Research Statement

PhD program in quantum technology and quantum systems engineering.

<u>Subject proposed:</u>

Study of the optical and electrical properties of Nano objects (QD, QWW, QW and QR) based on nitrides: effect of laser field.

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1. Introduction

The optoelectronics market is currently worth $ 20 billion a year, and it is expected to grow rapidly in the coming decades. This development is largely due to growth and progress in the lighting solid state and laser technologies.

The field of application of these materials is expanding very broadly considering recent advances and understanding of semiconductor physics. Indeed, these materials are the most used in light-emitting diodes emitting in the infrared and visible range (500 to 2000 nm), which replaced the conventional diodes by their high luminescence efficiency and their long life, thus reducing the cost of operation and maintenance of the light sources. Important economic and scientific stakes are at the origin of a competition to obtain an ever shorter wavelength and increasingly lower thresholds, especially for photodetectors that have many potential applications, in areas such as solar astronomy, missile detection and monitoring of combustion processes.

The development of structure to cover the blue and UV optical range (450 to 350 nm) and less advanced due to the difficulties of development and doping of materials with a wide bandgap. Moreover, the alloys being very resistive, it is very difficult to obtain Ohmic quality contacts.

Gallium nitride-based components, particularly those made by Nichia (Japan), are currently the most efficient in the field of light-emitting diodes, estimated at around $ 200 million in 1999, growing every year by 40% to 50%.

The elements III- nitrides (GaN, AlN, InN and their alloys) are semiconductors with remarkable properties. The most important is undoubtedly their direct band gap which varies from 1.9 eV for InN to 3.4 eV for GaN, and reaches 6.2 eV for AlN. Thanks to the concepts of band gap engineering developed in the framework of the traditional III-V semiconductors (arsenides, phosphides, antimonides), it is thus possible to cover the entire visible spectral range, but also the ultraviolet A (320- 400 nm) and B (280-320 nm). This point, complemented by the very high stability of the GaN base material, is at the origin of the industrial production of high-gloss blue and green light-emitting diodes (LEDs), and laser diodes (DLs) emitting at 0.4 µm.

1. State of Art:

There has been an increasing interest, both experimentally and theoretically, in the investigation of low-dimensional system (LDS) semiconductor heterostructures due to their intrinsic physical properties.

The impurity states in a typical system are widely studied experimentally and theoretically. For instance, Mutta et al. [1] have reported the experimentally investigations using transmission electron microscopy and photoluminescence on WZ (In,Ga)N/GaN QW for various structure parameters. The effects In concentration on the optical properties of WZ (In,Ga)N/GaN QW [2] and on the optical polarization characteristics of m-oriented InGaN/ GaN QW LED [3,4] are investigated.

The interaction of the intense laser field (ILF) with carriers in such structure forms a major domain of research both theoretically and experimentally which allowed the discovery of interesting physical phenomena. [5–8] Recently, several theoretical studies of the linear and nonlinear intersubband (ISB) conduction band optical absorption and the refractive index changes, based on the single QWs and multi quantum wells (MQWs) have been reported. [10–14]

The third-order nonlinear optical properties of low dimensional semiconductor systems have attracted much attention for both theoretical researches and practical applications such infrared photo detectors, far-infrared laser amplifiers, optical memory technology, light emitting diode, high-speed electro-optical modulators and so on [15- 17]. Liu et al. [16] have performed the calculation of linear and nonlinear optical intersubband absorption coefficients (ACs) and refractive index changes in cylindrical quantum well (CQWW). Sahin et al. [17] have investigated the hydrogenic impurity effect on the third-order nonlinear optical properties of one- and two-electron SQD.

2. Methodology and Proposed Research Plan:

- Investigate the well (barrier) size and compositions effects on ground-state binding energy using a numerical methods.
- Focus on the lowest energy states between the ground (l=0) and the first excited (l=1).
- Study on the effects of external ILF and internal CBENP on linear and nonlinear optical absorption properties of (In, Ga)N–GaN QW.

- Expand these studies to (In,Ga)N/GaN low dimensional systems and compare our results to those reported by Baser et al. which concern the cylindrical quantum well wire (CQWW) system [18,19].
- Investigate the effects of incident optical intensity, dot radius, hydrogenic impurity and potential barrier (In-fraction) on linear, nonlinear and total intrasubband ACs of 1s-1p, 1p-1d and 1d-1f transitions in (In,Ga)N/GaN SQDs.
- Investigate the effect of the pressure, the built-in electric field and their combination on the binding energy and the absorption spectra.
- Comparison between theoretical, experimental and numerical results.

3. Methods:

- Use python to numerically solve the Schrodinger equation to obtain eigenvalues and eigenvectors. To plot the curves of the binding energy, absorption coefficient and the refractive index according to the parameters to be studied
- Experimental measurement of the absorption coefficient.
- Experimental measurement of the refractive index.

4. Aims and Objectives:

Electrical and optical properties of wide bandgap group-III nitride based LDS semiconductors, have attracted much attention which offer a wide range of potential applications for fabricating optoelectronic devices, such as high- brightness blue/green light emitting diodes (LEDs) and laser diodes (LDs) with long lifetime [20,21].

To the best of our knowledge, InGaN double QWs are still an open issue and are less commonly used as the active layer. No work has been discussed to treat the combined effects of ILF and conduction band-edge non parabolicity (CBENP) on optical absorption in (In, Ga)N–GaN system.

All the research works mentioned above have been carried out within the parabolic band approximation. For more accuracy, LDS optical properties cannot be studied without considering the lift of the conduction band-edge due to energy dispersion relation in more realistic model.

-Use numerical methods to do the work mentioned above, instead of the variational method.

5. Anticipated Outputs:

We hope that the results presented will be useful for determining the optimum composition in alloys, the impurity position, and other parameters to improve optoelectronic devices.

I have numerical results, So I have plotted the binding energy as a function of the well width studying some of the internal parameters such as the width of the quantum barrier, the position of the impurity, the molar fraction of indium, and also the step of discretization, for simple, double and multiple quantum well, some of the external parameters such as the pressure and the built-in electric field. The same study for the wave functions and the state density. That will be published in an international journal.

6. Potential Impact:

The results obtained will be useful in the area of optoelectronic devices.

7. References:

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