Chen-lei LI, Xiao-hui JIANG, Yung HSU, Guan-hong CHEN, Chi-wai CHOW, Dao-xin DAI, 2019. Ten-channel mode-division-multiplexed silicon photonic integrated circuit with sharp bends. *Frontiers of Information Technology & Electronic Engineering*, 20(4):498-506. https://doi.org/10.1631/FITEE.1800386

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

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

Corresponding author: Dao-xin DAI
E-mail: dxdai@zju.edu.cn

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

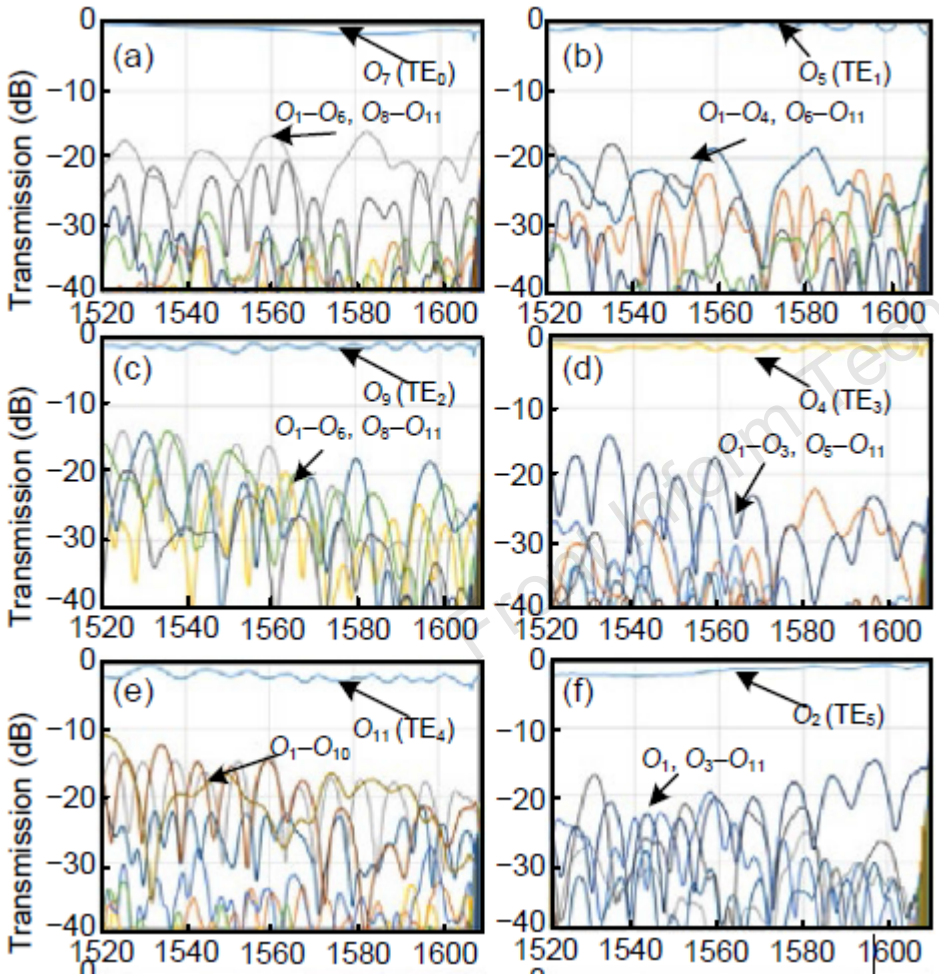
1. Ten-channel mode (de)multiplexer working with five cascaded dual-core adiabatic tapers is optimally designed for 10 modes (four TM modes and six TE modes).

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_{eff}=40 μm does not introduce significant excess losses or an inter-mode crosstalk.



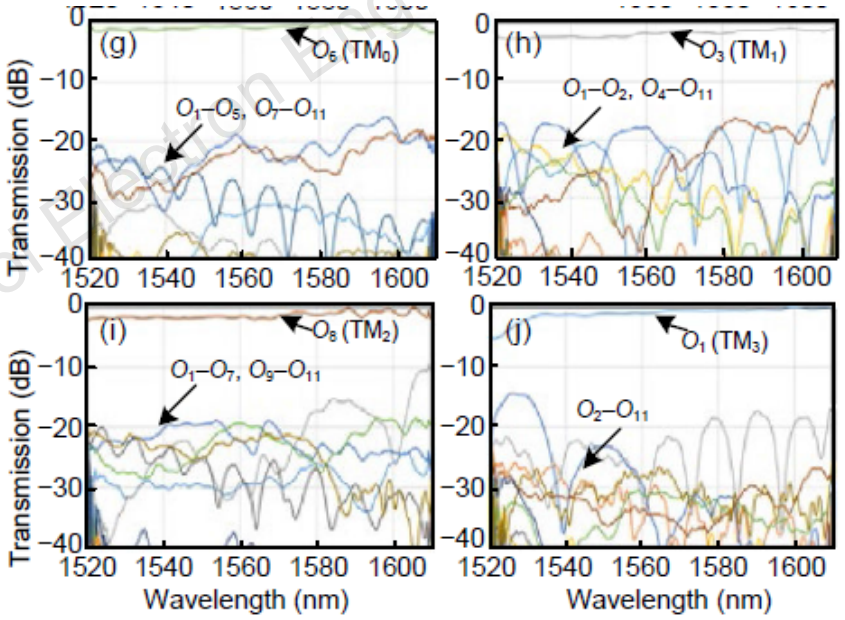


Fig. 6 Measured spectral responses at the output ports (O_1–O_{11}) when launching the TE$_0$ (a), TE$_1$ (b), TE$_2$ (c), TE$_3$ (d), TE$_4$ (e), TE$_5$ (f), TM$_0$ (g), TM$_1$ (h), TM$_2$ (i), and TM$_3$ (j) modes from the input end and going through the multimode bus waveguide comprising an S-bend consisting of two 90° Euler-bends with R_{eff}=40 μm

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.

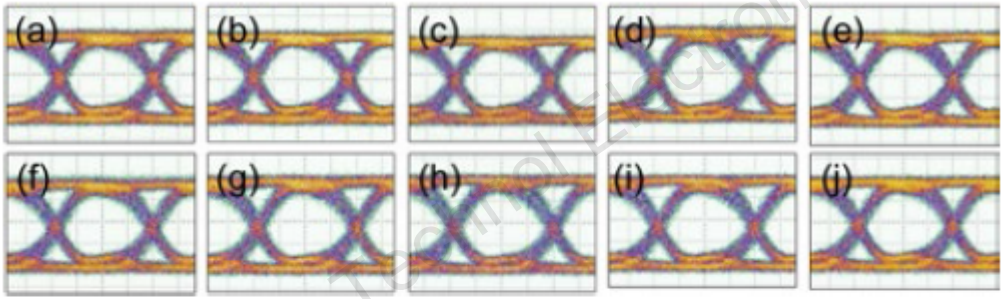


Fig. 10 Measured eye diagrams for data transmissions in the silicon PIC, which comprises a 10×1 mode multiplexer, a multimode bus waveguide with an S-bend based on modified Euler-bends, and a 1×10 mode demultiplexer: (a) TE_0-mode channel; (b) TE_1-mode channel; (c) TE_2-mode channel; (d) TE_3-mode channel; (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_{eff}=40 μm. 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).