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Single-layer terahertz metamaterials with bulk optical constant

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W.-C. Chen1, A. Totachawattana1, K. Fan2, J. L. Ponsetto1, A. C. Strikwerda3, X. Zhang2, R. D. Averitt3, and W. J. Padilla1

1Department of Physics, Boston College, 140 Commonwealth Ave., Chestnut Hill, Massachusetts 02467, USA
2Department of Mechanical Engineering, Boston University, 15 Saint Mary's St., Brookline, Massachusetts 02446, US
3Department of Physics, Boston University, 590 Commonwealth Ave., Boston, Massachusetts 02215, USA

Metamaterials have been drawn a great deal of attention, because they offer many exotic properties that might not be readily available for naturally occurring materials - negative refractive index being the prime example.[1] The true power of metamaterials originating from their ability to construct materials with a specific electric and magnetic response - the electric permittivity (epsilon) and the magnetic permeability (μ).

Those designer materials are widely used for many real-life applications. For many cases, singly layer metamaterials are sufficient for creating the desired functionality. As for some other cases, one might require to use multiple layered metamaterials to achieve much sophisticated responses. However, it is well known single layer metamaterials might not have true bulk properties, even though the extracted parameters can predict the optical responses very precisely. To this regard, we perform an experimental and computational study on what the conditions under which single layer metamaterials may be described by bulk optical constants. Terahertz time domain spectroscopy is utilized to investigate two types of geometries, both with two different sizes of embedding dielectric —cubic and tetragonal unit cells. The tetragonal metamaterials are shown to yield layer dependent optical constants, whereas the cubic metamaterials yielded layer independent optical constants. We establish guidelines for when epsilon and μ can be used as material parameters for single layer metamaterials. Experimental results at terahertz frequencies are presented and supported by full wave three-dimensional electromagnetic simulations.

Reference:

[1]R. A. Shelby, D. R. Smith, S. Shultz, "Experimental Verification of a Negative Index of Refraction". Science 292, 77–79. (2001).
[2] W.-C. Chen, A. Totachawattana, K. Fan, J. L. Ponsetto, A. C. Strikwerda, X. Zhang, R. D. Averitt, and W. J. Padilla,"Single-layer terahertz metamaterials with bulk optical constants" Physical Review B 85, 035112 (2012).

Author: CHEN, Wenchen (Boston College)

Presenter: CHEN, Wenchen (Boston College)

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