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A new integrated all-optical switch based on a micro-cavity

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Integrated all-optical switches [1] can be of great importance for optical transparent telecommunication network. All-optical switching is based on the phase change of the light due to the intensity in nonlinear optical (NLO) materials. The materials investigated up to now exhibit NLO coefficients which are still too low for realistic high speed devices performance at low optical power. A possible way to improve the NLO is enhancement of the electric field inside the material using micro-cavities. Recently, rotationally symmetric dielectric micro-cavities with radii larger than the wavelength are modelled theoretically for linear and NLO materials. These micro-cavities can confine large electromagnetic fields in small volumes and act as optical cavities with high quality factors (Q's $>10^4$ [2]). Examples of these micro-cavities are semiconductor microdisk lasers and Nd:YAG spherical lasers. All kind of NLO processes, such as stimulated Raman scattering and sum-frequency generation, have already been reported for liquid droplets, however, in integrated optic devices micro-cavities have not yet been used. The spatial distribution of the internal field in the cavity is in general dominated by the near resonance-mode, the whispering gallery mode, when the incident frequency is near one of the high-Q modes, ω_0. The switching speed of these high-Q micro-cavities is usually limited by the cavity lifetime τ, where τ is Q/ω_0. When Q is about 10^3 the cavity lifetime is in the case of cavities with radii of about 8 micron smaller than nanoseconds.

The proposed all-optical switching device is presented in figure 1. The device consists of a micro-cavity surrounded by a NLO material and sandwiched between two waveguides (see figure 1). NLO switching can be expected if the cavity is close to resonance. Then by increasing the intensity of the incident light, the high Q-resonance frequency will shift towards the incident frequency due to the refractive index change in the NLO material. In this way most of the power is coupled into the micro-cavity. Because of the symmetric shape of the device, most of the power of the micro-cavity then will be coupled back into the upper waveguide. In figure 2 can be seen that coupling between the mode of the wave guide and the mode of the micro-cavity [3] is possible. This device shows a certain analogy with a NLO Fabry-Perot, where high and low power output are the transmitted and reflected wave, respectively. Because of the high-Q values very low switching powers are sufficient when using presently available polymers, like AKZO NOBEL-DANS. Due to the small dimensions, the device can be integrated in a complex optical circuit.

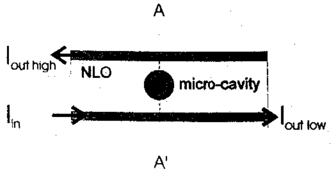

Figure 1: Top view all-optical switch

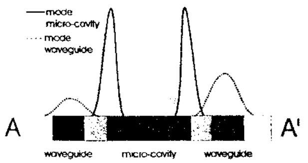

Figure 2: Cross section and modal distribution close to resonance

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[2] V.B.Braginsky, M.L. Gorodetsky, V.S. Ilchenko, *Phys.Lett A* **137**, 393-397
[3] M.M. Mazumder, S.C. Hill, D.Q. Chowdhury, R.K. Chang, *J.Opt.Soc.Am.B* **12**, 297-310

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Optical switches with low crosstalk based on low cost polymer waveguide technology

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Optical switches are considered to represent attractive components in all-optical networks as, for example, for circuit protection switching to by-pass a faulty system or cable, and in optical cross connects. Switching of cable TV in LANs, of high bit rate data in the optical backplanes of a computer and optical signals in sensors and vehicles (fly-by-wire) may be further applications in the telecommunications, microsystems and automotive area. High performance at low cost may be achieved if polymer waveguide technology is used.

A polymer (4x4)-switching matrix integrating eight thermo-optic (2x2)-directional-coupler-(DC)-type switches forming a microprocessor controlled (4x4)-space stage at λ = 1.55 µm was demonstrated for the first time in 1995. Due to the asymmetrical electrode configuration, crosstalk in the cross state of the (4x4)-matrix was limited to < -21.5 dB [1]. Using a modified electrode configuration to combine the symmetrical and asymmetrical switching behaviour, a novel (2x2)-DC-type switch exhibiting an extremely low crosstalk of -42 dB at the cross- and -45 dB at the bar-state, respectively, is reported. The length of the switch is 7 mm, and the switching power amounts to 3 mW and 20 mW, respectively, as shown in Fig. 1. Due to the excellent device performance, compactness and high fabrication tolerance, the switch represents a suitable building block for constructing larger switching matrices. Integrating eight of these switches, a (4x4)-matrix is demonstrated, which exhibits crosstalk values of <-30 dB in all switching states.

Where robust switching behaviour with respect to switching bias is vital but very low crosstalk is not required, digital optical switches (DOS) are preferred. Fig. 2 shows the transfer characteristics of a polymer (1x2)-Y-DOS. The switch consists of a Y-branch with a branch angle of 0.2°. The crosstalk remains below -30 dB for an applied switching power of ≥ 65 mW. This switch can be operated at both 1.3 µm or 1.55 µm wavelength and will be used to construct a (2x2)-DOS and a digital (4x4)-switching matrix.

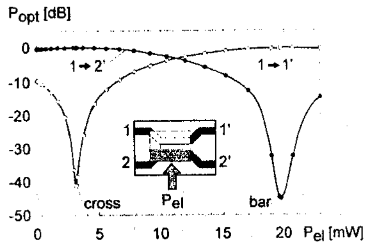

Fig. 1: Measured transfer characteristic of a (2x2)-DC-type switch at λ = 1.55 µm.

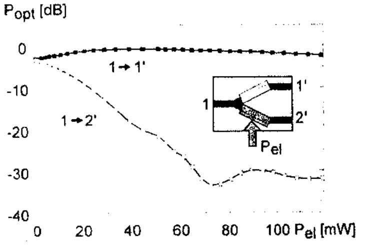

Fig. 2: Measured transfer characteristic of a (1x2)-Y-DOS at λ = 1.55 µm.

The switches were fabricated in PMMA using standard polymer waveguide technology (spin-coating, UV-exposure) on 3“ Si-substrates [2]. The waveguide dimensions are 6 µm x 6 µm and the optical attenuation is 0.3 dB/cm at 1.3 µm and 0.8 dB/cm at 1.55 µm, respectively. Due to the simple fabrication process involved, the polymer waveguide technology is of high interest for the cost-effective production of optical switches and other optical devices. Further work will be directed to alternative polymer materials providing lower optical loss and high thermal stability (Tg > 300 °C). Preliminary results will be presented.

References:

[1] N. Keil, et. al.: OFC'95, Postdeadline Papers, PD-17, 1995.
[2] N. Keil, et. al.: EFOC&N'95, Proceeding Vol. 2, pp.240 - 243, 1995.