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On the Dispersion Relation and Refractive Index of Optical Metamaterials — from thin film to bulk

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Summary

We analyze the dispersion relation of Bloch modes in metamaterials. Based on these results we derive an effective refractive index for plane waves. This refractive index is strongly anisotropic and may even exhibit discontinuities. It is compared with that retrieved from angular resolved reflection/transmission data of a finite slab. We introduce a technique to retrieve effective metamaterial parameters for arbitrary angles of incidence. Explicit expressions for both polarizations are derived and the constraints to be met for arriving at unique solutions are discussed. The method is applied to the fishnet structure and the difficulties in deriving meaningful values for the effective parameters are discussed. As the retrieved parameters show a strong temporal and spatial dispersion, we propose to classify them as wave instead of material parameters. They only serve to simplify the description of light propagation in metamaterials. Eventually we conclude that the refractive index may become meaningless and that only the use of the dispersion relation permits a reliable prediction of light propagation in metamaterials.

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