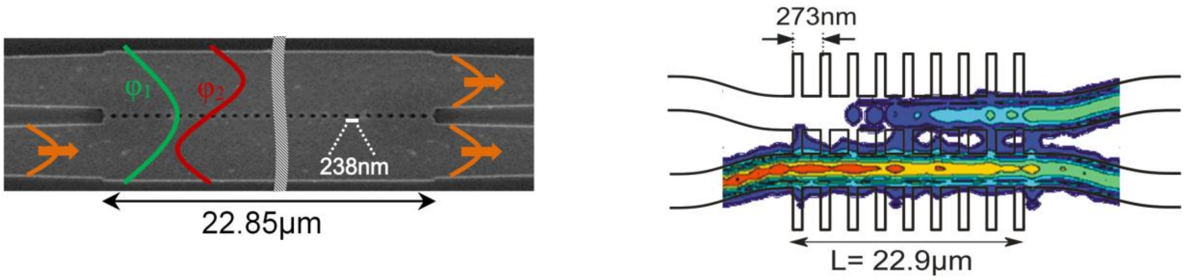
Molding silicon waveguide devices with sub-wavelength structures

R. Halir,[1] A. Ortega-Moñux,[1] A. Maese-Novo,[1] D. Pérez-Galacho,[1] I. Molina-Fernández,[1] J. G. Wangüemert Pérez,[1] P. Cheben,[2] J. H. Schmid,[2] D.-X. Xu,[2] S. Janz[2]

[1]Departamento Ingeniería de Comunicaciones, ETSI Telecomunicación, Universidad de Málaga 29071 Málaga, Spain

[2]National Research Council of Canada, Ottawa, K1A 0R6, Canada

Silicon-on-insulator is emerging as mayor platform for the realization of photonic integrated circuits. Due to its high index contrast ($\Delta n \approx 2$) it allows for very compact designs, which can be incorporated into CMOS fabrication processes, thereby paving the way for optical interconnects. However, as in most fabrication platforms, the refractive indices of the materials (silicon and silicon dioxide) can scarcely be modified, limiting the design space for waveguide devices. This has changed radically with the introduction of sub-wavelength gratings (SWGs), which enable refractive index engineering in silicon devices [1]. SWGs are periodic structures, alternating layers of silicon and a low refractive index material (silicon dioxide, air, or polymer), with a pitch small enough to suppress diffraction. An SWG behaves as a homogenous medium with an equivalent refractive index, which depends essentially on the duty cycle of the structure. A large variety of devices have been realized using this approach, including fiber-to-chip couplers and wavelength de-multiplexers. Here we present a multimode interference coupler with a sub-wavelength slot in its center [Fig. 1(a)]. The slot synthesizes a strip of low equivalent refractive index in the center of the device, thereby changing the modal interference in such a way that the length of the device is reduced by half without affecting its performance [2]. Furthermore, we discuss the use of SWG structures for engineering not only an equivalent refractive index but also dispersion. This enables the design of devices with enhanced bandwidth, such as directional coupler shown in Fig. 1(b). The transversal SWG structure compensates the variation of beat length with wavelength, extending the bandwidth of the device by a factor of five [3]. Interestingly this concept can be extended to multimode interference couplers, yielding operational bandwidths of around 450nm [4].



(a) (b)

Figure 1. a) A 2x2 MMI coupler with an index engineered sub-wavelength slot that reduces by half the length of the device. **b)** A directional coupler with a dispersion engineered sub-wavelength structure that increases the bandwidth of the device by a factor of five.

Acknowledgements: This work has been partially funded under Andalusian Regional Ministry of Science Innovation and Business project P09-TIC-5268, Spanish Ministry of Science project TEC2009-10152, the EU 7th Framework Program project MIRTHE ICT-2009-5 nº 257980, and the Universidad de Málaga - Campus de Excelencia Internacional Andalucía Tech.

References:

[1] P. Cheben, P. J. Bock, J. H. Schmid, J. Lapointe, S. Janz, D.-X. Xu, A. Densmore, A. Delage, B. Lamontagne, , and T. J. Hall, "Refractive index engineering with subwavelength gratings for efficient microphotonic couplers and planar waveguide multiplexers," Opt. Lett., vol. 35, pp. 2526–2528, 2010

[2] A. Ortega-Monux, C. Alonso-Ramos, A. Maese-Novo, R. Halir, L. Zavargo-Peche, D. Perez-Galacho, I. Molina-Fernandez, J. G. Wanguemert-Perez, P. Cheben, J. H. Schmid et al., "An ultra-compact multimode interference coupler with a subwavelength grating slot," Laser & Photon. Rev., vol. 7, pp. L12–L15, 2013

[3] R. Halir, A. Maese-Novo, A. Ortega-Monux, I. Molina-Fernandez, J. G. Wanguemert-Perez, P. Cheben, D.-X. Xu, J. H. Schmid, and S. Janz, "Colorless directional coupler with dispersion engineered subwavelength structure," Opt. Express, vol. 20, no. 12, pp. 13 470–13 477, Jun 2012

[4] A. Maese-Novo, R. Halir, S. Romero-Garcia, D. P´erez-Galacho, L. Zavargo-Peche, A. Ortega-Monux, I. Molina-Fernandez, J. G. Wanguemert-Perez, and P. Cheben, "Wavelength independent multimode interference coupler," Opt. Express, vol. 21, no. 6, pp. 7033–7040, Mar 2013