Linear and Non-Linear Optical Absorption of Neutral Donors in InAs/GaAs Camel-like Nanostructures

R. A. López-Doria[1,2], N. Hernández[1,2] and M. R. Fulla[1]

[1]*Escuela de Física, Universidad Nacional de Colombia Sede Medellín, Colombia*

[2]*Centro de Investigación CIENTIC, Institución Universitaria Pascual Bravo, Medellín, Colombia*

ralopezd@unal.edu.co

In the last two decades, we have witnessed the advancement and improvement of semiconductor heterojunction growth mechanisms, which has led to the creation of distinct types of semiconductor quantum dots (SQDs). As early as 2003, we can trace how molecular beam epitaxy (MBE) has been used to obtain SQDs with different morphologies, such as Quantum Rings [1]. The appearance of these new types of SQDs has surged the interest of many theoretical physicists who have studied many aspects regarding the nature of few-particle systems confined in the newly obtained geometries of the SQDs, such as electrical and optical properties [2][3]. Even though this is the case, a specific category of SQDs exists, the physics of which has yet to be thoroughly investigated. It was first grown by Granados et al. in 2003 [1] and is often referred to as a camel-like quantum dot (CLQD) due to the presence of two protuberances like that of a camel hump. In fact, to the best of our knowledge, no other authors have studied charge carriers confined into a CLQD from a theoretical standpoint. This fact constitutes the primary motivation for the present work, in which we focused on exploring the optical properties of a neutral donor confined into a CLQD. We propose a way to model a realistic CLQD by fitting the AFM data from a physically grown CLQD in Songmuang et al. [4] work through a mathematical model. In turn, this led us to approximate the geometry comprising the CLQD. The fit of the experimental AFM profile with the proposed mathematical model can be seen in Figure 1. Furthermore, using the envelope function and effective mass approximations, we set an eigenvalue problem to calculate the energy spectrum of the confined neutral donor in a CLQD. The method used to solve the associated differential equation was the Finite Element Method. Once the eigenstates were calculated we were able to study the Linear and Non-Linear components of the optical absorption through the density matrix formalism.

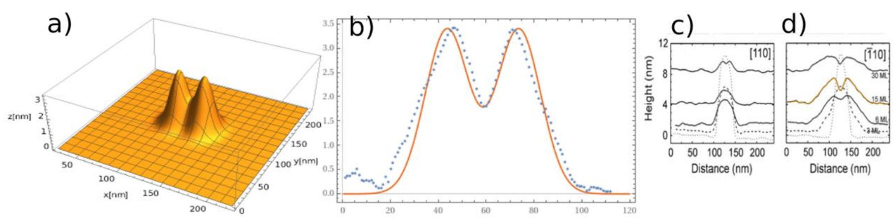

Fig.1. a) Plot of the proposed height profile model. b) AFM data in blue dots and the transversal view of the proposed profile in orange. c) and d) Experimental data taken from Songmuang et al. [4], in which the profile modeled is highlighted in orange.

References

[1] D. Granados, J. M. García, Customized nanostructures MBE growth: From quantum dots to quantum rings, in Journal of Crystal Growth, Vol. 251, North-Holland, 2003, pp. 213–217.

[2] Fomin, V. M. (2014). *Physics of Quantum Rings* (Vladimir M Fomin, Ed.). Springer Berlin Heidelberg. https://doi.org/10.1007/978-3-642-39197-2

[3] Zeng, Z., Garoufalis, C. S., & Baskoutas, S. (2014). Linear and nonlinear optical susceptibilities in a laterally coupled quantum-dot–quantum-ring system. Physics Letters A, 378(36), 2713–2718. https://doi.org/10.1016/j.physleta.2014.07.036

[4] Songmuang, R., Kiravittaya, S., & Schmidt, O. G. (2003). Shape evolution of InAs quantum dots during overgrowth. Journal of Crystal Growth, 249(3–4), 416–421. https://doi.org/10.1016/S0022-0248(02)02222-4