The Transmittance of Electromagnetic Waves and Field Correlations in Multilayered Microspheres with Quasi-periodic Structures

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Abstract— By means of the matrix transfer approach and the Green's function technique, the electromagnetic properties of the spectra transmission of coated microspheres with a multi-layer,the numerical quasi-periodic sequences from Cantor set and Pascal triangle structures are numerically studied.

The quasi-periodic structures allow to obtain the optical band intervals in the radiation field spectra. The location of the light in disordered systems offers a range of applications in the opto-electronics industry.

1. INTRODUCTION

In the following numerical investigation was working with Si and SiO_2 as two elementary layers the objective is to highlight the properties of electromagnetic oscillations in multi-layer micro-spheres quasi-periodic the cantor sequence set, Pascal triangle and Green's functions with control parameter (γ), numerical algorithms and numerical simulations, transmittance spectrum, peaks (resonances) narrow-dependent parameters (γ) and spherical harmonic numbers (m), calculations of frequencies obtained with a radial field distribution [1–3].

2. THE GENERALIZED CANTOR SET

The well-known set Cantor is created by repeatedly removing the open central third of a set of line segments. One can build various generalizations of the assembly by, for example, cutting the segments into a different number of intervals or choosing another scaling factor. In this work, a cell is constructed by replacing Cantor several times (not cleaned) of the third center of a stack assembly material layer if materials using both Si and SiO_2. The generalized radially set Cantor can be constructed from a stack for homogeneous iterations subsequent. In standard Cantor established the central fragment is eliminated in iterations leading to a "dust" fractal Cantor. However, in this paper we replace (rather than delete) fragment of the SiO_2 layer, while fragment is replaced by Si layer. This allows the construction of a solid spherical quasi-periodic stack with the generic properties of Pascal or a Cantor fractal patterns. For such fractal scale dimensionless factor γ that becomes a control parameter and takes values between 0 and 2.

2.1. The generalized Pascal Triangle

Advances in manufacturing technologies nano-structures and micro-spheres are given the possibility of studying multi-layer systems with all kinds of arrangements, which can lead to a lot of photonic and optoelectronic applications. In a micro-sphere such, only the narrow resonance spectrum (natural frequencies) can be seen as peaks in the frequency spectrum of the radiation. Therefore, it is of great interest to investigate how these characteristics are modified in a cell with a quasi-periodic spherical structure. In this paper, we investigate the optical properties of a micro-sphere layer with a dielectric stack, wherein the optical layers are built following of the Pascal or Cantor sequences.

2.2. Green Functions

The range of different structured constructs has promised a variety of physical phenomena of another unexpected way among which the experimental realization of a negative refractive index has been one of the main advantages. A typical meta-material combines continuous metal films with nanos-trip magnetic resonator that ultimately produce a negative index material. The film can be formed with a mixture of dielectric (for example, Si y SiO_2), forming a semi-metal film. These structures are fabricated using techniques preparing the meta-material structure in the optical range is even an advanced task. In recent experiments have shown that incorporation of the material gain in the meta-material makes it possible to produce an extremely low loss and an active-index. Optical negative index meta-materials (NIM) that is not limited by the inherent loss in the metal component. In this experiment NIM optic network structure is approximately periodicity. The mechanism of compensation of losses in the sample is simple to understand. When excited by a pump pulse with sufficiently high power, a population inversion is formed within molecules. This provides a boost pulse suitably delayed probe whose wavelength coincides with the wavelength of stimulated emission molecules. Working with quasi-periodic structures: Set of Cantor and Pascal's triangle; applying the Green's function, SiO_2 that is used as a gain medium when applying in the nucleus nano-emitter or any part of the area surrounded by different layers. This allows a pulse of the electromagnetic wave handled properly.

The films can be formed with a mixture of dielectrics, in this case Si and SiO_2 can form a semi-metal films.

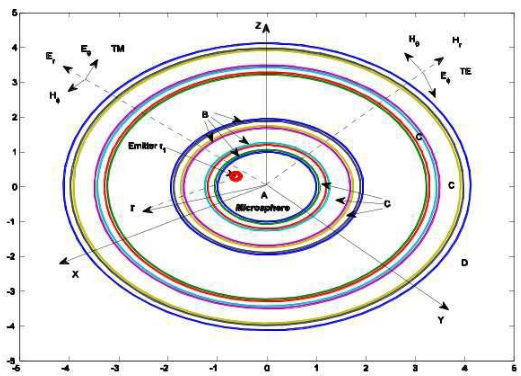

Figure 1: Micro-sphere multi-layer system with quasi-periodic structure added by a source of radiation (red circle).

In the following table the results of the simulation method used for calculation for the first two experiments 400 and 500 THz given by (E) in (A) angle type 0.5 and 0.9, (B) shows lens exposure or nanoesimor in this case 0.5, (C) Number of layers, 12, (D) maximum layer growth is handled with 4, (F) numbers of points in the 3D image (G) Type of angles, (H) the wall height of the outer layer 0.5, (I) the wall height of the inner layer.

Table 1: The parameters used in each spherical stack of quasi-periodic system.

	A	B	C	D	E	F	G	H	I
1	0.9	0.5	12	4	400	50			0.7
2	0.9	0.5	12	4	400	50			0.9
3	0.9	0.5	12	4	400	50			1.0
4	0.9	0.5	12	4	400	50			1.3
5	0.5	0.5	12	4	500	50	0.5	0.5	2.0
6	0.5	0.5	12	4	500	50	0.5	0.5	1.9
7	0.5	0.5	12	4	500	50	0.5	0.5	1.8
8	0.5	0.5	12	4	500	50	0.5	0.5	1.7

3. BASIC EQUATIONS

The quasiperiodic systems may be considered appropriate models to describe the transition of the periodic structure for perfect random structure. The spatial scale of the nanoemitter objects ($\sim$ 1–100 nm) is at least one order of magnitude smaller than the spatial scale of microspheres ($\sim 10^3$–10^4 nm). Therefore in the coated microsphere (Fig. 2), we can represent the nanoemitter structure as a point source placed at $\mathbf{r}'$ and having a dipole moment $\mathbf{d}_0$. It is well known that the solution of the wave equation for the radiated electromagnetic field $\mathbf{E}$ due to a general source $\mathbf{J}(\mathbf{r}')$ is

$$E_\theta = \frac{1}{kr\varepsilon}\frac{\partial^2\Pi(\rho,\theta,\varphi)}{\partial r\partial\theta}, \quad H_\varphi = \frac{i}{r}\frac{\partial\Pi(\rho,\theta,\varphi)}{\partial\theta}\sqrt{\frac{\epsilon_0}{\mu_0}}. \tag{1}$$

$$\mathbf{E}(\mathbf{r},\mathbf{r}',\omega) = -\mathbf{p}_0\mathbf{G}(\mathbf{r},\mathbf{r}',\omega) \tag{2}$$

$$\mathbf{G}(\mathbf{r},\mathbf{r}',\omega) = \mathbf{G}^V(r,r',\omega)\delta_{fs} + \mathbf{G}^{(fs)}(\mathbf{r},\mathbf{r}',\omega) \tag{3}$$

$$\mathbf{G}^V(\mathbf{r},\mathbf{r}',\omega) = \frac{\hat{r}\hat{r}}{k_s^2}\delta(r-r') + \frac{ik_s,}{4\pi}\sum_{q=e,}\sum_{n=1}^{\infty}\sum_{m=0}^{n} C_{nm}\mathbf{G}^V_{q,nm}(\mathbf{r},\mathbf{r}',\omega) \tag{4}$$

In the following image the distribution of magnetic and electric field is displayed. The structure depends on the parameters inserted in each range, we study the dependence of Green's function with respect to range, resulting from simulations without changing the parameter range (which is no more than a parameter set cantor) in the following figure you can see the sum given by Nmax12, RM4 = Rmax with a value of 4, $f = Atomf$ (frequency 400 Thz) for different types of exposure source 0.7, 0.9, 1.0 and 1.3 with a range of 1.0 and in third dimension.

4. NUMERICAL SIMULATION PERFORMED FOR CANTOR SET WITH GREEN FUNCTION

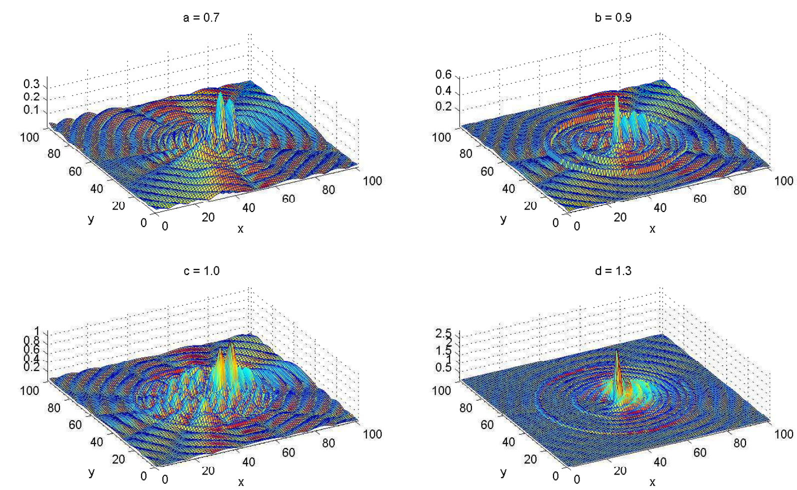

Figure 2: Parte distribution imaginary 3D Green's function for Cantor multilayers with layers Si and SiO_2 for parameters indicated in the Table 1.

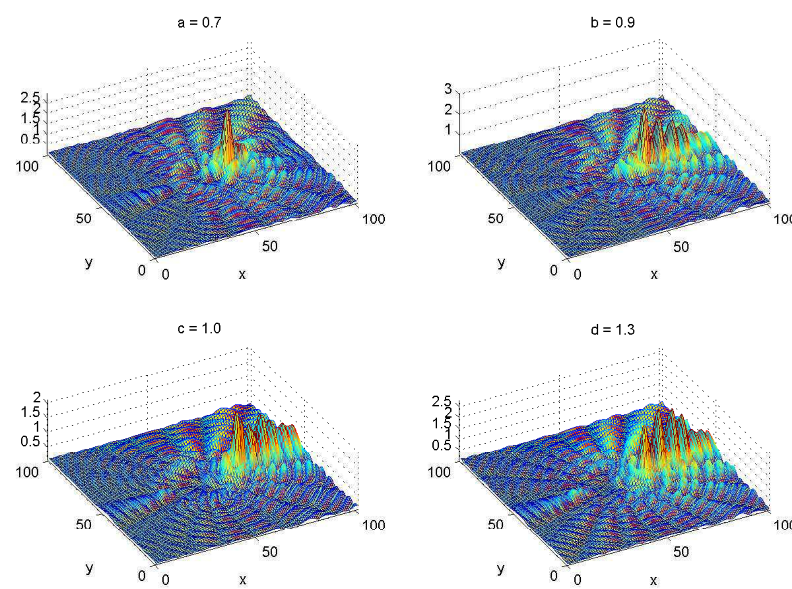

Figure 3: Parte distribution imaginary 3D Green's function for triangle Pascal multilayers with layers Si and SiO_2.

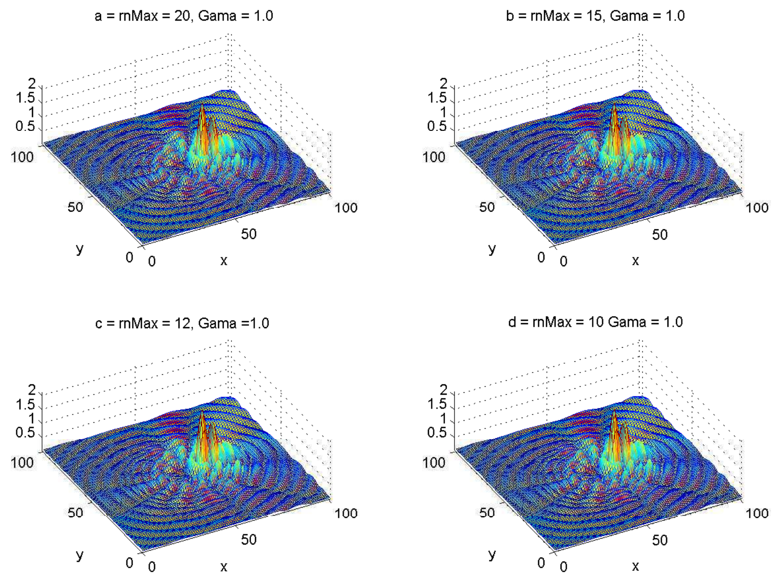

Figure 4: Simulation analysis of the Cantor set and function Green TM&TE. Here a distinct change in the sum of 20, 15, 12 and 10 and the exposure source is 1.5 working with TM&TE.

5. CONCLUSION

In this paper we have numerically studied the electromagnetic properties (narrow peak positions) of the transmission spectra for microspheres coated by a multilayered stack with the generalized Cantor and Pascal structures. As opposed to the standard Cantor system with removed $\gamma/3$ $[\gamma = 1]$ sections the generalized solid stack with alternating Si/SiO_2 layers (in place of empty Cantor section) for such fractal pattern with general values of γ it is considered. It is found that the variations of parameter γ significantly affects the structure of the optical spectra. The waves phase interference in such a fractal pattern leads to creation of extremely narrow frequency peaks assisted by the progressively decreased radially inhomogeneous defects. Such peaks can be used in modern optoelectronics, e.g., for construction narrow optical filters.

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