Nanorod of strongly prolate ellipsoidal shape: asymptotically exact solution

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Annotation (Resume)

In the last decade there is a rapidly growing interest in nanosized crystalline semiconductor structures of various shapes. Physical properties of nanosized objects such as nanorods, nanowires and quantum dots have been intensively investigated both theoretically and experimentally [1]. The most important result that has been revealed in these investigations is the strong interdependence between the character of energy spectrum of the nanosized object and its geometrical parameters size and shape. Sizetunable control of spectral and optical characteristics of the nanosized objects opens exciting possibilities for the creation of new functional materials that can be used in unlimited application.

Modern growth techniques make possible to obtain nanosized objects of different geometrical shapes and sizes. In literature there are many works devoted to theoretical study of spherical, cylindrical, pyramidal, ellipsoidal, semiellipsoidal nanosized objects [2-5]. For nanorod of cylindrical shape the problem can be solved exactly assuming that the potential, which is experienced by a charged particle (electron or hole), is zero inside the cylinder and that it is infinite outside [2]. For nanorod that has the shape of an ellipsoid of revolution with major semi-axis (the nanorod axis) much larger than the minor semi-axes (the nanorod radius), the problem is usually treated in cylindrical coordinates by using an adiabatic approximation [3-5]. Within this approximation, the "slow" motion of an electron (or hole) parallel to the nanorod axis is initially neglected and the spectrum of the electron in two dimension confinement perpendicular to the nanorod axis is found. The parallel motion is treated by averaging the Hamiltonian over the "fast" motion of the electron strongly confined in two dimensions. The difficulties which arose in [3-5] are connected with the consideration of nanrod that has the shape of an ellipsoid in cylindrical coordinates.

Obviously, spheroidal coordinates contain the symmetry intrinsic to nanorod of ellipsoidal shape. Therefore, it should be expected that spheroidal coordinates will be the most appropriate for the solution of the problem.

In the present work we consider nanorod of strongly prolate ellipsoidal form. We treat the problem in spheroidal coordinates that enables us to solve the problem without usage of adiabatic approximation. We derive the asymptotically exact expressions for the energy spectrum and for the wavefunctions of an electron confined in ellipsoid. The obtained expression for the energy spectrum is valid for the low-lying as well as for the higher levels, and hence is free from the limitation of expressions obtained by previous authors [3-5].

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