A Nanoelectromechanically Tunable, High-Index-Contrast Interference Directional Coupler


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One of the most exciting and practical application of a directional coupler is the switch modulator in which the amount of optical power coupling is adjustable. A method of tuning a single mode interference high-index-contrast (HIC) directional coupler with a nanoelectromechanical (NEM) mechanism is proposed. An electromechanically tunable directional coupler has the benefit of providing large changes in effective index, of being transparent, and requiring low power. An HIC system has the added benefit of permitting a size reduction that allows machined nanostructures to optically guide light at a wavelength of 1.55 microns as well as to mechanically actuate.

Using GaAs waveguides with a ~300-nm-square cross-section, directional couplers are fabricated so that they are anchored atop of AlO	extsubscript{y} as well as suspended over a trench. The anchored portions of the waveguides are adiabatically curved to a lithographically-defined coupling separation that exists suspended over the trench. The desired mechanical compliance determines the extent to which the adiabic curves are situated over the trench. The amount of optical power coupling is adjusted by the electromechanical actuation of the waveguide separation and the S-bend curvature. The selected method of electromechanical actuation utilizes a gap-closer mechanism. A gap-closer is a “spring”-suspended, parallel capacitive plate mechanism that is allowed to mechanically deflect in order to reduce its capacitance. In planar MEMS/NEMS, the “spring” is usually a mechanical compliant beam (i.e., the suspended portion of the directional coupler). Gap-closers are characterized by large mechanical force densities over small displacements, which make them well suited for this particular application.

Molecular beam epitaxy is used to define layer thickness. Traditional micromachining techniques are used to lithographically define the topology and provide optical, electrical, and mechanical isolation. After these processes, high-index-contrast is accomplished by stream oxidation that transforms crystalline high Al-content Al\textsubscript{x}Ga\textsubscript{1-x}As alloys to an amorphous Al\textsubscript{x}O\textsubscript{y} oxide. Nanostructure mechanical latches and bi-stable mechanisms are expected to aid in improving alignment accuracy. Nanostructure mechanical levers can be used to tailor the shape and angle of deflection. The device is expected to operate within the MHz regime in a speed-optimized design.