THz Dichroic Plates for Use at High Angles of Incidence

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Abstract—**The design of a high frequency dichroic plate consisting of an electrically thick self supporting metallic mesh that can be used in a linearly polarized quasi-optical system at high angles of incidence is described. The measured and computed performance of a 2.5-inch aperture mesh is given. This mesh has a 3-dB cutoff frequency of 875 GHz and less than 0.75 dB of transmission loss from 950–1350 GHz at incidence angles of 0, 30, and 45 degrees. The results of a multimode waveguide analysis corroborate the measured data.**

I. Introduction

THE DICHROIC PLATE [1] is a structure whose electromagnetic wave transmission and reflection coefficients vary with frequency or polarization direction. They are often employed as quasi-optical filter elements from microwave to near infrared wavelengths. The most common form of inductive (high pass) dichroic plate consists of a thick metallic screen perforated in a regular manner with uniform holes. As a rough rule of thumb the passband frequency starts at approximately 1.2 times the cutoff frequency of the dominant waveguide mode in the hole (a function of the hole cross-sectional shape) and the hole to hole spacing should be kept as small as possible. For sharp cut-off the plate thickness should exceed a quarter of a guide wavelength for the dominant mode in the holes. More exact design criteria have been derived by C. C. Chen [2], [3].

At microwave and long millimeter-wave frequencies plates composed of circular holes in various lattice configurations can be made easily by conventional machining techniques. In the submillimeter wavelength bands (300–3000 GHz) standard photolithographic techniques are not suited to etching or growing the electrically thick metallic grid required to get the desired sharp cutoff response from the dichroic plate. In addition, the perforation size and spacing are such that conventional drilling is impractical and laser drilling leaves poorly defined holes and irregular septa. In a recent paper [4] we described a fairly simple procedure we have developed for producing electrically thick free standing metallic mesh for use throughout the submillimeter wavelength bands. The same techniques can be used to fabricate free standing parallel wire grid polarizers currently made by hand or machine assisted winding of fine wire around a prefabricated mandrel.

In this letter, we report the theoretical and measured results of a design program that culminated in the fabrication of a low loss 1-THz dichroic plate with a 1-dB passband of 35 percent that can be used with linearly polarized radiation at incidence angles of as much as 45 degrees.

Manuscript received October 3, 1990; revised October 24, 1990. This work was carried out at the Jet Propulsion Laboratory, California Institute of Technology under contract with the National Aeronautics and Space Administration.
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IEEE Log Number 9041271.

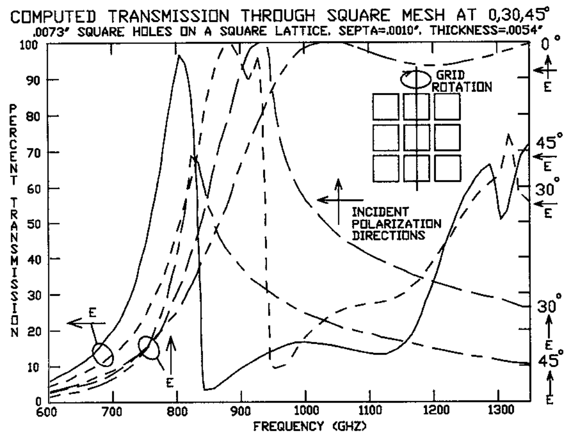

Fig. 1. Computed transmission curves for a dichroic plate composed of square holes in a square lattice at three angles of incidence and two polarizations. Normal incidence curves (0°) are the same in both polarizations due to symmetry. Hole size and center to center spacing are 0.0073" × 0.0073" and 0.0083" × 0.0083" respectively and the grid thickness is 0.0054". Data were derived from the computer analysis described in [7] with twenty waveguide modes included.

II. Analysis, Design, and Measurements

For electrically thick dichroic plates consisting of uniform circular or square holes on a square or triangular lattice one finds that both the transmitted power and bandwidth decrease rapidly when the angle of incidence exceeds about 20 degrees [5], [6]. This is illustrated dramatically in Fig. 1 where a theoretical plot of transmitted power versus angle of incidence is displayed for a 1-THz dichroic plate consisting of square holes on a square lattice. The computer analysis used to obtain these results will be described in a subsequent report [7] and, like the approach taken in [2], incorporates a complete method of moments solution. The results in Fig. 1 have been verified experimentally using the grid described in [4].

Despite the poor performance indicated by Fig. 1, it is possible to design a thick dichroic plate which can be used over a broad bandwidth at incidence angles as great as 45 degrees in a singly polarized system. The trick is simply to reduce the grid constant along the plane of polarization of the incident radiation while rotating the dichroic plate about an axis perpendicular to this plane [5]. The predicted performance improvement at high incidence angles is shown in Fig. 2 where we have merely reduced the height of the square holes.

This grid was actually fabricated using the method described in [4] and its transmitted power versus frequency was measured on a Bruker FTS120HR scanning Fourier transform spectrometer. The resulting data are shown in Fig. 3 for three different angles of incidence. Comparing Figs. 2 and 3, the agreement between the computer analysis and the measured data is quite

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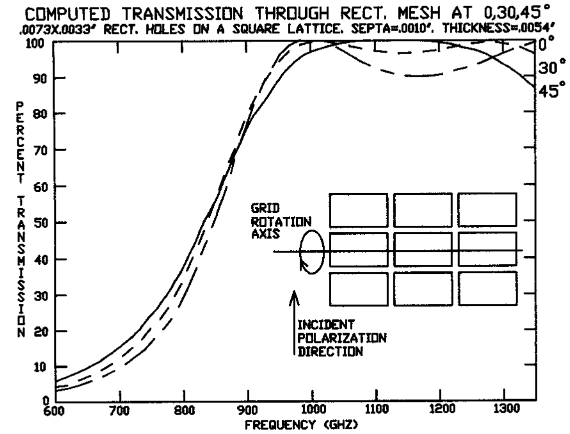

Fig. 2. Computed transmission curves for a dichroic plate composed of rectangular holes on a square lattice at three angles of incidence with polarization as shown. Hole size and center to center spacing are 0.0073″ × 0.0033″ and 0.0083″ × 0.0043″ respectively and the grid thickness is 0.0054″.

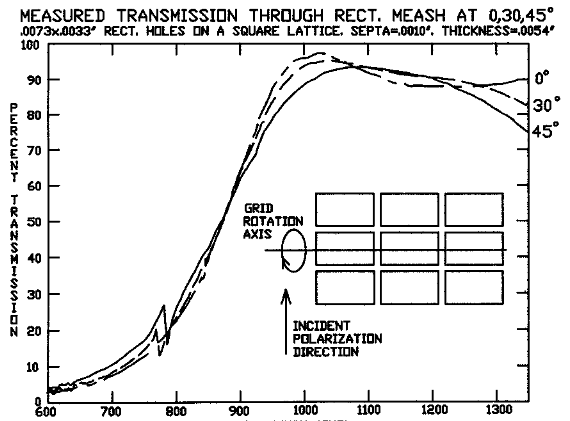

Fig. 3. Measured transmission curves for the grid shown in Fig. 2 at three angles of incidence. Polarization sense is shown. Grid was fabricated using the method described in [4] and has a 2.5 inch diameter clear aperture.

good especially when one considers that metallic losses have not been taken into account in the analysis and that the actual grid varies somewhat in thickness and hole uniformity over the surface. Additional results will be presented in a longer paper.

Summary

Using a previously described method for making thick metallic mesh filters for use at submillimeter wavelengths a 1-THz grid having a transmission bandwidth of 35 percent at an incidence angle of 45 degrees in the plane of polarization has been designed, fabricated and tested. The transmission curves agree well with a computer analysis of the dichroic plate which shows that by reducing the grid constant (hole size) in the plane of incidence it is possible to design grids that can work at high incidence angles over substantial bandwidths.

Acknowledgment

The authors would like to thank Tim Crawford and Dr. Herb Pickett, the former for helping us, and the latter for allowing us to measure the 1-THz grid on their Fourier transform spectrometer. We would also like to acknowledge the contribution of John Lichtenberger for developing the electroforming techniques used to fabricate the grids. Finally, we would like to thank Dr. Martin Schneider and both reviewers for several helpful comments on the text of the manuscript.

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