60-dB Bragg gratings in planar waveguides

Jouanno, Jean-Marc; Hübner, Jörg; Kristensen, M.

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ever, receiver input power is estimated to be sufficiently high to realize 16×16 as well as 8×8 .

In GDPC-SW with SM-to-MM combiner, power penalty due to amplified spontaneous emission (ASE) and coherent cross talk should be checked. We have carried out a 10-Gbit/s signal transmission experiment using the setup shown in Fig. 3(c). A 1550-nm optical signal is created by a distributed feedback laser-diode (DFB-LD) and a LiNbO₃ modulator. Fiber-to-fiber gain of SOAGs is 8 dB at 25 mA injection current. The loss of 8:1 SM-to-MM combiner silica waveguide is 1.5 dB. In the experiment, one of the two SOAGs was always in the on state and another was in the off state. Figure 3(a) shows a bit-error-rate (BER) curve. Power penalty due to ASE noise of the SOAG is estimated to be <0.3 dB. Degradation due to coherent cross talk was not observed in the BER measurement, because the extinction ratio of the SOAG was more than 50 dB.

Figure 3(b) shows the signal waveform. The switching interval was 13 ns (128 bit). Turn-on-delay responses of SOAGs were compensated by simple electronics.² As a result, the switching has been performed within 1 ns.

As a conclusion, we have proposed a novel GDPC-SW that incorporates SOAGs and an SM-to-MM combiner, and demonstrated 10-Gbit/s/port throughput, and 1-ns switching. We estimated that the switch can be extended up to 16×16 scale. This switch will remarkably improve the interconnection network performance in symmetric multi-processor systems.

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WL60

60-dB Bragg gratings in planar waveguides

J.-M. Jouanno, J. Hübner, M. Kristensen, *Mikroelektronik Centret, Technical University of Denmark, Bldg. 345 East, DK-2800 Lyngby, Denmark; E-mail: jmj@mic.dtu.dk*

Bragg gratings are widely used as wavelength-selective elements in fiber devices.¹ Integrated optics is a very attractive alternative for realizing such components. This way, multifunctional devices with high mechanical and thermal stability can be made using a technology with potential for mass-production. The main limitation until now was the quality of the gratings written in planar waveguides. We report here 60-dB transmission dips obtained with 6-mm-long Bragg gratings written in Ge-doped planar waveguides.

The waveguides have been made by depositing silica layers on silicon substrates by plasma-enhanced chemical vapor deposition (PECVD). The core dimensions are $6 \mu\text{m} \times 6 \mu\text{m}$ and the index step is $5.5 \cdot 10^{-3}$. The glass photosensitivity is enhanced by placing the waveguides in a deuterium chamber at high pressure for several days.² Bragg gratings are then induced by illuminating the waveguides with UV light through a phase mask.³ The exposure was performed at 248 nm using a KrF excimer laser. The UV-beam intensity distribution was

WL60 Fig. 1. Transmission spectrum of a 6-mm-long Bragg grating written in a planar waveguide.

WL60 Fig. 2. Reflection spectrum of a 6-mm-long Bragg grating written in a planar waveguide.

approximately Gaussian leading to an apodization of the 6-mm-long gratings. The filter function was characterized by using amplified spontaneous emission (ASE) from an erbium-doped fiber pumped at 1480 nm as a light source. The spectra are recorded by an optical spectrum analyzer [Ando-AQ6315A].

The transmission spectrum is shown in Fig. 1. 60 dB transmission dip has been measured indicating an index modulation higher than $9 \cdot 10^{-4}$. The measured transmission dip corresponds to the optical spectrum analyzer dynamic range. The filter function is, therefore, probably not fully resolved but the measured value represents, to the best of our knowledge, the strongest grating ever reported in planar waveguides.

The reflected spectrum is shown in Fig. 2. The 3-dB bandwidth is 2.6 nm and the sidelobe rejection is around 20 dB.

The high-index modulation obtained in planar waveguides indicates that a variety of filter functions may be realized by changing the grating parameters. Moreover, for the same glass photosensitivity stronger filters may be written in planar waveguides than in optical fibers due to the geometry. In standard fibers, the distance between the phase mask and the core is indeed 62.5 micrometers while in planar waveguides the cladding layer thickness may be below 20 micrometers. Thus higher UV light visibility may be achieved and thereby a higher index modulation.⁴

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WL61

New thermal stabilizing control of acousto-optic tunable filter using digital feedback technique

Takeshi Fukuda, Ryouichi Watanabe, Masayuki Kashima, Hideaki Okayama,* Masato Kawahara, *Kansai Laboratory, Oki Electric Industry Co., Ltd., 1-2-27 Shiomi, Chuo-ku, Osaka-shi, 540 Japan; E-mail: mabe@kansai.oki.co.jp*

Tunable filter is one of the key devices for the future wavelength-division multiplexing (WDM) system. The acousto-optic tunable filter (AOTF) has many advantages such as fast tuning speed and high resolution power.¹ But, the selected wavelength by AOTF is varied by the influence of ambient temperature due to the temperature dependency of LiNbO₃ as this device material. Therefore, there is a formerly stabilizing technique of AOTF by way of constant temperature control with Peltier elements.² But, there are problems that the electric power consumed mainly by Peltier element and the scale of circuit become large in this way. We propose the new technique of stabilizing control of AOTF using digital feedback technique.

WL61 Fig. 1. Configuration of stabilizing circuit.

WL61 Fig. 2. Stability of wavelength control.

WL61 Fig. 3. Transmitting power and power penalty of AOTF.

We constructed the WDM network system of eight wavelength channels with channel separation of 3.2 nm. In this system, the total stability of wavelength tuned by AOTF is necessarily under about 0.1 nm. The configuration of our stabilizing circuit is shown in Fig. 1. To obtain the necessary wavelength stability, we use direct digital synthesizing (DDS) technique to generate the driving frequency of AOTF. Thermal data from thermistor is A/D-converted, converted to the correction data stored in memory, added with the channel select signal and input into the digital input port of DDS oscillator.

By this controlling method, it became possible to reduce the electric power consumption and the circuit size. The satisfying stability of wavelength control under ± 0.065 nm was obtained in room temperature by our method as shown in Fig. 2. The power penalty that occurs on AOTF in the condition of the bit error rate $< 1E-10$ is shown in Fig. 3 and the bit rate of signal was 2.5 GHz. The reason for this power penalty depending on the deviation from the center wavelength of AOTF is now under investigation.

In spite of the influence of this power penalty, enough tunability of AOTF and enough signal-to-noise ratio were obtained by our new method using digital feedback technique.

*Semiconductor Technology Laboratory, Oki Electric Industry Co., Ltd.

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WL62

Integration of polymer waveguide electro-optic modulators and VLSI electronics using standard lithographic fabrication techniques

Srinath Kalluri, Mehrdad Ziari, William H. Steier, Larry R. Dalton,* Zaheed Karim,** *Department of Electrical Engineering, University of Southern California, Los Angeles, California 90089-0483; E-mail: kalluri@scf.usc.edu*

Over the last few years, electro-optic (EO) polymers have reached the state of technological maturity where devices for practical applications become feasible. For example, polymers with EO coefficients stable up to 300°C¹ and r_{33} coefficients of 55 pm/V² have been discovered recently. The ease with which polymers can be processed into multilayer devices by standard Si processing techniques makes them attractive for optoelec-