Optical Microcavities in Distributed Bragg Reflectors

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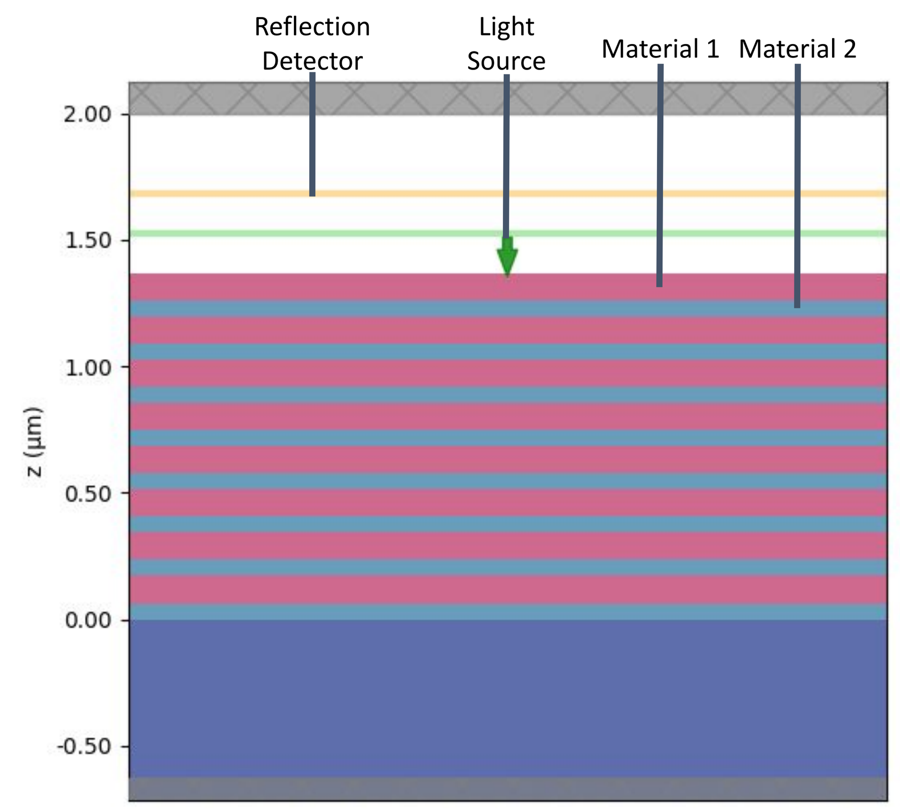
Introduction

- Photonic crystals are structures that utilize periodic variations in refractive index to control light. They create optical properties such as opalescence and structural coloration (ex. butterflies or silverfish).
- A Distributed Bragg Reflector (DBR) is a 1D photonic crystal that consists of alternating layers of low and high refractive index dielectrics with thickness of λ/4n.
- They are near-perfect reflectors for the design wavelength, and are used as high power mirrors for lasers and in lithography tools for semiconductor fabrication.
- Anomalies within layer thickness can create optical microcavities that trap light at a certain frequency for use in lasers, filters, and sensors.



Limitations/Future Directions

Challenges

- DBRs require the material to have precise thicknesses and high uniformity of refractive indices.
- Simulations are limited by high computational costs for larger simulation size and structural complexity.
- FDTD method relies on a quickly decaying field in order to converge on a solution, so resonant structures such as cavities can be difficult to accurately model.

Future Directions

- See if general trend of symmetry creating the highest quality microcavities is replicable when different layer materials are used.
- Investigate effect of cavity length on reflectance and microcavity quality.

References/Acknowledgements

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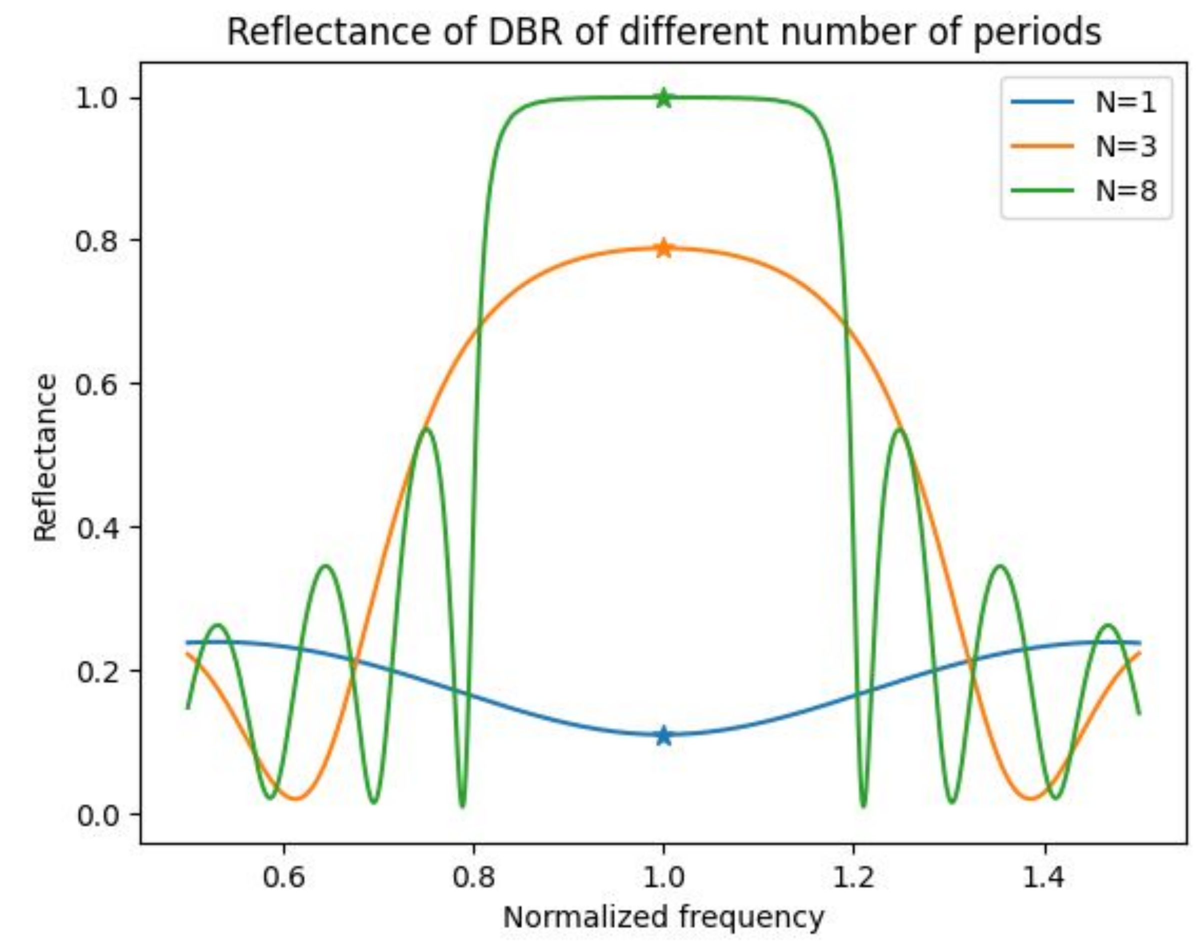
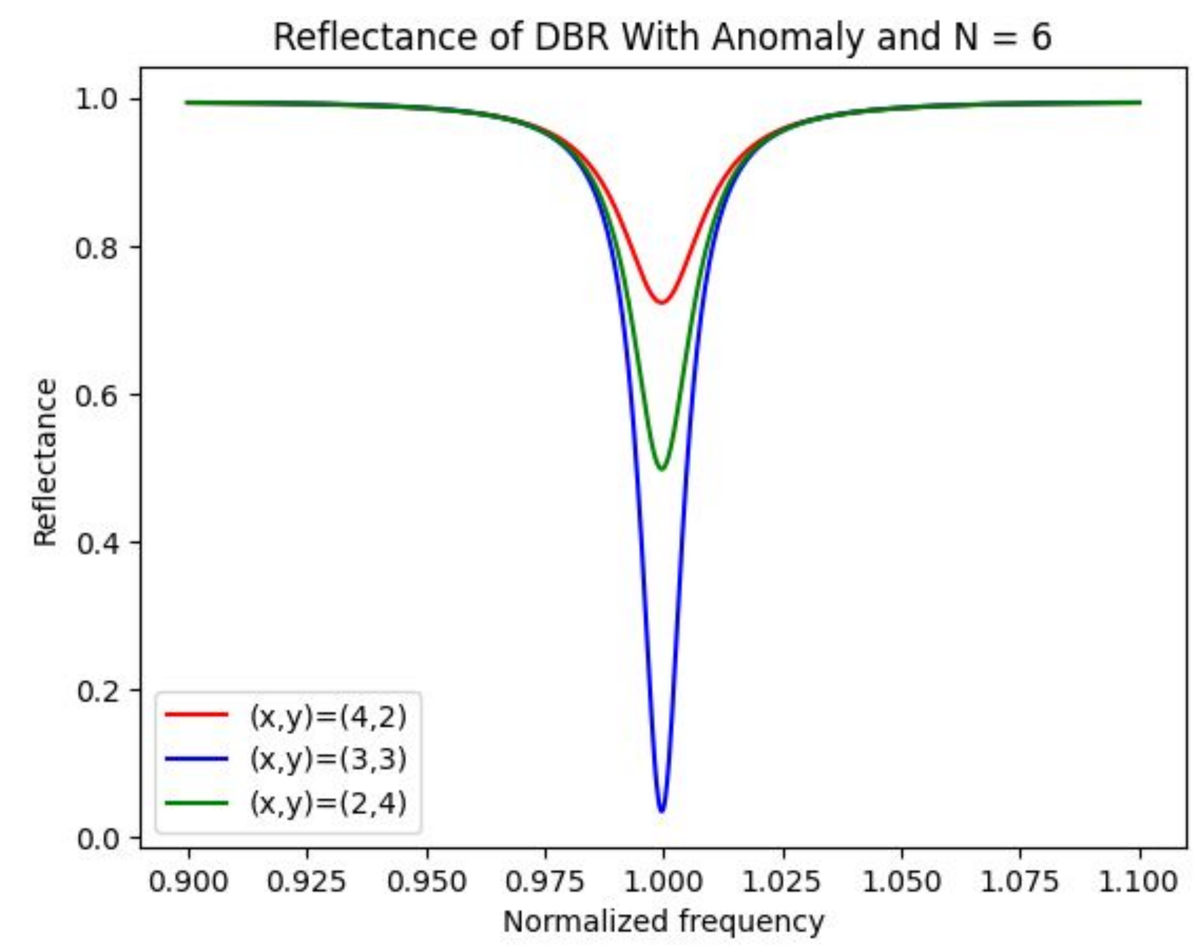
Dielectric or Bragg Mirror and Its Applications. (2024, July 26). Omega Optical. https://omega-optical.com/blog/dielectric-bragg-mirrors/

Resources

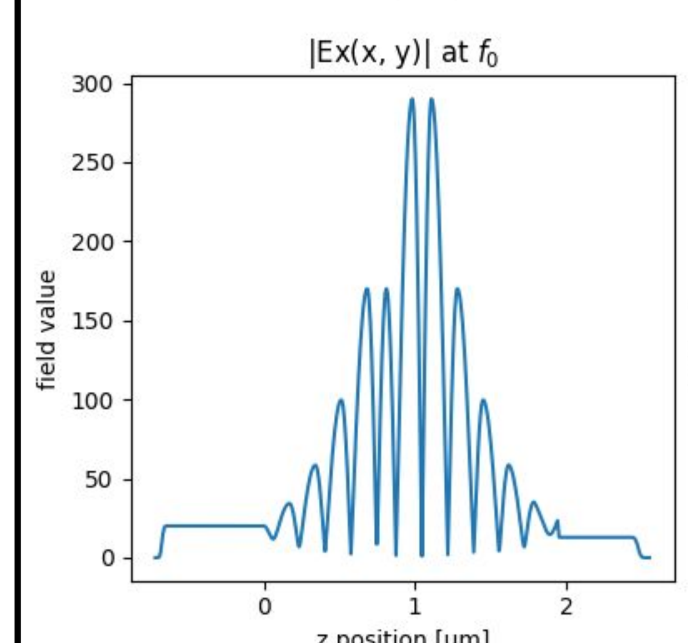
Code and slideshow with full results and double cavity output graphs

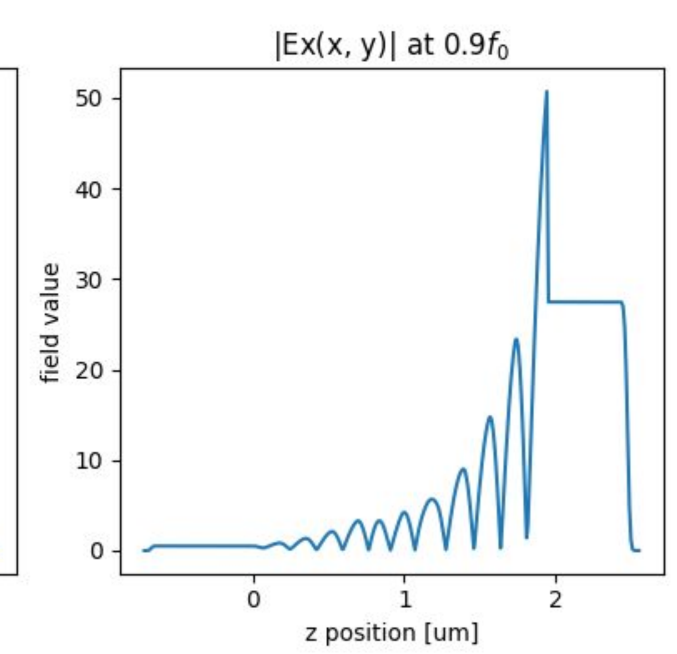
Methodology/Results





'x' is number of layers above anomaly layer, 'y' is layers below





Regular DBR:

- FDTD simulations with 1, 3, and 8 TiO_2-SiO_2 layers were modeled. Reflectance in a frequency range around a target wavelength (630 nm) was measured and plotted for each case.
- More layers resulted in the expected near-perfect reflectance at and around the target frequency.

Single Microcavity:

- Simulations were then run for each case where a total of 2-12 TiO_2-SiO_2 layers were variably distributed on each side of a TiO_2 anomaly layer (doubled thickness). Reflectance and intensity of the E field were recorded and plotted.
- Symmetrical layouts, as well as those with an extra bottom layer, achieved the lowest reflectance at the target wavelength and highest quality of the microcavity. All microcavities were wavelength-specific.

Double Microcavity

- An extra TiO_2 anomaly layer and section of regular layers were added to the single microcavity setup.
- Presence of two microcavities was observed. Both microcavities' qualities were maximized with equal layers in the top and bottom sections, and 1 layer separating the cavities.
- Microcavities were wavelength-specific, and the cavity farther from the source had a weaker confined field than the one closer.