Inverse-designed multi-wavelength, multi-mode optical interconnects using soliton microcombs

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Abstract: We demonstrate 130 Gbps transmission in each of 4 spatial modes using Si_3N_4 soliton microcombs and inverse-designed silicon mode multiplexers. Out of 52 carriers, 42 data channels show natively error-free data transmission.

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Use of optical interconnects can address data transfer limits of electrical link technology. Chip-scale optical communications have been mainly developed with multi-wavelength laser source and wavelength-division multiplexing (WDM) techniques [1–4]. In this work, we demonstrate inverse-designed photonic circuits to add new degrees of freedom for massively parallel optical communications. The inverse-design approach searches the full parameter space with fabrication constraints [5], and can be used for practical implementations of photonic systems.

We designed a mode-division multiplexer (MDM) for four spatial mode channels within a $6.5 \times 6.5\ \mu m^2$ device footprint. The silicon photonic MDM exhibits peak insertion loss less than 0.8 dB, 3-dB bandwidth wider than 150 nm, and channel crosstalk less than -18 dB for all mode channels. A chip-scale soliton microcomb with 300-GHz frequency spacing is an optical source of the transmitter (see Fig.1a). The multi-wavelength source is de-multiplexed using a commercial 100 GHz ITU grid based DWDM and external modulators encode independent data on each channel (10-Gbps NRZ). All wavelength channels are recombined and transmitted through a silicon photonic back-to-back MDM chip. The light at the MDM output is directly detected using a 14 GHz bandwidth photodiode, and the detected signal is sent to an error analyzer and an oscilloscope. A total of 52 data channels are derived from all the comb lines in the C band and 4 spatial mode channels. It is important to note that we can derive more wavelength channels using adjacent frequency bands and narrower comb spacing. Detailed information on the experiment setup and device design are described in [6]. Fig. 1b-c presents measured eye diagrams and bit-error-rates (BERs) of all data channels. A total of 42 data channels show BERs lower than 10^{-12}, and signal degradation at specific wavelength channels (e.g. C46, 49, and 52) is attributed to lower comb line power. We also demonstrate 1.28-Tbps data transmission using a mode-locked laser with a 20-GHz wavelength channel spacing [6]. Furthermore, we demonstrate chip-to-chip optical link across four spatial mode channels in combination with a rectangular core fiber [7] and inverse-designed grating couplers.

In conclusion, we have demonstrated multi-dimensional data communication at 130 Gbps per spatial mode channel using soliton microcomb lines in the C band. Near-term future work will focus on enabling a chip-to-chip optical link with a microcomb source and multimode fiber [7], increasing the data rate per spatial mode channel, and enabling a full integration of a WDM-MDM link. We believe this work shows the viability of a silicon photonic WDM-MDM architecture with integrated laser sources to meet bandwidth density and FEC-free requirements of computing fabrics.

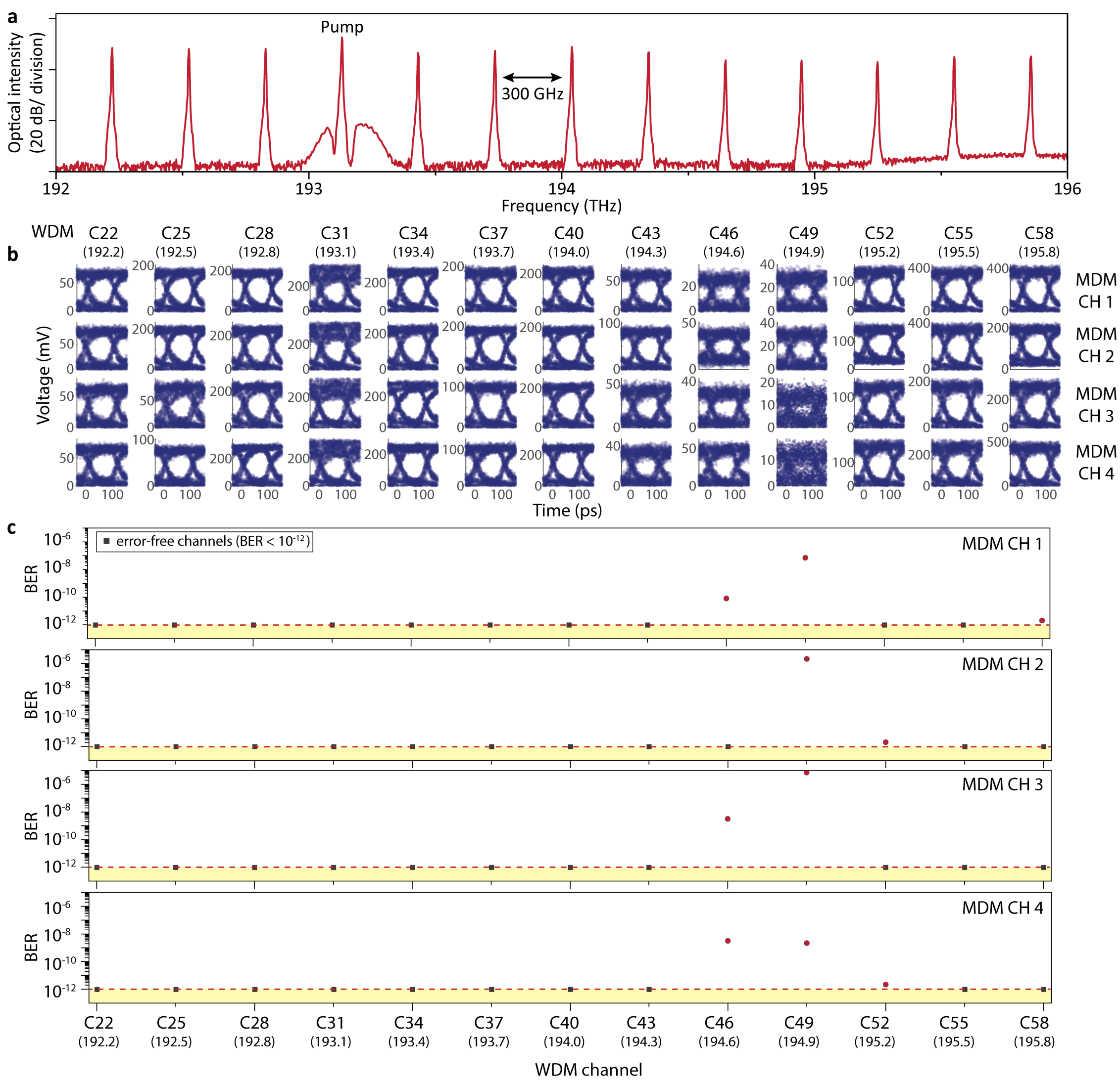

Fig. 1: **On-chip multi-dimensional data communication with soliton microcombs (a)** Optical spectrum of soliton microcombs in C-band. (b) 10-Gbps eye diagrams of 52 data channels (13 wavelengths and 4 spatial modes). (c) Measured bit error rates (BERs) of data channels. The plots are adapted from [6]

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