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The Single-Angle Plane-Wave Spectral Response of One-Dimensional Photonic Crystal Structures

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Abstract: The multiple-incident-angle transmittances or reflectances of fabricated 1-D photonic crystal (PC) structures are measured. Regularization methods are applied to these measurements to determine the single-angle plane-wave spectral response of the structure.

OCIS codes: (300.6340) Spectroscopy, infrared; (000.3860) Mathematical methods in physics.

The single-angle plane-wave transmittance or reflectance of a photonic crystal (PC) structure is an appropriate characterization parameter. By having this information, the transmittance or reflectance of the structure to any incident beam consisting of superimposed plane waves can be computed.

Multiple-incident-angle transmittance or reflectance measurements of fabricated 1-dimensional PC structures are obtained using an FTIR microscopy system. In the system, an infrared beam is focused onto the PC structure using a Schwarzchild reflecting microscope objective. The transmittance or reflectance of the structure is recorded incrementally as the sample is rotated with respect to the objective axis. Each measurement records the response of the structure to a composite beam of light. The composite beam consists of superimposed single-angle plane waves incident over a range of angles from θ_{min} to θ_{max} (Fig 1) determined by the physical parameters of the Schwarzchild reflecting objective and the angular orientation of the objective with respect to the sample. Multiple measurements can be formulated into a matrix algebra problem [1]. In this problem, the coefficient matrix describing the incident light for the multiple measurements is poorly conditioned due to measurement noise, discretization error, and numerical rounding errors. To stabilize the inverse computation, Tikhonov regularization methods are applied to the noisy measured data to compute the single-angle plane-wave response [2]. The maximum error limit of the regularization method is identified using the simulated transmittance of an ideal structure with random noise introduced (Fig 2). The measurement method is applied to determine the single-angle plane-wave spectral response of fabricated 1-dimensional PC structures (Fig 3).

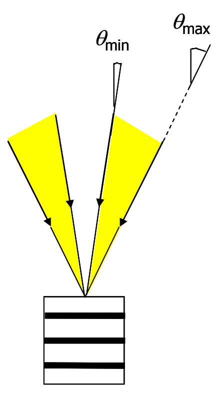

Fig 1. Focused light from a reflecting objective is introduced at angles ranging from θ_{min} to θ_{max} . The objective axis is shown at normal incidence to the sample.

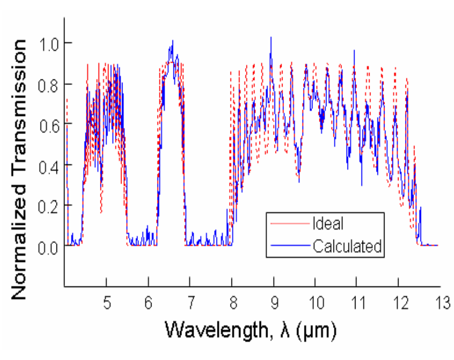

Fig 2. Simulation of a single-angle plane-wave transmittance for a 20° angle of incidence with 5% noise is shown together with the ideal response.

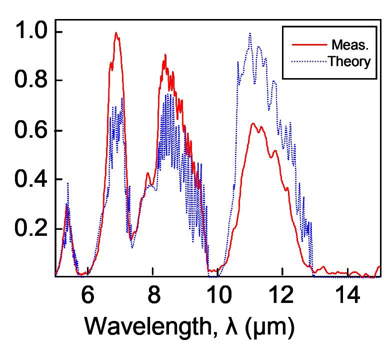

Fig 3. The single-angle plane-wave measured transmittance (using regularization) for a 16° angle of incidence is shown together with a theoretical calculation.

[1] T. K. Gaylord and G. R. Kilby, "Optical single-angle plane-wave transmittances/reflectances from Schwarzchild objective variable-angle measurements," *Rev. Sci . Instrum*. 75, pp. 317-323, Feb. 2004.
[2] P. C. Hansen, *Rank-Deficient and Discrete Ill-posed Problems/Numerical Aspects of Linear Inversion*. SIAM, 1998.