Optical Properties of Multilayer Dielectric Media: Symmetry and Electric Field Enhancement

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Photonics is a branch of science that studies how the light propagates through the material and how to modify its propagation, such as how to prevent the propagation or to localize the light, which can be useful to amplify the electric field. To achieve this, one can use a system containing N layers of varying dielectric media in one dimension. By manipulating the sequence of dielectric media within the multilayer system, one can control the light propagation through it. In this work, we study the optical properties of multilayer system, such as the transmission probability of light (T), the electric field inside the structure and the absorption of light. We use one-dimensional multilayer system containing N layers made of two kinds of dielectric media A and B. We expect that the T depends on the sequence of the dielectric media. We will show the existence of symmetries on the multilayer system that does not change the value of T. One of symmetries found in this work is shown in figure 1. We will also show that the value of T can be expressed for any sequence by the formula $T = \frac{4(\varepsilon_A \varepsilon_B)^{|q|}}{\left(\varepsilon_A^{|q|} + \varepsilon_B^{|q|}\right)^2}$, where q is a newly defined integer quantity, which we call "charge" of the sequence. This "charge" is defined such that the sequences having the same "charge" value will have the same T value, which explains the symmetry.

Figure 1: The mirror symmetry: Mirrored sequence of dielectric media will give the same transmission probability (T). The charge of (a) and (b) are +1 and -1, respectively.

The electric field inside the structure is also calculated. We find that the electric field is enhanced at the center of multilayer, which is useful for application such as enhancement of Raman signal. In order to use the enhanced electric field, we make an air gap for putting other material. We expect that the enhancement factor depends on the sequence and the number of layer. When we put absorbing material, such as graphene inside the air gap, the absorption of light, which is normally around 2.3%, is also enhanced due to the enhanced electric field. Studying the optical properties of the multilayer system can be useful for designing a sequence of with desirable properties, such as a sequence with specific T or sequence, which allows high absorption of light.