Simulations of quasiperiodic subwavelength grating structures for filtering and other applications

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Recently, as a flexible and perspective alternative to standard silicon-on-insulator (SOI) nanophotonic platform, subwavelength grating structured (SWG) waveguides and more advanced nanophotonic structures based on this novel concept have attracted increasing attention within the community. Such structures relay on Bloch wave propagating concept, in contrast to standard index guiding mechanism. In this way, they can indeed provide a promising alternative to standard nanophotonic platform, due to a variety of signal processing functions provided with tunability of SWG structure parameters. This additional variability in the (effective) refractive index functionalities, applied in designs of novel integrated-optical nanophotonic components and devices, provides welcomed flexibility of present and potential for new concepts and components, without significantly increasing fabrication complexity. A SWG structure is based on a (quasi)-periodic arrangement between two different materials, i.e. rectangular blocks of silicon of different dimensions embedded into a lower-index superstrate, with a period much smaller than the wavelength of the light. Clearly, by changing the filling factor, i.e., the duty-cycle of the SWG structure, its effective refractive index can be varied essentially between that of the superstrate and that of substrate (silicon). Applying this idea, several types of SWG based structures and devices have been proposed in last couple of years, such as straight guides, crossings, mode transformers and convertors, polarization converters, ring resonators, MMI couplers, and specially designed tapered couplers for efficient light in/out coupling into SWG structures. However, it was not until recently when several of us have realized and theoretically demonstrated, with the help of properly tuned quasiperiodic modulation in grating structuring, that the SWG concept can also be used for designing SWG filtering devices such as Bragg optical filters.

This contribution is thus devoted to a detailed numerical analysis of various novel designs of nanophotonic structures based on SWG with additional quasiperiodic modulation. For the numerical analysis, we effectively used and combined two approaches, either 3D Fourier modal methods, based on our two recently developed in-house and independent algorithms, aperiodic rigorous coupled wave analysis (aRCWA) and bidirectional expansion and propagation method based on Fourier series (BEX) with the Lumerical's 2.5D FDTD commercially available propagation method. This comparison have not only enabled to ensure the reliability of the results, but also determined the advantages as well as limitations of the individual approaches. Based on that, we propose, simulate, and possibly optimize, the behavior of several filters and other structures based on SWG and quasiperiodicity modulation concept, with the discussion of their potential applicability.