A MEMS Device for Continuously Tunable Optical Buffering

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The main function of an optical buffer is to introduce a controllable delay to an optical signal in telecommunication networks. The possibility of continuously tunable optical buffering in coupled silicon waveguides by mechanical reconfiguration of the system has recently been proposed [1]. Here we present design and fabrication of such an optical buffer using III-V semiconductors. The buffer consists of two Indium Phosphide free-standing waveguides with optimal dimensions of 200 nm×300 nm separated by an air gap that can be varied in the range of ~50–500 nm. The device is designed to operate at a wavelength of 1550 nm. Due to the subwavelength size the waveguides support only the fundamental symmetric mode that is confined in both waveguides while the antisymmetric mode is below cut-off. Changing the size of the air gap varies the mode confinement within the waveguides and hence the effective refractive index of the structure, thus generating tunable optical delay to a propagating signal.

Fig. 1(a) shows a schematic design of the buffer. The free-standing waveguides are suspended in air by pillars ~3 μm above the bottom substrate. To minimize optical losses at pillars, S-shaped tapers are designed at the pillar intersections. A pillar separation of ~100 μm ensures sufficient flexibility of the waveguides and enables mechanical oscillation frequency of the order of 100 kHz to provide fast response time and to reduce vibration noise. MEMS actuation is proposed to control the air gap between the two waveguides. We modelled an actuation scheme where the waveguides are charged with the same polarity, creating electrostatic repulsion and increasing separation between them, as shown schematically in Fig. 1(a). We estimated that the air gap between the waveguides with initial spacing of 50 nm is increased to 500 nm with only 3 V applied between the waveguides and the bottom substrate. The predicted variation of the group index for the TE polarized propagating mode with applied voltage is shown in Fig. 1(b), which corresponds to a delay time change of ~10 ps in a 1 mm long device.

The free-standing waveguides were fabricated on an InP-InGaAs-In(Ga)P layered substrate grown by molecular beam epitaxy. The device layer of In(Ga)P (1% of Ga in InP) was n-doped with a carrier concentration of 1×10^{17} cm^{-3}; the InGaAs layer (~3–4 μm thick) served as a sacrificial layer. The waveguides, pillars and MEMS structures were patterned using electron beam lithography followed by plasma etching. Cr/Au contacting electrodes were integrated into the structure to enable electrostatic actuation. After the sample patterning, the waveguide structure was successfully released using HF etch. A section of the free-standing waveguides is shown in Fig. 1(c). We are currently working on the optical characterization and experimental demonstration of electrostatic actuation of this device.

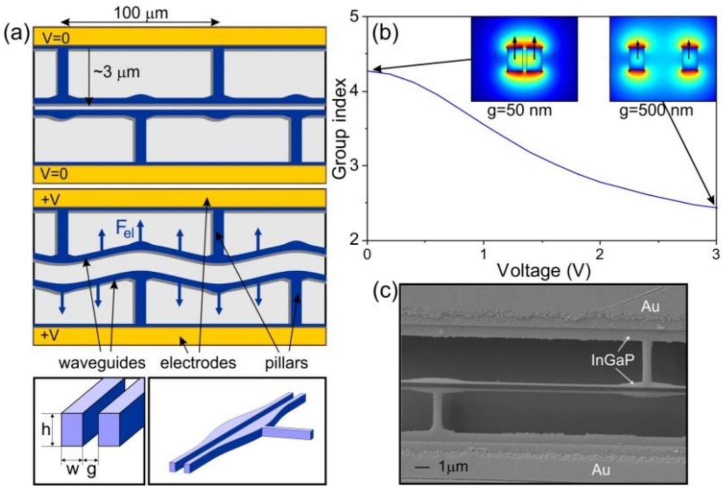

Fig. 1 (a) Schematic of the optical buffer (top view, not to scale) in the "voltage-off" (top) and "on" (middle) state; 3D images of coupled optical waveguides of height *h*, width *w*, separated by an air gap *g* and S-shaped taper at the pillar connection point (bottom). (b) Group index for the symmetric TE mode as a function of the voltage applied to the waveguides. Insets show the symmetric TE mode profile for g = 50 nm and g = 500 nm. (c) SEM image of the fabricated waveguides and pillar supports (top view).

References

[1] P. Horak, W. Stewart, W. H. Loh, "Continuously tunable optical buffer with a dual silicon waveguide design," Opt. Express **19**, 12456 - 12461 (2011).