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Invited

Monolithic Photonic ICs for Photonic Networks

Hiroshi Yasaka and Yuzo Yoshikuni

NTT Photonics Laboratories
3-1, Morinosato Wakamiya, Atsugi-shi, Kanagawa-Pref., 243-0198 Japan
Phone; +81-462-40-2820,
Facsimile; +81-462-40-2859,
E-mail; yasaka@aecl.ntt.co.jp

1. Introduction

Recently, demands on large-capacity multimedia communication networks to handle large amounts of data for supplying many kind of services have much increased. Photonic transport networks (PTN) based on wavelength division multiplexing (WDM) and wavelength routing technologies will play an important role in future large-capacity multimedia communications. The photonic transport system (PTS), which routes or cross-connects multiple wavelengths, is the key network element to realize PTN. A PTS based on the virtual wavelength path (VWP) concept will offer many benefits for network operation [1]. A PTS with 320Gb/s throughput has already been demonstrated [2]. In such a system, many optical components are used to realize highly functional transport nodes. Light sources, optical intensity modulators, optical amplifiers, optical switches, optical combiners, and optical demultiplexers are key components in the system. To fabricate a highly-functional compact PTS, these components have to be realized in small size. Semiconductor optical components are advantageous for this purpose, because they are very small and also have capability of monolithically integrating several optical components on the same semiconductor substrate in a compact size. Monolithically integrated photonic components will show high functionality with small size.

The multiple signals in an optical fiber with various wavelengths are divided into individual optical paths in the PTS and cross-connected to the desired output optical fiber after being processed and multiplexed to a WDM signal. The optical signal experiences optical losses of the used passive optical components in the PTS and the signal to noise ratio (SNR) of the optical signal degrades. To restrain SNR degradation and keep signal quality high, compact optical amplifiers are indispensable to amplifying the signal intensity and keeping SNR high. The amplification should be done in the individual optical path of the PTS, so the number of the optical amplifiers, which should be used in the photonic transport nodes, becomes large when the throughput of the PTS becomes large. Semiconductor optical amplifiers (SOAs) meet this demand [3]. SOAs provide optical gain to the optical components when they are integrated into other optical components. They can also be used as optical gates [4].

In this paper, the authors introduce some activities on monolithic photonic integrated circuits (ICs) toward future large-capacity photonic transport networks.

2. Photonic ICs

In the PTN, channel monitoring is indispensable in maintaining the stability of the operation of the system. A compact channel monitoring optical circuit is useful for this purpose. The optical circuit has been realized by integrating an optical filter and photo-detectors on the same semiconductor substrate. Here, an arrayed waveguide grating (AWG) filter based on InP is adopted as wavelength demultiplexer [5]. The photograph of the monolithically integrated wavelength monitor on an InP substrate is shown in Fig. 1.

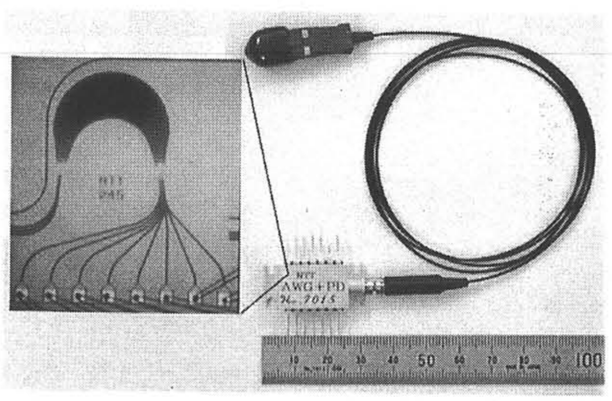

Fig. 1 WDM channel monitor fabricated on InP substrate and its module

This device is designed for the equally(200GHz)-spaced 8-channel WDM system and is conposed of an AWG and eight photo-detectors (PDs). A WDM signal is demultiplexed by an AWG filter and the individual channel is introduced into a PD in accordance with signal wavelength. The received optical signal is converted to an electrical signal by the PDs and the signal wavelength and power are monitored. The chip size is only 3 x 3mm^2. The module of the WDM channel monitor is very compact and the size is almost the same as the conventional light source (for example, DFB laser) modules. The output electrical spectra of the monitor are shown in Fig. 2. The crosstalk among the neighboring channels is higher than 20dB. This small-size monitor will be used at various points of the PTS to monitor the individual channel power and wavelength.

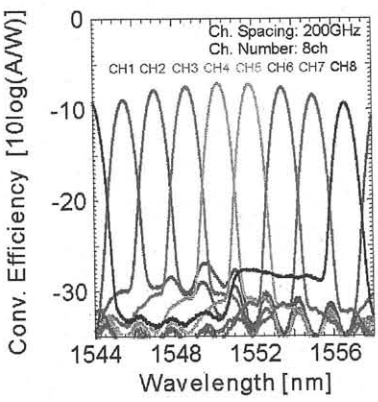

Fig. 2 Output spectra of WDM channel monitor

A channel selection function is also indispensable in the PTS to select or drop arbitrary wavelength channels from the WDM signal. The WDM channel selector is also useful in the VWP-PTS system, in which an opto-electric wavelength converter is used and an arbitrary wavelength light is selected by using a silica-based wavelength selectable optical switch [6]. A compact eight-channel WDM channel selector is realized by integrating two AWG filters and eight semiconductor optical amplifier (SOA) gates on an InP substrate [7]. Fig. 3 shows the photograph of the channel selector chip, whose size is 5 x 4 mm^2.

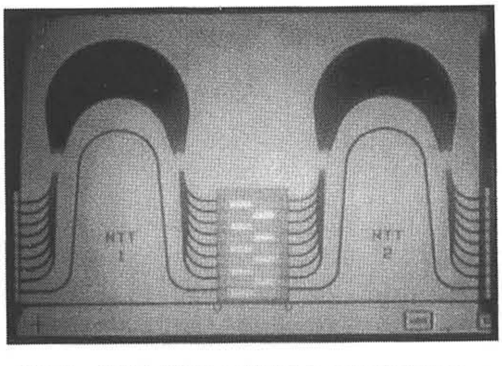

Fig. 3 Eight-channel WDM channel selector fabricated on InP substrate

The input WDM signal coupled into one of the input waveguides of the first-stage AWG filter is demultiplexed and delivered to the output optical waveguides of the AWG filter in accordance with their wavelengths. The divided signals are introduced into the SOA gates and then multiplexed again by second-stage AWG filter after selecting which channel is selectively output by the electrical signal applied to the SOA gates. The spectra of the selected outputs from the WDM channel selector are shown in Fig. 4. Loss-less operation of the selector can be done when the bias current to an SOA gate is 200mA, where the SOA gate has sufficient optical gain compensating the optical losses of AWG filters. The crosstalk among the neighboring channels is as high as 40dB.

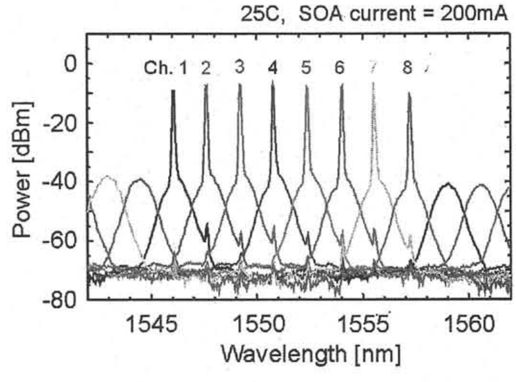

Fig. 4 Output spectra of WDM channel selector

Here, some monolithically integrated photonic ICs are introduced. Demands for monolithic integration of functional optical components will increase in the near future.

3. Summary

Highly functional and compact monolithically integrated photonic ICs on semiconductor substrates will play an important role in realizing future large-capacity and highly functional photonic transport networks.

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