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Closed-form formulae of effective parameters of stacked fishnet metamaterial

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A stacked fishnet metamaterial with a unit cell comprising a metallic hole-array layer and an insulator layer has been expected to exhibit hyperbolic dispersion. Here, we propose new closed-form formulae of effective parameters of the stacked fishnet metamaterial working at long-wavelength regime. These simple effective parameters are derived by applying the coupled-mode analysis to obtain the reflection and transmission coefficients which are then compared with those of a homogenized structure. The effective parameters show that the stacked fishnet metamaterial can behave as both type-II hyperbolic medium and elliptical medium depending on the filling ratio of the hole-array layer, dielectric constant of a dielectric layer, dielectric constant of a material filling the hole-array, and the excitation strength of an incident light on the hole-array. Importantly, the transition wavelength is inversely proportional to the square root of the filling ratio of the hole-array layer meaning that deep-subwavelength hyperbolic dispersion can be achieved with small filing ratio. This finding will greatly aid the design of deep-subwavelength imaging devices and optical lithography with the long-wavelength radiations.

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