hi-NA fiber, a higher-order mode cutting filter for the pump light, a directional coupler (DC), a pitch converter, and another SSC for the EDWA. The higher-order mode cutting filter consists of a tapered waveguide and an S-bend waveguide, as shown in the inset of Fig. 1 (b). Simulation results for the directional coupler during demultiplexing with and without the mode filter are shown in Fig. 2. The directional coupler was designed to demultiplex C-band signals and pumping light at 980 nm to cross and bar ports, as shown in Figs. 2 (a) and (b), respectively.

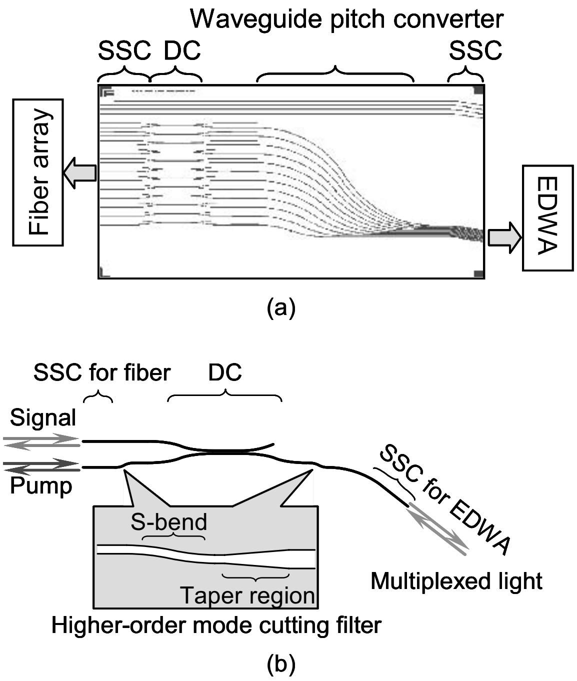

Fig. 1: Design of WDM coupler: (a) structure of the 8-channel arrayed WDM coupler, (b) one of the 8-channel arrayed WDM coupler.

Single-mode propagation is essential for low crosstalk. Because the wavelength of the pump light is much shorter than that of the signal light, if there is no mode filter, higher order modes of pump light can easily propagate along the directional coupler and then couple to the cross port, as shown in Fig.2 (d). This crosstalk degrades the NF of EDWA systems. Therefore, we added a higher-order mode cutting filter to suppress the crosstalk. In the wider portion of the tapered waveguide, both fundamental mode light and higher-order mode pump light can propagate. At the end of the waveguide, the fundamental modes of the signal and pump lights are still strongly confined in the core, as shown in Figs. 2 (a) and (b), respectively. The higher-order mode lights are weakly confined and radiate at the S-bend waveguide, as shown in Fig.2 (c). Simulation showed that, with the mode filter, the excess loss for the fundamental mode signal light was less than 0.1 dB, and the crosstalk was reduced by more than 24 dB.

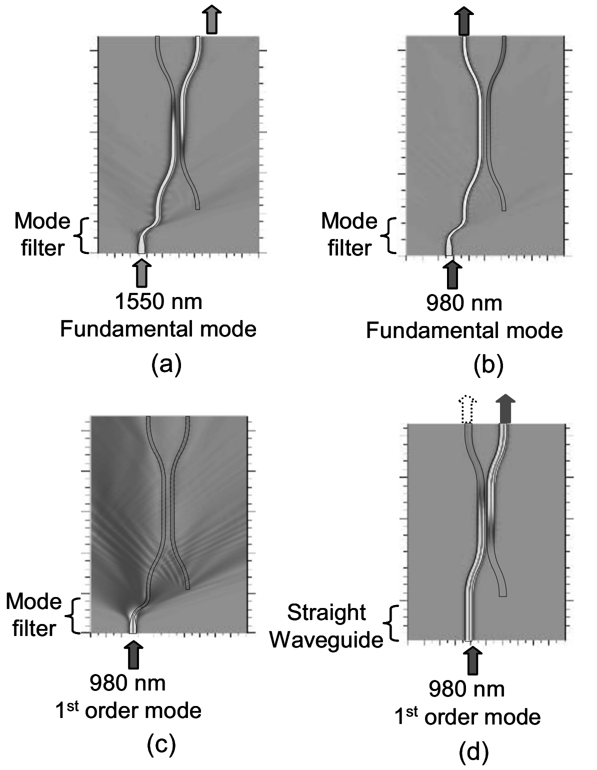

Fig. 2: Simulated operation of directional coupler during demultiplexing: (a) fundamental mode signal light with filter, (b) fundamental mode pump light with filter, (c) 1st order mode pump light with filter, and (d) 1st order mode pump light without filter

Performance

We fabricated an 8-channel arrayed WDM coupler with a higher-order mode cutting filter. The chip had a footprint of 11 × 5 mm.

As shown in Fig. 3, the insertion loss of the coupler was less than 2.0 dB, and the polarization-dependent loss was better than 0.2 dB over the full C-band. The estimated fiber-to-PLC coupling loss was about 0.7 dB/facet, and the estimated excess loss of the mode filter and directional coupler was about 0.5 dB. As shown in Fig. 4, the inter-channel loss uniformity was better than 0.3 dB. The crosstalk between the pump and signal lights was less than −30 dB. These characteristics are suitable for EDWA application.

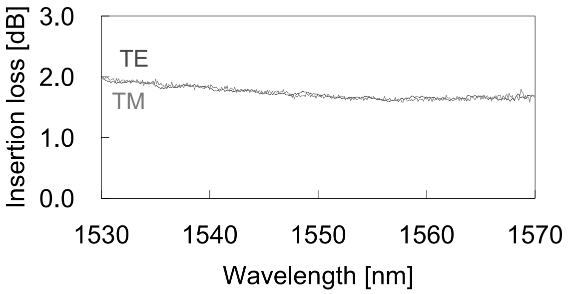

Fig. 3: Measured wavelength-dependent loss of WDM coupler

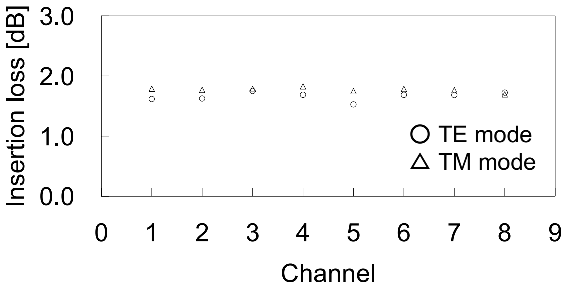

Fig. 4: Inter-channel loss uniformity of WDM coupler @1550 nm

Conclusion

We have developed a planar-waveguide 8-channel arrayed WDM coupler for multiplexing and demultiplexing C-band signals and 980-nm pump light for EDWA applications. It uses a directional coupler with a higher-order mode cutting filter. The WDM coupler chip is compact and can be directly connected to an arrayed EDWA chip. The insertion loss is less than 2.0 dB over the full C-band, and the inter-channel loss uniformity is better than 0.3 dB. The crosstalk between the pump and signal lights is less than −30 dB. This coupler is thus suitable for EDWA application.

Acknowledgements

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References

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