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The capability to support optical waves with very large wave vectors (high-k) is one of the principle features of hyperbolic metamaterials (HMMs). These waves play the key role in HMM applications such as imaging and lifetime engineering. Effective medium approximation (EMA) as widely used analytical method to predict HMMs behavior, has shortcomings in calculating high-k modes of practical structures. EMA is applicable to a subwavelength unit cell of implicitly infinite periodic structures. Using conventional EMA, in the present paper, boundary effects and spatial dispersion are taken into consideration to properly compute the high-k modes of finite-thickness multilayer HMMs. Applying nonlocal homogenization to stacks of alternating metal-dielectric layers, the corresponding effective medium is examined as a high-k waveguide sandwiched between the substrate and an ambient superstrate. The developed theory enables us to recognize two types of bulk waves coined as short-range and long-range propagating modes. Number of such modes as well as their cutoff conditions are quantified for the first time. Validity of the developed theory is verified both numerically by rigorous simulations of the multilayer structures with the transfer matrix method and experimentally by optical characterization of the HMMs in infrared regime.

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