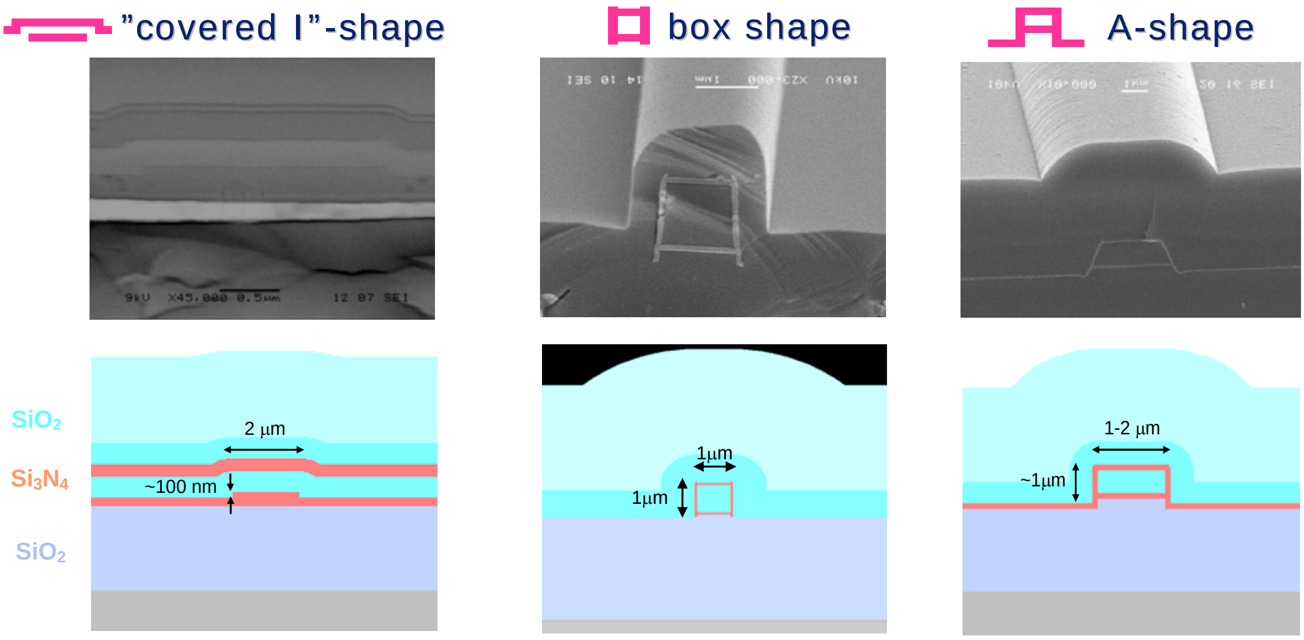
TriPleX™ Planar Lightwave Circuits

TriPleX™ waveguides form a new class of integrated-optic planar lightwave circuits using low-cost, CMOS-compatible technology. The waveguides are based on LPCVD processing of alternating Si_3N_4 and SiO_2 layers. This technology allows for medium and high index-contrast waveguides that exhibit low channel attenuation. In addition, TriPleX™ waveguides are suitable for operation at wavelengths from < 500 nm through 2 µm and beyond.

Design by geometry

Channel attenuation in TriPleX™ waveguides is very low. Important waveguide characteristics, such as modal birefringence, minimum bending radius, and insertion loss are completely dependent upon the geometry of the waveguide layer structure. As a result, desired performance is not determined by material characteristics, but simply by design of the waveguide geometry. This leads to a vast design freedom and extremely stable performance.



The channel geometry of a TriPleX™ waveguide comprises a composite core having a low index inner-core of SiO_2 and a high index outer-core of Si_3N_4. The structure is fabricated on a conventional substrate, such as thermally oxidized silicon or glass. A typical composite core has a cross-sectional area of approximately 1 μm^2; however, each specific design depends strongly upon its intended application. Modal characteristics are determined solely by the geometry of the structure. And, the constituent material layers have very reproducible characteristics, as the core materials are stoichiometric films that are deposited using Low-Pressure Chemical Vapor Deposition (LPCVD). The fabrication process is completely CMOS-compatible. Finally, TriPleX™ waveguides can be highly cost-effective as only one photo lithographical step is required in most cases [1-3].

Results

The table below provides characteristic operating performance for a single-mode boxed-shaped TriPleX™ waveguide, which was designed for low propagation loss and low modal birefringence. As this data demonstrates, for such waveguides, both attenuation and modal birefringence can be quite low. Overall loss, as well as polarization-dependent loss, therefore, can be kept to levels normally associated with low-contrast conventional waveguides. In addition, the coupling efficiency associated with the coupling of a TriPleX™ waveguide and an optical fiber can also be high. Such coupling efficiency results from a close match of mode profiles in both the waveguide and the fiber.

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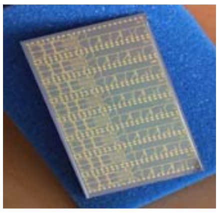
It should be noted that modal birefringence can be tailored over a wide range: from very small, for communications applications, to very large, for sensor applications wherein it is desirable to strip one polarization mode completely.

Group Birefringence (B_g)	Channel Attenuation (dB/cm)	Polarization Dependent Loss (PDL) (dB/cm)	Insertion Loss (IL) (no spot size converter (dB))
$< 1\times10^{-4}$	< 0.10	<0.10	0.15 (small core fiber - 3.6 μm MFD)

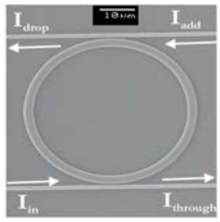
Table 1: *Performance characteristics for a boxed-shaped TriPleX™ waveguide.*

Applications

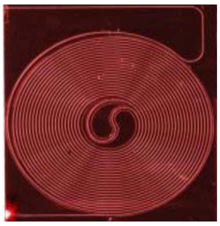
XiO Photonics has targeted several applications for which it believes TriPleX™ waveguide technology affords particular advantage. These include:



Optical Beam-Forming Networks
Smart Antenna systems are being developed to enable efficient and cost-effective wireless communication in spacecraft and airliners. In such systems, optical Beam-Forming Networks based on an all-optical True-Time Delay offer improved performance over electronic phase-shifters [4]. The frequency independence of an all-optical True-Time Delay enables a simpler, less expensive control system and improved overall system performance.



Reconfigurable Optical Network Components
The Reconfigurable Optical Add-Drop Multiplexer (ROADM) is considered a key network element for achieving high system functionality at low cost [3]. ROADMs offer advantages such as: an electro-optical (EO) conversion-free data path, monolithic integration of multiple functions, cost savings in packaging, small device-area, low power consumption, and reconfigurability that enables increased system flexibility.



Sensing Networks
A biochemical or chemical sensor can be readily formed by etching a sensing window in the top-cladding of an integrated waveguide [5]. High-contrast waveguides are well-suited for IO-sensing applications because they exhibit a very large evanescent-field component. In addition, the integration of mode filters, interferometric principles and other optical functions needed for highly sensitive and selective sensing is readily accomplished in high-contrast waveguides, such as TriPleX™ waveguides.

References

[1] U.S. Patent application nr. 10/756627-001, "Low modal birefringent waveguides and methods of fabrication", January 2004.

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[3] F. Morichetti, A. Melloni, M. Martinelli, R.G. Heideman, A. Leinse, D.H. Geuzebroek and A. Borreman. "Box shaped Dielectric Waveguides: A new Concept in Integrated Optics", Journal of Lightwave Technology, Vol. 25, No 9, September 2007.

[4] C.G.H. Roeloffzen, L. Zhuang, R.G. Heideman, A. Borreman, and W. van Etten, "Ring resonator-based tunable optical delay line in LPCVD waveguide technology", proc. Leos Benelux Ch., 2005.

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