Analysis of Cylindrical Hyperbolic Metamaterials by using Effective Medium Approximation

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Among the varieties of metamaterials proposed and fabricated the cylindrical hyperbolic metamaterials (CHMMs) have recently gained a significant role in the field of metamaterials and nano-photonics. They display strong anisotropy and hyperbolic (or indefinite) dispersion, which originates from one of the principal components of their electric permittivity or magnetic permeability tensor having the opposite sign to the other two principal components. These subwavelength scale metal and dielectric nanostructures have opened up exciting opportunities for manipulating the optical response. Such anisotropic structured materials exhibit unusual optical properties, including strong enhancement of spontaneous emission, diverging density of states, negative refraction and enhanced super-lensing effects [1].

We are investigating these structures by means of effective medium approximation (EMA), to establish a more comprehensive model. This work can also give an insight into the physics behind the optical response and other interesting phenomena like super scattering, invisibility [2] and absorption associated with CHMMs. The EMA can also significantly reduce the computational efforts needed to simulate the electromagnetic response of the system. We propose a new EMA model which is comparatively better than the existing models and it depends on the order of configuration of materials used in the structure. Study of these hyperbolic structures is important as they have different applications in nanotechnology like super-scattering, absorption enhancement, invisible metamaterials etc. Fig. 1 shows a representative model of one of the CHMMs.

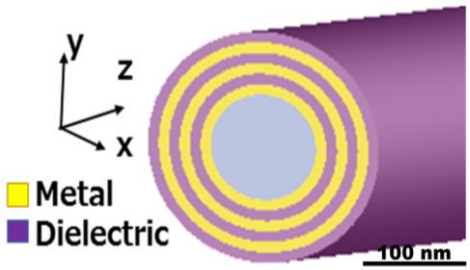

Fig. 1 Schematic of the CHMM structure.

For a similar structure with total 6 layers consisting of Silver and TiO_2 (5nm each), the comparison of different EMA model to the multi-layer analytical solution is shown in Fig. 2. It is observed that for this case presented our model is better than the existing EMA model.

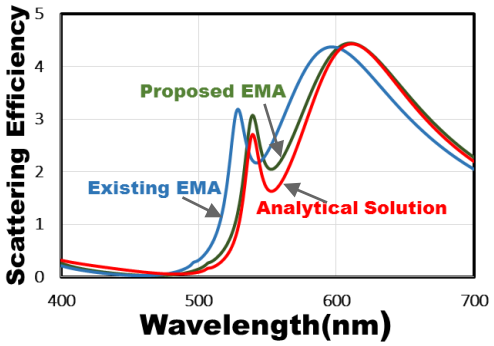

Fig. 2 Comparison of scattering efficiency of a structure calculated by different methods

References:

1. *Zubin et.al., Opt. Express,**14,**8247 (2006).*
2. *Kim et. al., Sci. Rep. **5**,16027(2015).*