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Optical fiber-to-chip assembly process for ultra–low loss photonic devices based on silicon nitride for space applications

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Introduction:

We demonstrate an efficient fiber array-to-chip assembly process with 32x32 input/output ports. The proposed approach is based on using a pre-alignment coupling structure to separately align the input and output ports. The assembly process has been experimentally validated in photonic integrated circuits fabricated with a silicon nitride-based ultra-low-loss waveguide technology (9.5 dB/m propagation loss). The developed technology and alignment procedure is poised to be used in high-count port PICs supporting multi-beam operation for space applications

1. Ultra-low low loss Silicon nitride PIC platform

- Large aspect ratio waveguides (2.8µmx 0.1µm)
- Fabrication with LPCVD and i-line lithography
- Optimized Reactive ion etching to ensure smooth sidewalls
- 1.6 µm low-temperature oxide (LTO) cladding annealed at 1000ºC (t>x hours)
- Low modal confinement (neff≈1,45) and low loss (9,5dB/m)

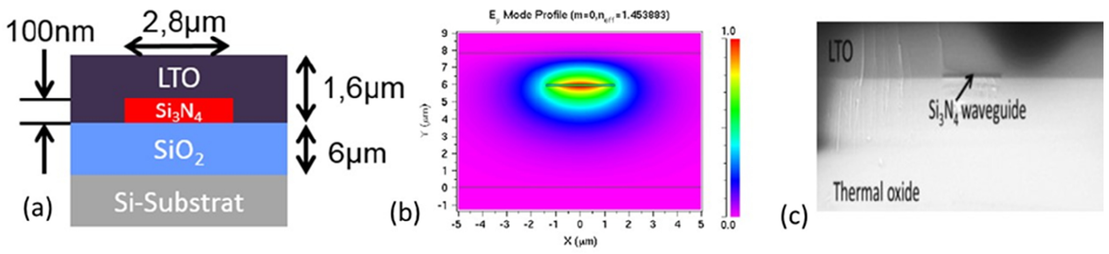


Figure 1.(a) Ultra-low loss photonic waveguide cross-section, (b) simulated mode profile for TE polarization and (c) SEM micrograph of the fabricated waveguide

2. Design of the pre-alignment photonic coupling structures

- Negative angle grating couplers to ease the alignment procedure
- 1/99 directional couplers -> constant port-to-port output powers (-20dB)

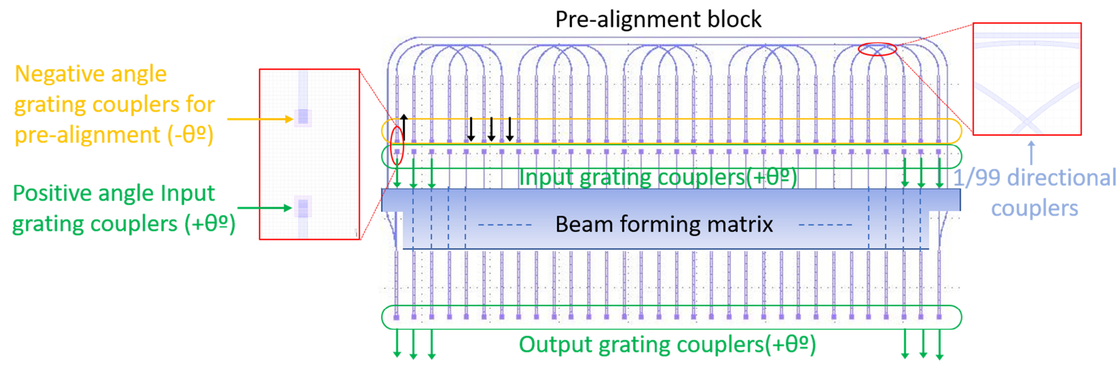


Figure 2. Layout for fiber array pre-alignment

3. Experimental demonstration of the fiber array-attach process

- Step 1: Alignment of the input fiber-array with the raw of negative angle grating couplers (-θº)
- Step 2: Measurement of adjacent ports to check each fiber/grating coupler relative position
- Step 3: Measurement of the most distant I/O grating couplers (ports 1-32) to check the fiber array-PIC relative position
- Step 4: Translation of the fiber array from the negative angle grating couplers (-θº) to the positive angle ones (+θº)
- Step 5: Alignment of the output fiber array with the row of output grating couplers.

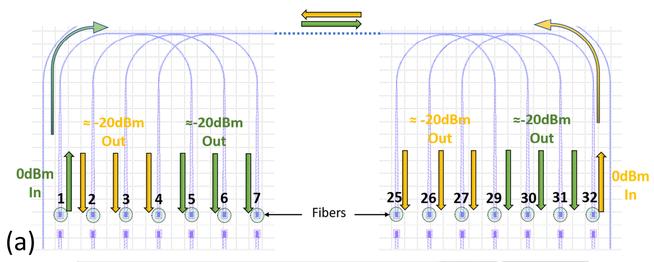
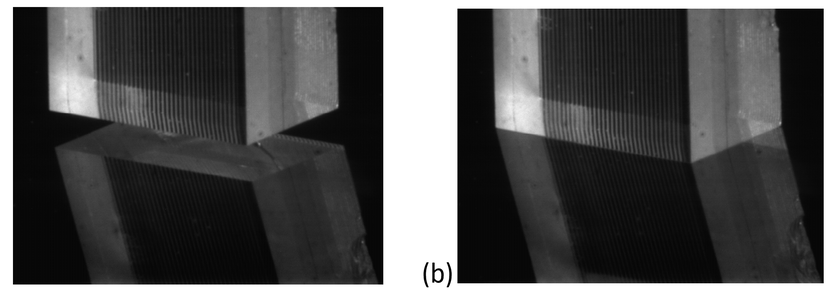


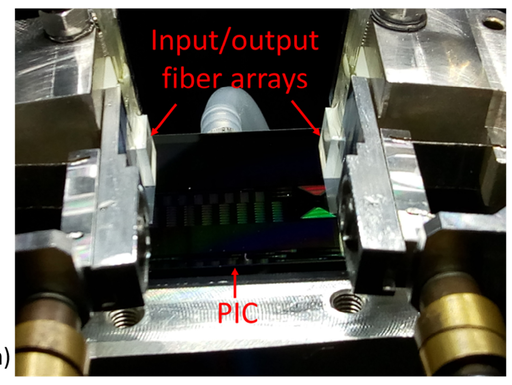
Figure 3.(a) Pre-alignment layout (b) side view of the fiber array aligned with the row of backward coupling (-θº) grating couplers



(a) (b)

Figure 5.Picture of the fiber array (a) before and (b) after touchdown

Bench overview after alignement of both Input/Output fiber arrays



(a)

Single-mode fiber arrays

Coupling loss fiber-to-fiber: 9.3dB±0.7dB

Insertion loss:4.65±0.35 dB/grating coupler

Polarization-maintaining fiber arrays

Coupling loss fiber-to-fiber: 10,1dB±0.6dB

Insertion loss: 5.05±0.3 dB/grating coupler

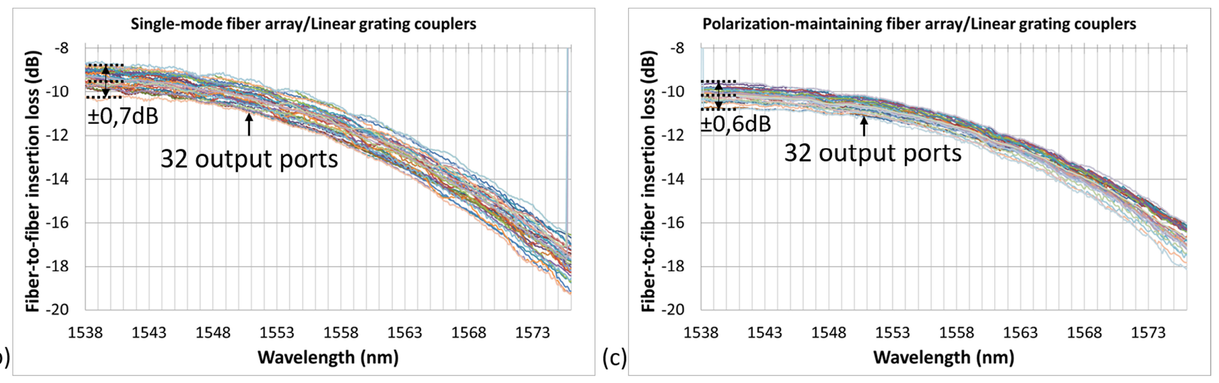


Figure 4.(a) Picture of the alignment bench after I/O fiber/PIC alignment (b) Spectral transmissions with single mode fiber (SMF) -arrays (through the 32x32 I/O ports and c) with polarization maintaining (PM) fiber-arrays

CONCLUSIONS:

A fiber array-to-PIC assembly process to optically interconnect ultra-low loss photonic integrated circuits with a high number of input/output ports has been demonstrated. The proposed approach is based on using pre-alignment photonic structures to ease the alignment process, hence allowing us to reduce the assembly time and cost. Low loss grating couplers have also been developed and demonstrated. These results represent a significant step forward towards the integration of photonic technologies for space applications.

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