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Ten-channel mode-division-multiplexed silicon photonic integrated circuit with sharp bends

Key words: Silicon; Multimode; Waveguide; Euler-bends

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Motivation

1. Mode-division multiplexing (MDM) using multiple modes in a multimode bus waveguide can strongly enhance the link capacity of optical interconnects.
2. For an MDM system with a multimode bus waveguide, there might be a significant mode mismatch when the bending radius is small.
3. With Euler curves, sharp waveguide bends with a sharp radius and low losses are realized for fundamental mode.
4. Sharp bends based on modified Euler curves provide a good option for on-chip multimode data transmissions.

Main idea

1. A sharp multimode waveguide bend based on a modified Euler curve is demonstrated for the multimode bus waveguide supporting 10-mode channel on-chip transmissions.
2. The multimode PIC is demonstrated by integrating a pair of 10-channel on-chip mode (de)multiplexers and a multimode bus waveguide with sharp bends.
3. Ten-channel on-chip mode (de)multiplexers used here are based on cascaded dual-core adiabatic tapers.

Method

1. Ten-channel mode (de)multiplexer working with five cascaded dual-core adiabatic tapers is optimally designed for 10 modes (four TM modes and six TE modes).
2. The multimode bus waveguide with a sharp S-bend comprises two sharp bends based on a modified Euler curve.
3. Commercial software (Lumerical FDTD) was used to simulate the light propagation in the designed multimode waveguide bend.

Major results

1. The S-bend based on 90° Euler-bends with $R_{\text{eff}}=40 \mu\text{m}$ does not introduce significant excess losses or an inter-mode crosstalk.

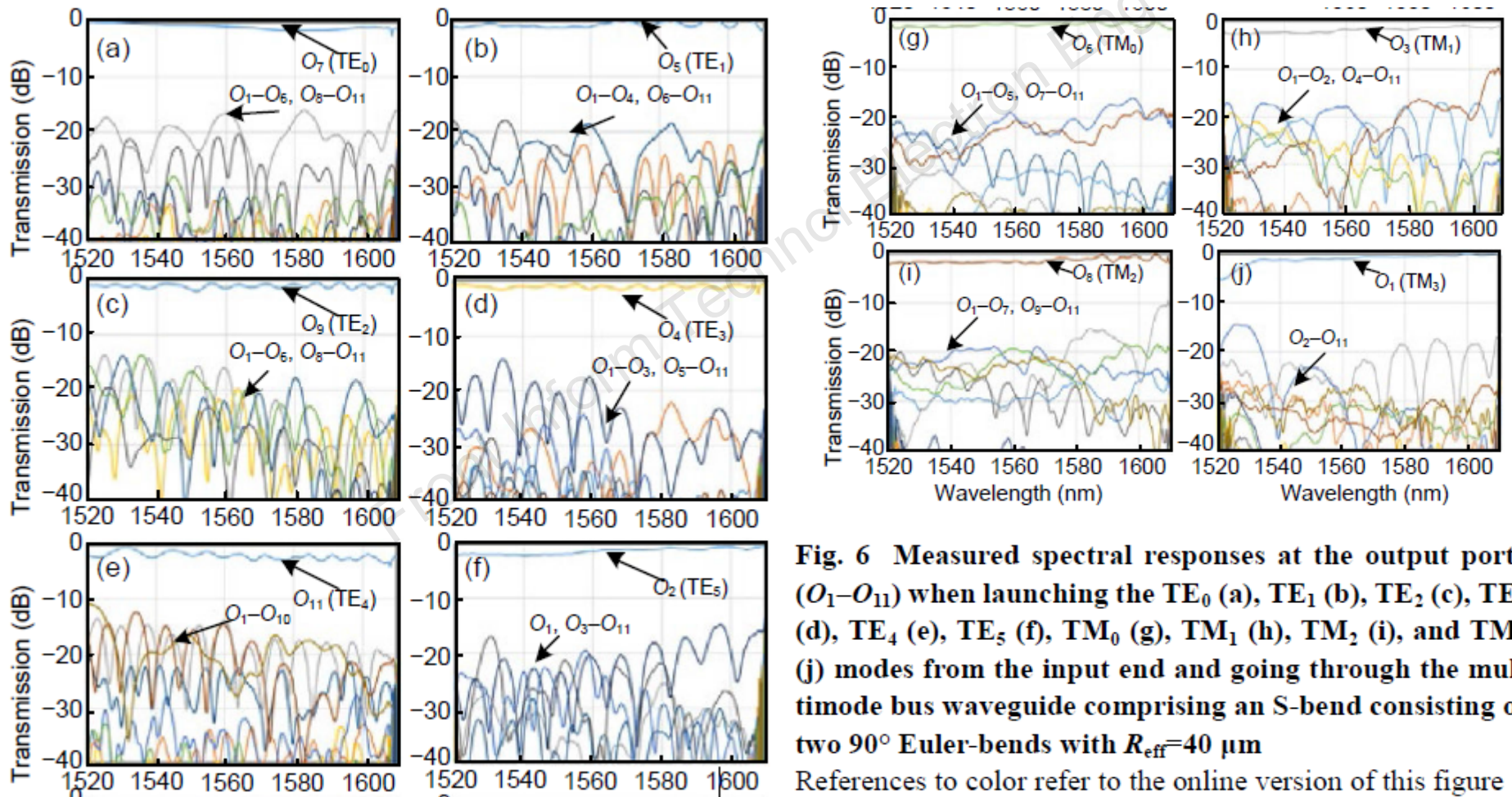


Fig. 6 Measured spectral responses at the output ports (O_1 – O_{11}) when launching the TE_0 (a), TE_1 (b), TE_2 (c), TE_3 (d), TE_4 (e), TE_5 (f), TM_0 (g), TM_1 (h), TM_2 (i), and TM_3 (j) modes from the input end and going through the multimode bus waveguide comprising an S-bend consisting of two 90° Euler-bends with $R_{\text{eff}}=40 \mu\text{m}$

References to color refer to the online version of this figure

Major results

2. Eye-diagrams for these 10 mode-channels are clear and widely open.

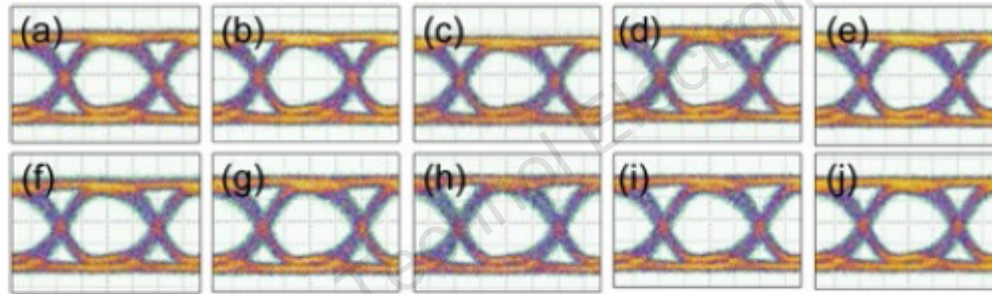


Fig. 10 Measured eye diagrams for data transmissions in the silicon PIC, which comprises a 10×1 mode multiplexer, a multimode bus waveguide with an S-bend based on modified Euler-bends, and a 1×10 mode demultiplexer: (a) TE_0 -mode channel; (b) TE_1 -mode channel; (c) TE_2 -mode channel; (d) TE_3 -mode channel; (e) TE_4 -mode channel; (f) TE_5 -mode channel; (g) TM_0 -mode channel; (h) TM_1 -mode channel; (i) TM_2 -mode channel; (j) TM_3 -mode channel

The bit rate is 26 Gb/s for a single mode channel

Conclusions

1. We have proposed and demonstrated multimode silicon PICs enabling on-chip transmissions with 10 mode channels by monolithically integrating two 10-channel mode (de)multiplexers and a multimode bus waveguide with a sharp S-bend based on modified Euler-bends.
2. The modified Euler-bends are optimally designed to have a small effective bending radius of $R_{\text{eff}}=40 \mu\text{m}$. Simulation results show that the designed Euler-bend works very well with low excess losses and low inter-mode crosstalk for all the mode-channels.
3. Measurement results have shown that the fabricated silicon PIC has low losses (0.9–1.9 dB) as well as low inter-mode crosstalk (about <-20 dB) in a bandwidth above 80 nm (1520–1600 nm).