SPIE Newsroom

10.1117/2.1200806.1166

Designing a next-generation waveguide by geometry

Willem Hoving, Douwe Geuzebroek, and Rene Heideman

TriPleX waveguide technology has the potential to become the standard for industrial integrated optics in visible and infrared light applications.

Planar lightwave circuits (PLCs) have broad application in areas ranging from space to telecommunications to sensing. For example, PLC technology can be used in optical true-time delays for phased array antennas. These delays make possible a simpler, less-expensive control system and improved performance that could benefit wireless communication in space and air.[1] PLCs also have utility in integrated-optic network components, such as optical add-drop multiplexers (OADMs).[2] These devices help achieve high system functionality in fiber-to-the-home networks. Finally, PLC techniques can be used for optical sensors and emerging visible applications, since they enable integration of mode filters, interferometric principles, and other optical functions required for compact, highly sensitive and selective devices. Figure 1 gives an overview of optical integration technologies.

Integrating functions has several advantages over discrete solutions. Lower costs, mass production, stability, and form factor (footprint area and volume) are all well-known drivers for integration. Achieving integration in the field of optics will require meeting a number of specifications. First, to ensure tight bends and consequently small structures, the technology must offer high contrast in refractive index between the light-guiding layer and the surroundings. Second, there must be a way of correcting for additional losses owing to the greater number of functions. Third, because polarization is so important, there must be a way to control it. Finally, transparency for a large range of wavelengths is essential to guarantee the maximum flexibility required of an industrial standard for integration.

We have developed the TriPleX waveguide technology, which is capable of meeting these requirements. It consists of alternating layers of silicon nitride (Si_3N_4) and silicon dioxide (SiO_2) formed by CMOS-compatible low-pressure chemical vapor deposition (LPCVD). TriPleX is fully transparent for wavelengths

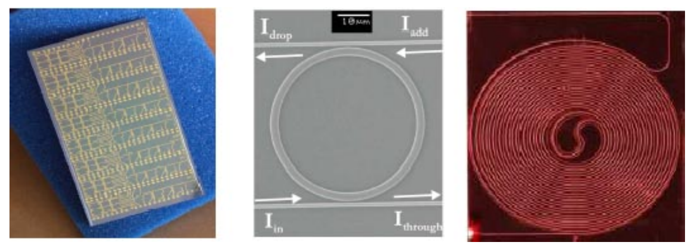

Figure 1. *Examples of optical integration: (from left to right) optical beam forming for phased array antennas, microring resonator filter for R-OADMs, and spiral waveguide for optical sensor. R-OADMs: Reconfigurable OADMs.*

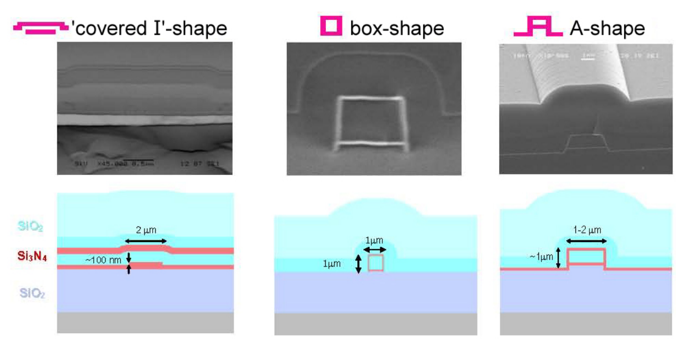

Figure 2. *Scanning electron microscope image (top) and schematic view (bottom) of cross-sections of typical waveguide structures, with LPCVD silicon nitride (Si_3N_4) (dark red) as the basic waveguiding layer, filled with and in turn encapsulated by silicon dioxide (SiO_2) (grey/blue and green/blue).*

from <400nm up to 2μm and beyond. The technology also allows for medium- and high-index-contrast waveguides.

As shown in Figure 2, the channel geometry approximates a 'hollow core' system. It consists of a low-index inner core of SiO_2 cladded with the high-index outer core of Si_3N_4. The nitride shell has typical outer dimensions in the order of 1μm^2, with its precise characteristics depending strongly on the desired

Continued on next page

10.1117/2.1200806.1166 Page 2/2

Table 1. *Performance characteristics for a box-shaped TriPleX waveguide for telecom applications (wavelength: ∼1500nm).*

Group birefringence (B_g)	Channel attenuation (dB/cm)	Polarization-dependent loss (dB/cm)	Insertion loss to small-core fiber (dB) without spot-size converter
$<1\times10^{-4}$	<0.06	<0.10	0.15

application. Channel attenuation in TriPleX waveguides is very low over a wide range of wavelengths from visible (<400nm) through the IR range (2μm and beyond). Essential waveguide features such as modal birefringence, minimum bending radius, and insertion loss depend only on the geometry of the waveguide layer structure. This leads to vast design freedom and extremely stable performance over time, as all the constituent materials are LPVCD end products, which have stoichiometric composition. Consequently, there is no unwanted absorption peak near 1505nm due to N–H bonds from hydrogen incorporation. Finally, TriPleX waveguides can be highly cost-effective, since in most cases only one photolithographic step is required.[2–4]

Table 1 provides characteristic operating performance for a single-mode box-shaped TriPleX waveguide. Both attenuation and modal birefringence as well as polarization-dependent loss are kept to levels normally associated with low-contrast conventional waveguides. In addition, the efficiency associated with the coupling of a TriPleX waveguide to an optical fiber can also be high and is optimized through appropriate tapering of the waveguide shape.

In conclusion, the TriPleX technology is interesting for applications that require coupling into and out of the optical fiber network infrastructure. The reasonably small bending radii allow small footprints, and thus reduced cost. The results reported for TriPleX demonstrate its high potential for large-scale integrated optics, not only in telecommunications but also applications in the newly emerging areas of data communications, sensing, and visible light. Within the SmartMix program MEMPHIS,[5] a consortium of 22 companies, universities, and research institutes is developing photonic integration technology to open the way to major new applications for the use of light in medical diagnostics, health care, entertainment, and communications. A major activity is to integrate microelectronics and photonics in one common technology platform.

Author Information

Willem Hoving and Douwe Geuzebroek
XiO Photonics
Enschede, The Netherlands

Rene Heideman
LioniX B.V.
Enschede, The Netherlands

References

1. 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. IEEE/LEOS Benelux**, pp. 79–82, 2005.
2. R. G. Heideman, A. Melloni, M. Hoekman, A. Borreman, A. Leinse, and F. Morichetti, *Low loss, high contrast optical waveguides based on CMOS compatible LPCVD processing: technology and experimental results*, **Proc. IEEE/LEOS Benelux**, pp. 71–74, 2005.
3. R. G. Heideman and M. Hoekman, *Low modal birefringent waveguides and methods of fabrication*, **US Patent 10/756627-001**, 2004.
4. 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*, **J. Lightwave Technol. 25** (9), 2007.
5. http://www.smartmix-memphis.nl Website of the Memphis (Merging Electronics and Micro- and Nano-Photonics in Integrated Systems) project. Accessed 21 May 2008.