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Silica-Based Planar Lightwave Circuits for the Future Photonic Networks

Akira Himeno

NTT Photonics Laboratories
162 Tokai, Naka-gun, Ibaraki, 319-1193, Japan
Phone: +81-29-287-7407 Fax: +81-29-287-7877 e-mail: himeno@iba.iecl.ntt.co.jp

1. Introduction

The rapid and global spread of the Internet and multimedia communications has accelerated the growth in optical communications networks. Optical wavelength-division multiplexing (WDM) transport networks [1] and optical access networks for fiber-to-the-home [2] have been developed to enlarge the network service capacity and increase its flexibility. Planar lightwave circuits (PLC), in which fiber-matched silica-based waveguides are integrated, can provide various key practical devices for such optical networks [3]. This is because they are suitable for large-scale integration, offer long-term stability, and can be mass produced. Figure 1 shows examples of PLC applications in advanced optical networks.

This paper reviews recent progress on silica-based planar lightwave circuits with an emphasis on new devices and technology developed in NTT Laboratories.

2. New Fabrication Technology

Very recently a number of new technologies have been developed to improve PLC fabrication. One such technology is related to PLCs with higher Δ design to allow the dense integration of various kinds of circuits and reduce the cost of PLC devices [4]. GeO_2-doped silica waveguides on Si with a Δ of ~1.5% (super-high Δ or SH Δ) and a core size of ~4.5 μm^2 have been successfully fabricated by improving the conventional fabrication method, which consists of flame hydrolysis deposition and reactive ion etching. The bending loss of these waveguides is less than 0.1 dB/90 degrees for the TE and TM modes up to a radius of 2 mm. The propagation loss is 0.05 dB/cm for a 40 cm long waveguide. This value is almost the same as that of the 0.75% Δ waveguide, with which many kinds of AWG have been developed [5].

Another technology is focused on lowering AWG insertion loss incorporating vertically tapered waveguides in an arrayed-waveguide. This approch can reduce the transition loss that occurs at the junction between slab and arrayed-waveguides [6]. With 0.75% Δ waveguides, the novel structure provides a loss reduction of 1.5 dB and a minimum insertion loss of 0.8 dB. Moreover, the structure is useful for waveguides with various Δ values and has no detrimental effect on the AWG characteristics.

3. Evolution of AWG

The new technologies described above have been used to extend the AWG family from small channel number AWGs for metropolitan networks to larger channel numberAWGs designed to increase network capacity.

AWGs with a large number of channels and a narrow channel spacing are the next targets as regards future photonic networks. A SH-Δ waveguide with small bending radius will allow us to construct very-large-scale PLCs. A

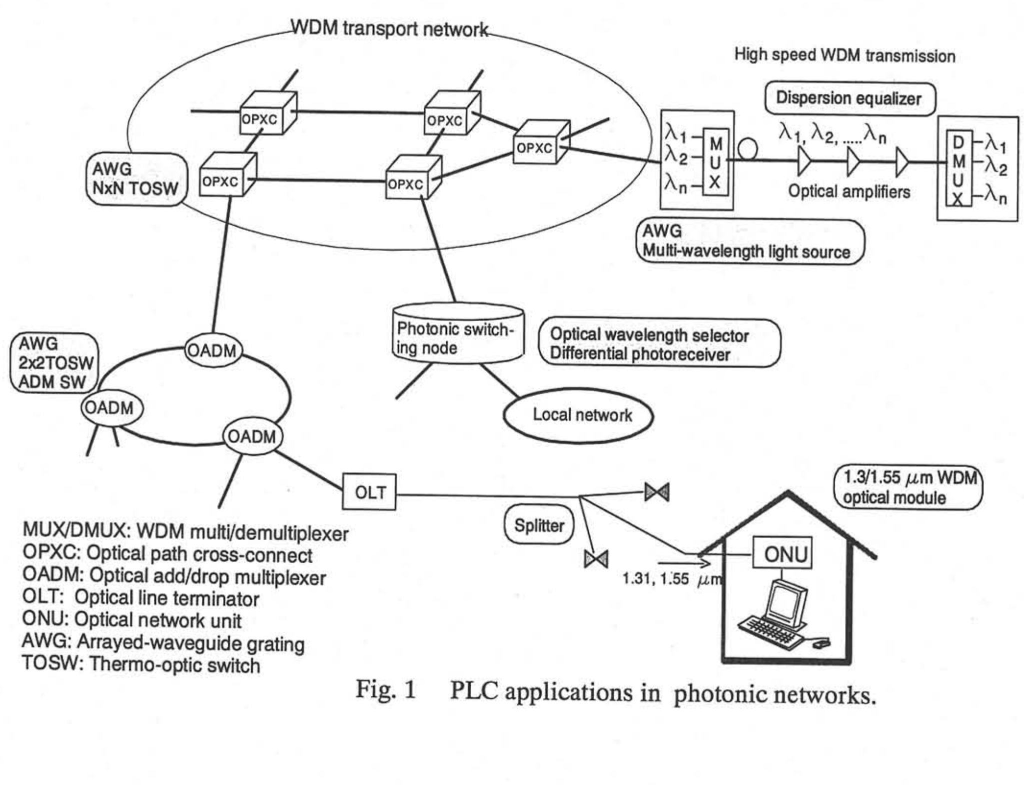


Fig. 1 PLC applications in photonic networks.

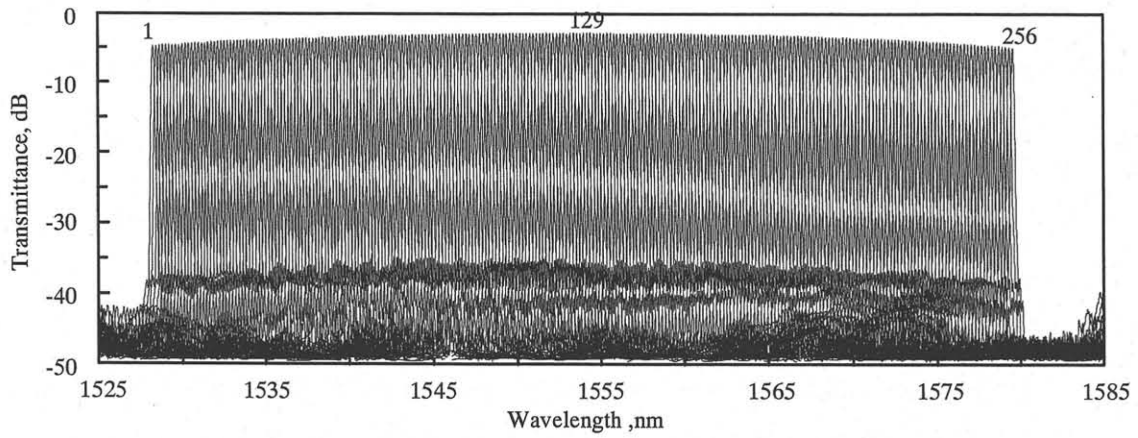


Fig. 2 TE mode spectra of SH-Δ AWG with 256 channels and 25 GHz spacing.

256-channel 25 GHz spacing AWG was fabricated using this Δ waveguide [4]. The TE mode spectra of this AWG are shown in Fig. 2. A very low on-chip loss is obtained, which from 4.4 to 6.4 dB for the central and peripheral output ports. The 3-dB bandwidth and crosstalk are 0.12 nm and -33 dB, respectively. The PD-λ of the AWG is less than 0.03 nm.

4. Silicon Terrace Technology

Optical hybrid integration is a promising way of producing low cost and functional optical components where opto-electronic devices are integrated with a silica-based PLC on Si. Si terrace technology in silica PLCs can provide platforms for hybrid integration [7]. A schematic illustration of a PLC platform with a silica-on-terraced-silicon structure [27] is shown in Fig. 3.

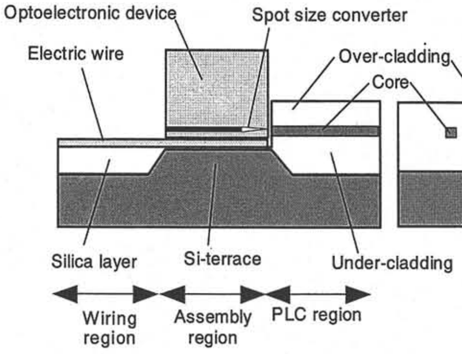
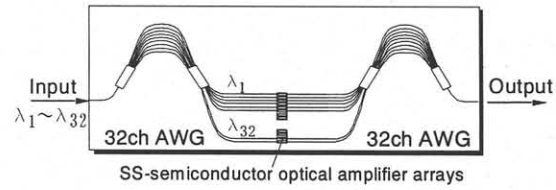


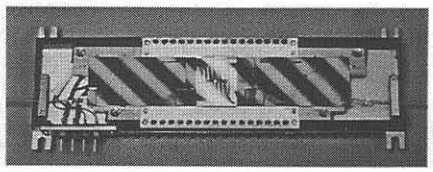
Fig. 3 PLC platform with silica-on-terraced-silicon

The optical-wavelength-selector, which is a key component in WDM systems, can select optical packets from among several optical WDM signals by tuning on the corresponding optical gates. Recently, a 32-channel selector module was developed using this technology (Fig. 4) [8]. It consists of two AWGs and 32 hybrid-integrated spot-size converted semiconductor optical amplifiers

The fabricated module has excellent characteristics including an average insertion loss of 2.3 dB, a low on/off crosstalk of better than –45 dB and a short switching time of less than 1 nsec. Thus the technique will play an important role in the realization of functional opto-electronic devices for future photonic network systems.



a) Configuration



b) Photograph of fabricated module

Fig. 4 Hybrid-integrated 32 ch wavelength selector

5. Conclusion

This paper has described the most recent developments in relation to PLC devices and technologies for WDM applications. The current and soon to be developed PLC components and technologies will contribute to the construction of dense WDM networks and photonic networks.

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