Properties of two-dimensional resonant reflectors with zero-contrast gratings

Mehrdad Shokooh-Saremi and Robert Magnusson

1Department of Electrical Engineering, Ferdowsi University of Mashhad, Mashhad, Iran
2Department of Electrical Engineering, University of Texas at Arlington, Arlington, Texas 76019, USA
*Corresponding author: magnusson@uta.edu

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The spectral properties of high-reflection mirrors imbedded with two-dimensional (2D) subwavelength periodicity are investigated. The reflectors are designed in a silicon-on-glass film that is partially etched to implement a zero-contrast interface between the grating pillars and the sublayer, thereby annulling the local reflections and phase changes associated with hard interfaces. This approach has shown impressive results for 1D polarized reflectors; here we strive to discover analogous wideband unpolarized reflectors. Using particle swarm optimization, we report wideband unpolarized reflectors in the 1.4–2.0 μm wavelength band. A 2D reflector with square pillars exhibits 99% reflectance across a bandwidth exceeding 350 nm and possesses tolerance against angular deviations. The complementary structure with rectangular periodic voids achieves a bandwidth of 370 nm. A comparable, optimized 2D high-contrast grating reflector with grating pillars residing directly on the substrate yields a 99% bandwidth of 240 nm. © 2014 Optical Society of America

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Resonant photonic elements have recently drawn much attention and shown high capability as functional photonic devices [1]. Leaky waveguide modes can be excited when an incident light beam is coupled into a film via an inscribed period under phase-matching conditions. This stimulates a guided-mode resonance field response in the spectrum [2–5]. The physical basis can be further explained in terms of the photonic band structure and the associated leaky-wave effects near the second stop band [6]. Resonant devices such as biosensors, tunable filters, display pixels, polarizers, bandpass filters, and wideband reflectors can be realized using this operational principle [8]. The electromagnetic resonance response and leaky-mode field interactions can be complex. Hence, it is expedient to apply efficient design and optimization methods to determine the device parameters yielding the desired spectra.

In a recent Letter, we proposed wideband resonant reflectors in which grating ridges reside atop a layer of identical material [9]. The boundary between the ridge and the sublayer thus possesses zero refractive-index contrast, thereby eliminating local interface reflections and phase changes. We call this device class “zero-contrast gratings,” in contradistinction to “high-contrast gratings” which rely on a refractive-index step at this interface [10]. Numerical modeling of simple gratings with two-part periods shows that zero-contrast grating reflectors outperform comparable high-contrast grating reflectors on key measures [9]. A polarized reflector presented there exhibits a 99% reflectance band of nearly 700 nm in width [9]. As a complementary practical pursuit, it is the objective of the present contribution to investigate zero-contrast resonance devices possessing two-dimensional (2D) spatial modulation. The ultimate aim is to provide efficient, wideband, polarization-independent reflectors.

For decades, in the literature, 1D and 2D gratings inscribed on high-refractive-index media have been referred to as “strongly modulated gratings.” The recent terminology “high-contrast gratings” pertains specifically to a substantial refractive-index discontinuity at the grating/substrate interface [10] that exists, in addition to the ordinary strong modulation between grating ridges and troughs. The term “zero-contrast grating” thus refers precisely to the same interface without ambiguity.

Figure 1 displays the model 2D zero-contrast resonance reflector studied. The grating parameters, including periods, layer thicknesses, and fill factors, as well as the refractive indices of the device materials and the surrounding media, angle of incidence, azimuthal angle, and polarization angle influence the resonance response. The grating parameters generally define the operational spectral region, whereas the grating modulation strength Δε = nF2 − nL2 strongly affects the spectral width [11,12]. Photonic devices with a variety of spectral properties are achievable upon proper placement and manipulation of the resonance peaks. The 2D periodic elements are conceptually similar to their 1D counterparts and share identical physical basis. However, the 2D elements are