Design of subwavelength grating metamaterial waveguides for communications and sensing applications

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Abstract: In this work we will cover some of our recent advances in the design of state-of-the-art silicon photonic devices based on all-dielectric subwavelength grating (SWG) metamaterials. Specifically, we will focus on the design of tilted SWG waveguides, integrated anisotropic SWG lenses, spectral filters based on SWGs and SWG structures for evanescent field sensing.

1. INTRODUCTION

All-dielectric subwavelength grating (SWG) structures are one of the most powerful tools for designing state-of-the-art silicon photonic devices, because they provide control over the refractive index, dispersion and birefringence of the synthetized artificial metamaterial.

An SWG is a periodic structure with a pitch smaller than the wavelength of light propagating through it, so diffraction effects are avoided [1]. In its simplest implementation, it is composed of two materials (silicon and silicon dioxide) and the designer only has two geometrical parameters to optimize: the pitch and the duty cycle. Even with these restrictions, SWGs have been successfully applied to a plethora of high-performance integrated silicon devices for datacom, telecom and sensing applications: fiber-chip couplers, ultra-broadband directional couplers and multimode couplers, polarization splitters, spectral filters, evanescent field sensors, etc [2,3].

SWGs enable the implementation of refractive indexes between those of silicon ($n_{Si} \sim 3.476$) and silicon dioxide ($n_{SiO2} \sim 1.444$) simply by controlling the ratio between these two materials within a period. In the same way, the mode confinement can be easily designed. Since the obtained equivalent index is highly dependent on the polarization of light, SWG based metamaterials are anisotropic, specifically they behave like a negative uniaxial crystal. This behavior should be considered during the design process for some applications. Finally, it is worth mentioning that fabricable SWG structures are highly dispersive if we assume a minimum feature size MFS ~ 100 nm, available with e-beam lithography and some deep-uv processes. The dispersion depends on the proximity of the SWG operating point to the Bragg regime and once again can be controlled with the pitch and duty cycle of the structure, thus allowing the design of broadband devices.

In this talk we will summarize our latest contributions in the field of silicon photonic devices based on SWG metamaterials. Specifically, we will cover 4 points: i) Tilted SWG waveguides, which introduce a new geometrical degree of freedom for designers [4]; ii) Integrated anisotropic SWG lenses working as compact beam-expanders and collimators iii) Narrow band spectral filters based on SWGs and iv) SWG structures for evanescent field sensing.

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