Design of optical metamaterial waveguide structures (Invited paper)

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Subwavelength gratings (SWGs) are periodic structures with a pitch (Λ) smaller than the wavelength of the propagating wave (λ), so that diffraction effects are suppressed. These structures thus behave as artificial metamaterials where the refractive index and the dispersion profile can be controlled with a proper design of the geometry of the structure. SWG waveguides have found extensive applications in the field of integrated optics, such as efficient fiber-chip couplers, broadband multimode interference (MMI) couplers, polarization beam splitters or evanescent field sensors, among others. From the point of view of nano-fabrication, the subwavelength condition ($\Lambda << \lambda$) is much easier to meet for long, mid-infrared wavelengths than for the comparatively short near-infrared wavelengths. Since most of the integrated devices based on SWGs have been proposed for the near-infrared, the true potential of subwavelength structures has not yet been completely exploited. In this talk we summarize some valuable guidelines for the design of high performance SWG integrated devices. We will start describing some practical aspects of the design, such as the range of application of semi-analytical methods, the rigorous electromagnetic simulation of Floquet modes, the relevance of substrate leakage losses and the effects of the random jitter, inherent to any fabrication process, on the performance of SWG structures. Finally, we will show the possibilities of the design of SWG structures with two different state-of-the-art applications: i) ultra-broadband MMI beam splitters with an operation bandwidth greater than 300nm for telecom wavelengths and ii) a set of suspended waveguides with SWG lateral cladding for mid-infrared applications, including low loss waveguides, MMI couplers and Mach-Zehnder interferometers.