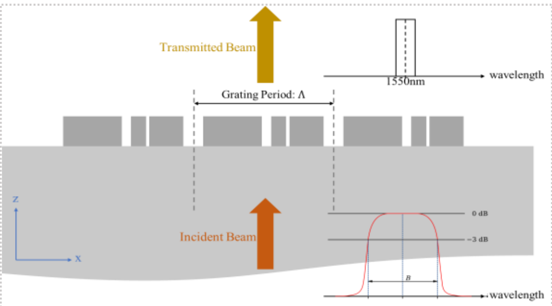
1550nm Band-Pass Filter Metagratings Based on Inverse Design Method

WoongJae Baek[1,2], Hwi Kim[1*]
[1]*Department of Electronics and Information Engineering, Korea University, Sejong 30019, South Korea*
[2]*Department of Physics, University of Illinois at Urbana-Champaign, Illinois 61820, United States*
* hwkim@korea.ac.kr

We propose that silicon-based metagratings capable of band pass filter can be realized using inverse design. To demonstrate the transmittance and bandwidth of our approach, we simulated metagratings can efficiently filter out the 1550nm wavelength with bandwidth of 40nm. We predict inverse design method will enable new types of high-performance photonic devices and novel approaches to nanoscale light field control.

I. Introduction

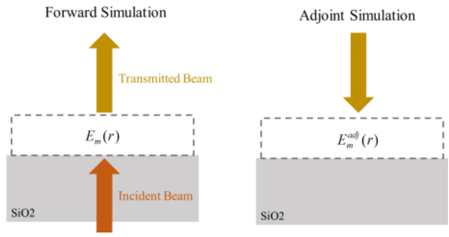
Bandpass filter (BPF) is a device that allows frequencies within a given range to pass through while attenuating frequencies outside of that range. BPFs are used in a variety of applications, including wireless transmitters to limit the output signal's bandwidth to the bare minimum or removal of spurious noise. Near infrared light BPF is especially crucial in LiDAR (Light Detection and Ranging) systems, but conventional design methods and intuitive structures of the band pass filter[1] still have difficulties to filter out narrow bandwidth and high transmittance signal in the range of near infrared wavelength. Metasurfaces, or metagratings, are subwavelength-thick artificial nanostructured interfaces that manipulate light using spatially ordered meta-atoms. To overcome the limits of present BPF structures, we present a device consisting of metagratings that can filter out 1550 nm wavelength as shown in Fig. 1, which is designed using adjoint-based topology optimization.



[Fig.1] The surface profile of a grating structure

II. Design and Simulation Method

To proceed the adjoint-based topology optimization, the gratings are assumed to be made up of pixels with relative permittivity of the dielectric material ($\varepsilon_{dielectric}$). The permittivity distribution in the grating area are design variables of the optimization, which permittivity of air converts to dielectric permittivity over the iterations[2].



[Fig.2] Schematic of the forward and adjoint simulation used to optimize the topology

We define the figure of merit (FoM) as

$$FoM = |T_{\lambda=t}|^2 - \left|\sum_{\lambda=i}^{t-1} T_\lambda\right|^2 - \left|\sum_{\lambda=t+1}^{N} T_\lambda\right|^2 ,$$

where 'T' is transmittance coefficient, the subscript 'λ' denotes the wavelength, 'N' is the total number of discrete wavelengths in incident beam and 't' indicates the target band pass wavelength, which is 1550 nm in our research. The maximum FoM is achieved by calculating the gradient of FoM, which requires only two simulations: direct($E(r)$) and adjoint($E_{adj}(r)$) field to evaluate the derivatives at all pixels in a grating as shown in Fig. 2. Both fields are obtained by Rigorous coupled-wave analysis (RCWA) based Fourier Modal Method (FMM), and the calculated gradient is optimized via Adam optimization algorithm. Once the gradient is calculated, a bias function, β is added to slowly push the pattern towards a binary structure. The bias function starts with a small value and increases as the iteration to avoid initial unnecessary binarization and its computational cost. Finally, to remove tiny nanoscale features in the device design, we applied Gaussian blurring filter to the material.

Acknowledgements

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References

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