19th International Young Scientists Conference
Optics and High Technology Material Science

SPO 2018

Scientific Works
October 25-28, 2018

Kyiv, UKRAINE

TARAS SHEVCHENKO NATIONAL UNIVERSITY OF KYIV (TSNUK)
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Nineteenth International Young Scientists Conference

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CONTENT

Scientific Problems of Optics (SPO 2018) conference: young scientists choose optics as their future research career

Optics has always been my passion. Nature by itself evokes incredible, spectacular manipulations with light. Natural photonic crystals, halo effect and mirage in atmosphere fascinate human's mind for centuries. Understanding of the mystery of light nature has become the "idée fixe" for many generations of physicists. Nowadays, when daily life runs as a high-speed train, the society is entering the information epoch and nature of light seems to be completely understood, we realize anyway to highlight new properties of light-matter interaction, go more and more inside the high-field physics and attosecond science, manipulate coherent quantum systems and build up a quantum computer.

During my undergraduate studies one of professors strictly declared: "Due to diffraction limit it's absolutely impossible to observe directly an atom." What a shame, roughly a decade later the tunnel and atomic force microscopes were invented. For the first time human realized to capture an image of atom. Similar and even more general example concerning scientific advances appeared slightly before, in the middle of the XX century. At that time the scientific community was seriously debating about the full decay of optics, this field seemed to be saturated and over. Apparently, optical science was standing at the very beginning only. In 1954 C. H. Townes introduced the concept of stimulated emission of radiation, soon after, in 1958, N. Basov and A. Prokhorov developed efficient optical cavities with positive feedback and finally in 1960 T. H. Maiman completed the story of **L**ight **A**mplification by **S**timulated **E**mission of **R**adiation. One of greatest discoveries of the XX century named **LASER** exploded scientific research as well as technology progress. Just in two years, in 1962, the Second Harmonic Generation phenomenon was observed. Optical science had passed its threshold and the era of non-linear optics started. Up to now, laser science and non-linear optics doesn't stop advancing and the half of Nobel Prize 2018 in Physics was awarded to Gérard Mourou and Donna Strickland for their method of generating high-intensity, ultra-short optical pulses.

As a head of Chair of Optics at Taras Shevchenko National University of Kyiv, I insisted to establish a fruitful education program in Optics for my students. Their schedule includes classical fundamental disciplines like Interference and Diffraction Theory, Optics of Anisotropic Media or Spectroscopy. At the same time our Chair of Optics follows the newest achievements in optics, application of optical methods in solid state physics and light-matter interaction processes, consequently many new classes are proposed: Non-linear and Quantum Optics, Nanophotonics and Nanoelectronics, Plasmonics, High-Field Physics, Attosecond Science or Biophotonics. Solid background plays an essential but not the most crucial role in future researches. The key idea I have learned in science is to reject

AP.13

MODELLING OF ELECTRON STATES IN CYLYNDRICAL AND CONICAL QUANTUM DOTS

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We study electron states in cylindrical and conical quantum dots with infinitely high walls. The Schrödinger equation for stationary s-states of electrons in a cylindrical coordinate system [1] has the next form:

$$\frac{\partial^2\psi_1}{\partial r^2}+\frac{1}{r}\cdot\frac{\partial\psi_1}{\partial r}+\frac{\partial^2\psi_1}{\partial z^2}+\frac{2mE}{{}^2}\cdot\psi_1(r,z)=0 \qquad (1)$$

The solution of equation (1) for a cylindrical quantum dot can be represented as:

$$\psi_1(r,z)=\phi_1(r)\cdot\phi_2(z)=A_1\cdot J_0(k_1\cdot z)\cdot\sin(k_2\cdot z) \qquad (2)$$

We use boundary conditions $\psi_1(R,z)=\psi_1(r,H)=0,\quad 0\le r\le R_1;\ 0<z\le H_1$

to obtain wavenumbers: $k_{1,n}=\frac{b_{n_1}}{R_1}\quad k_{2,n}=\frac{\pi\cdot n_2}{H_1}$ (3)

where b_{n_1} - zeros of the zero order Bessel function $J_0(k_1\cdot z)$, $n_2=1,2,\ldots$ - quantum numbers, R_1 - the radius and H_1 - the height of cylindrical quantum dot.

Therefore, the eigenvalues of energy are given by $E_1=\frac{{}^2}{2m}\cdot(k_1^2+k_2^2)$ (4)

The amplitude of a wave function is determined by the normalization condition $\int\limits_V\left|\psi_{n_1,n_2}\right|^2 dV=1$, and equals to $A_1=\frac{\sqrt{2}}{\sqrt{\pi\cdot H_1}\cdot R_1\cdot J_1(k_{n_1}\cdot R_1)}$ (5)

The solutions of the wave functions $\psi_1(r,H_1)$ and $\psi_1(R_1,z)$ are presented in the Fig.1

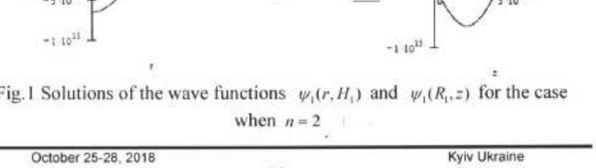

Fig.1 Solutions of the wave functions $\psi_1(r,H_1)$ and $\psi_1(R_1,z)$ for the case when $n=2$

We consider the wave function and eigenvalues of electron energy for the case of a conical quantum dot as well [2]. At the surface of a conical quantum dot cylindrical coordinates are connected as $r=\frac{R_2}{H_2}\cdot z$ and $z=\frac{H_2}{R_2}\cdot r$, where R_2 - the radius and H_2 - the height of a cone.

Using boundary conditions $\psi_2\left(r,\frac{H_2}{R_2}r\right)=0$, we find the dependence of the eigenvalues of energy on the coordinate Z:

$$E_{2,n}(z)=\frac{{}^2}{2m}\cdot\left[\frac{b_n^2\cdot H_2^2}{R_2^2\cdot z^2}+\frac{n^2\cdot\pi^2}{z^2}\right] \qquad (6)$$

The minimal dimensions of a conical quantum dot is determined by the dimensions of a quantum system $H_{\min}=R_{\min}=2\cdot10^{-9}\,м.$

The discrete eigenvalues of the electron energy may also be determined by the numerical finite difference method, so the probability density (square of the wave function module) can be visualized. For example, when $H_2=\sqrt{3}\cdot R_2$, $z=\frac{H_2}{2}$ and $n=1$ the amplitude A_2 of the wave function $\psi_2(r,z)=A_2\cdot J_0(k_3\cdot z)\cdot\sin(k_4\cdot z)$ is determined by the normalization condition $\int\limits_V\left|\psi_{2,1}\right|^2 dV=1$:

$$A_2=\frac{\sqrt{6}}{\sqrt{\pi}\cdot H_2^{3/2}\cdot J_1(2b_1)} \qquad (7)$$

To conclude, we considered the simplest mathematical models of quantum dots (cylindrical and conical) with perfectly reflective walls. We obtained wave functions and eigenvalues of energy for finite motion of the s-electron in these quantum-sized structures.

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