Subwavelength Index Engineering for SOI Waveguides

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Abstract- Photonic structures with a sub-wavelength pitch, small enough to suppress diffraction, can behave as equivalent homogenous materials that can be engineered to exhibit a specific refractive index and dispersion. Here we discuss the design of a variety of integrated photonic devices, ranging from grating couplers to multimode interference couplers, for which the use of sub-wavelength structures enables unique characteristics. We will place special emphasis on the design and experimental demonstration of multi-mode interference couplers with an unprecedented bandwidth beyond 200nm at telecom wavelengths.

When integrated photonic waveguides are patterned at the sub-wavelength scale, their optical properties can significantly, enabling the designer to change their refractive index and dispersion [1-3]. These sub-wavelength gratings (SWG) have found applications in efficient fiber-to-chip couplers [4], enhanced waveguide sensors [5] and mid-infrared waveguides [6], to name a few.

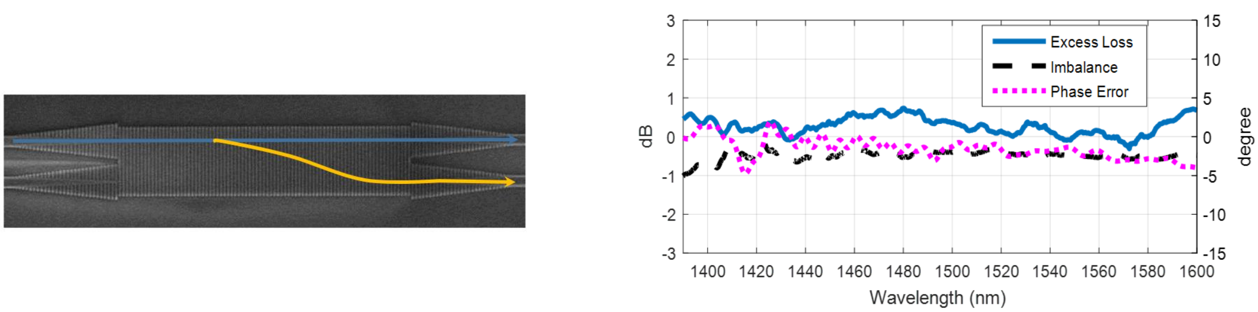

Figure 1. Left: Subwavelength engineered, ultra-broadband multimode interference coupler. Right: Measured performance of the device indicating virtually perfect performance in a bandwidth of more than 200nm

SWG structures can also be used extend the operational bandwidth of directional couplers and multimode interference couplers, both in the near-infrared and the mid-infrared wavelength bands [7-9]. Such couplers divide the lightwave in the input waveguide with a 50/50 ratio between the output waveguide waveguides, introducing a 90º phase shift (see Fig. 1 – Left panel). In these devices the sub-wavelength structure is used to adjust the refractive index and the dispersion of the metamaterial waveguide. Full 3D finite-difference-time-domain (FDTD) simulations indicate that multimode interference couplers based on these structures can operate over more than 400nm of bandwidth covering all major telecommunication bands simultaneously. The left panel in Fig. 1 depicts a scanning electron microscope of a SWG engineered multimode interference device. The input and output waveguides are gradually tapered from conventional strip waveguides to wider, sub-wavelength segmented waveguides, to match the index with the central multimode region. The pitch and duty-cycle of the central region is designed to provide a virtually wavelength independent interference of the propagating higher order modes. The measurements, shown in the right panel of Fig. 1b reveal a splitting ratio (imbalance between the two outputs) that is virtually flat and close to the ideal value of 0dB (indicating 50/50 splitting) over a bandwidth in excess of 200nm. Furthermore, the phase between the outputs deviates from the ideal 90º by less than 5º over that same bandwidth, while excess losses are controlled to less than 1dB.

We believe that the outstanding performance afforded by such ultra-broadband devices will give rise to a wide range of novel applications in communications in the near-infrared and in sensing in the mid-infrared.

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