Novel Sub-wavelength Screens for Sensor Applications

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Abstract
Simulations were conducted involving metallo-dielectric screen filters with various patterns. Two main patterns were examined: crosses and cylindrical round holes.

Introduction
An incident plane wave strikes a metallic filter. In response, electrons in the metal oscillate and the wave is mostly reflected. At resonance, the incident beam excites a standing wave resulting in high-transmittance. Transmittance through the filter is therefore a function of the wave frequency. In other words, electrons within the metal will re-emit some wavelengths better than others. This study is to determine how various screen patterns affect the filter output.

Design Specifications
Periodicity constant: \( g = 16.85 \, \mu m \)
Length of Rectangular Cross: \( 2a = 3.84 \, \mu m \)
Length between Crosses: \( 2b = 1.79 \, \mu m \)
Thickness of Cross: \( t = 3 \, \mu m \)

Crosses Simulation Results

Design Specifications
Periodicity constant: \( g = 100 \, \mu m \)
Length of Rectangular Cross: \( 2a = 3.84 \, \mu m \)
Length between Crosses: \( 2b = 1.79 \, \mu m \)
Thickness of Cross: \( t = 3 \, \mu m \)

Cylindrical Hole / Square Cuts

From several simulation trials it was observed that filters with square and hexagonal openings yield similar results to filters with a cylindrical round hole. Therefore in this study, cylindrical hole cuts were used and compared with openings in the shape of crosses.

Design Specifications
Periodicity constant: \( g = 100 \, \mu m \)
Diameter: \( D = 40 \, \mu m \)
Screen Thickness: \( t = 5, 10, 20 \, \mu m \) (Varying)

Cylindrical Hole Simulation Results

Crosses Simulation Results

Simulation Discussion
Both graphs represent the peak wavelengths and resonance widths. Simulation for the cross indicated a peak wavelength of 29 \( \mu m \) while the periodicity constant of the screen was only 16.85 \( \mu m \). In contrast, the cylindrical holes exhibited a peak much closer to the periodicity constant and its wavelength graphs had a narrower shape. The ratio of bandwidth to peak value was approximately 16%. The different curves on the cylindrical hole graph represented different thicknesses of the filter, black being 5 \( \mu m \), blue 10 \( \mu m \), and red being 20 \( \mu m \).

Conclusion
We have studied the effect of screen openings on the filter transmittance pattern. A cross pattern resulted in a moderate slope curve useful for filtering a broad band of frequencies. The round cylindrical opening resulted in a steeper slope curve and therefore may be useful for narrow band frequency filtration. The cylindrical hole graphs also showed that for thinner filter thicknesses, a larger transmittance bandwidth occurred.

Practical Applications
Broad band filters have been used by NASA on projects such as the Cosmic Background Explorer (Cobe) satellite. Cobe used broad band filters to investigate radiation in space due to Big Bang. Narrow band filters have recently been used in synchrotrons to act as Fourier transform spectrometers; providing a frequency distribution for particles.

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References
[1] B. Hooberman, “Everything You Wanted to Know About Frequency-Selective Surface Filters but Were Afraid to Ask”, pp 1-6, May 2005