THE GANDHIGRAM RURAL INSTITUTE
(Deemed to be University)
Ministry of Education, Govt. of India
ACCREDITED BY NAAC WITH 'A' GRADE (3rd CYCLE)

Dr.M.G. SETHURAMAN
CONTROLLER OF EXAMINATIONS i/c

GANDHIGRAM-624 302
DINDIGUL DISTRICT
TAMIL NADU, INDIA

Fax:+91-451-2452222 Phone:+91-451-2454222	EPABX :+91-451-2452371 to 2452376	E-mail: controllergri@gmail.com

Ref: E1(A)/Ph.D./**PHY-97**/2020-21/

Date: 09.12.2020

To

Prof. SURIANI ABU BAKAR,
Nanotechnology Research Centre,
Faculty of Science & Mathematics,
Universiti Pendidikan Sultan Idris,
Email: absuriani@yahoo.com

Sir/Madam,

Sub: Gandhigram Rural Institute– Acceptance of examinership for evaluation of Ph.D. thesis – reg.

******

I am pleased to inform that your name has been suggested in the panel of Examiners to evaluate the following Ph.D. thesis:

Title of thesis	**SOME INVESTIGATIONS ON THE DONOR AND EXCITON STATES IN QUANTUM RING SYSTEMS.**
Submitted by the candidate With code No.	**Ms. I.JANET SHERLY, (PHY-97)**
Under the guidance of	**Dr. P.NITHIANANTHI,** Asst. Professor, Department of Physics, Gandhigram Rural Institute- (Deemed to be University) Gandhigram-624 302.

Please convey your acceptance to evaluate the thesis. A synopsis is enclosed for your reference. If the offer is accepted, please furnish details pertaining to you in the enclosed format and **mail it to reach me** on or before **16.12.2020 (or within 7 days after the receipt of this letter)**

If you are NOT able to accept the offer, kindly inform me by return of post enclosing the synopsis, in the enclosed cover.

Please note that the thesis will be sent to you for evaluation only if you are appointed as an examiner from the panel of examiners accepted to evaluate the thesis.

Yours faithfully,

15/12

CONTROLLER OF EXAMINATIONS i/c

Encl: Synopsis

3/5

Some Investigations on the Donor and Exciton States in Quantum Ring Systems

Synopsis of the Thesis to be Submitted to

The Gandhigram Rural Institute – Deemed to be University

in partial fulfillment of the requirements for the award of the

DOCTOR OF PHILOSOPHY

By

I. JANET SHERLY

Department of Physics

The Gandhigram Rural Institute – Deemed to be University

Gandhigram – 624 302

Tamil Nadu

India

November - 2020

CHAPTER I

Introduction

Quantum Ring (QR) which is a doubly connected ring like structure in the nanoscale is quite interesting because of its peculiar properties. It exhibits unique density of states for charge carriers which makes them favourable for the realization of many prospective in the electro-optical and magneto-optical applications. Their unique doubly-connected topology and their intriguing energy structure shows great potentialities in single-photon emitters, photonic detectors and sources including quantum computing, magnetic random access memory, and other spintronic devices. QR made of semimagnetic materials have unique properties and it has been under extensive theoretical and experimental investigations. Semimagnetic heterostructures is a substitutional alloy of either II-VI or IV-VI semiconductors with magnetic ions. The magnetic properties of the semimagnetic materials like Zeeman splitting and Faraday rotation which is a direct consequence of the exchange interaction between the carrier and the magnetic ion not only provide a brief understanding of the different properties of these fascinating systems but also offers a tool to control the carrier dynamics through external perturbations. All these magnetic phenomena not only depend on the energy transfer between ions and carrier but also governed by the concentration of magnetic ions.

Vertical coupling, horizontal coupling and concentric coupling are all possible in QR structures and the carrier states initially localized in individual QR are quantum mechanically coupled, thus forming delocalized states extending over the coupled rings. Coupled rings can be easily modified into symmetric and asymmetric system by tuning the ring dimensions. The provision of additional carrier confinement and the feasibility of tuning the ring dimensions have made Concentric Double Quantum Rings (CDQRs) a step superior to single quantum ring in utility for specific applications.

In an effort to enlighten the properties of QR and to analyse the envisioned ideas about the nonmagnetic and semimagnetic single rings and coupled rings under electric field and magnetic field, a detailed theoretical study has been made on the donor and exciton states in QR systems. The structure of the thesis is as follows.

Thesis Overview

The entire thesis is broadly divided into two parts: **Part A - Theoretical investigation on the donor and exciton states in non-magnetic GaAs/$Al_{0.3}Ga_{0.7}As$ quantum ring** and **Part B - Theoretical investigation on the donor and exciton states in semimagnetic CdTe/CdMnTe quantum ring**. Initially, studies have been made on both single and double non-magnetic quantum rings. Since double quantum rings exhibit more interesting properties, investigation on semimagentic systems is restricted to double rings only. Thus, part A contains four chapters (II – V) and part B contains three chapters (VI – VIII). The effect of magnetic field and band nonparabolicity on the carrier dynamics in a single GaAs/$Al_{0.3}Ga_{0.7}As$ QR has been presented in **chapter II**. Stability of exciton formed inside a single QR under two different confining potentials has been calculated through diamagnetism and it has been discussed in **chapter III**. The effect of location on the stability of exciton has also been investigated. The dimensional effect on the donor localization in non-magnetic Concentric Double Quantum Ring (CDQR) and the effect of impurity location has been calculated and the results are reported in **chapter IV**. **Chapter V** gives behavior of the exciton states of CDQR heterostructures enclosed by SiO_2 ligand matrix under electric field. The stability of direct and indirect excitons for various electric field and ring dimensions has been estimated through diamagnetism. One of the interesting feature of QR is its magnetic response. To explore the inherent magnetism possessed by the circular QR structure and its magnetic response, donor states in Diluted Magnetic Concentric Double Quantum Ring (DMCDQR) under external magnetic field has been investigated and included in **chapter VI** of the thesis. The effect of magnetic field on the carrier stability in both symmetric and asymmetric rings has been discussed. The effect of magnetic ion concentration on the carrier stability has been estimated through Bound Magnetic Polaron (BMP) and the results are presented in **chapter VII**. **Chapter VIII** deals with the exciton states in DMCDQR under electric field. The role of SiO_2 matrix in deciding the stability of exciton formed inside coupled and decoupled rings has also been discussed. **Chapter IX** consolidates the research findings and suggests ideas of implementing the observed results for the upcoming challenges in the research area and extension of this work for device applications has been discussed. All the numerical calculations are carried out using licensed software "Wolfram Mathematica-L3602-1453".

Part A - Theoretical Investigation on the Donor and Exciton States in Non-magnetic GaAs/$Al_{0.3}Ga_{0.7}As$ Quantum Ring

CHAPTER-II

Donor States in Single Quantum Ring

Carrier dynamics in a GaAs/$Al_{0.3}Ga_{0.7}As$ Quantum Ring (QR) under the influence of an external magnetic field along with the effect of conduction band non-parabolicity has been studied using variational method.

i) Confinement of donor in a quantum ring under magnetic field

Under magnetic field, donor in QR experiences additional quantisation through splitting of subband energy levels. The spacing between these split energy levels are more in narrow rings and this promotes larger confinement. But in a wider ring there is more lateral space which reduces the inter energy spacing. Larger magnetic field push the carrier towards the boundary for certain ring dimensions. Hence the spatial dimension and external perturbation has an important influence on the donor energy levels.

ii) Inclusion of conduction band non-parabolicity: A realistic approach

In reality, the conduction bands are non-parabolic in nature except at k=0. As ‘k’ increases the band starts to deviate and this curvature decides the effective mass of the carrier which reduces the Binding Energy (BE). This effect is more significant for narrow rings. Also it has been observed that the incorporation of band non-parabolicity factor is more effective for edge impurities when compared to other impurity locations. Thus the nonparabolicity factor adds a betterment to the ideal QR structures.

iii) Localisation of on and off centered donors

To understand the effect of impurity location, donor has been lodged in various locations and it is found that BE gradually decreases when the impurity moves from the center to either side of the ring. It is also observed that prevalence of impurity at the edges favors more tunneling and therefore the carrier bound to on and off centred donors undergo different confinement.

CHAPTER-III

Exciton States in Single Quantum Ring of Different Confining Potential

Effect of confining potential on the exciton stability at various locations in a parabolic and square GaAs/$Al_{0.3}Ga_{0.7}As$ quantum ring has been estimated.

i) Exciton localization in different ring dimensions

Importance of dimensional effect on exciton localisation can be realized by varying the ring dimension and it is found that the ring dimension has similar effect in Parabolic Quantum Ring (PQR) and Square Quantum Ring (SQR) but for the magnitude of BE. When the ring dimension is comparable to the exciton Bohr radius, the electron cloud piles up around the hole. Enlarging the ring width reduces the probability for detecting the exciton. Thus the ring dimension ultimately decides the exciton localisation.

ii) Effect of confining potential on the exciton dynamics

The shape of the confining potential can effectively regulate the carrier dynamics and on that note carriers in a larger PQR can easily tunnel into the barrier because of the trough of the parabola. This feature is in contrast to SQR case where the carriers remain inside the ring because of wider space in square confinement. Moreover, in a square potential the band bending at the interface introduces triangular potential barriers. Therefore, on reaching this barrier the carrier loses its mobility and confined to this region at the interface. But in a parabolic potential, the compositional profile has a reverse effect and the carrier oscillates about the center. The complete study made in two different confining potentials reveals that the potential greatly alters the exciton localisation.

iii) Exciton stability at different locations in the ring

The constituent particles of exciton have been located at and away from the center to understand the interface effect. Among all locations, On Center Exciton (OCE) possess larger BE because the electron will be completely in the vicinity of the hole. The effect of parabolic potential is larger for Partially Centered Exciton (PCE) and On Inner Edge Exciton (OIEE) because once when the carriers march towards the edges they could feel the effect of parabolic potential due to its curvature. The interplay between the exciton location and confining potential can be confirmed from all these facts.

iv) Dimensional instability through the height of the ring

The versatility of QR system can be clearly understood by largely minimizing the ring dimension. If the height of the ring is reduced to a larger extent the exciton will have confinement only along the radial direction. The confinement along the z direction will be very negligible. Now the system will no longer be a QR but a quantum annular disc. Though squeezing the height of the QR completely is an ideal case dimensional instability can be clearly understood only in such limiting conditions.

v) Diamagnetic susceptibility: A measure of inter-particle separation

The permanent dipole moment of exciton is very sensitive to the carrier confining potential and this necessitates the analysis of inter-particle separation. The inter-particle separation is estimated through diamagnetic susceptibility (χ_{dia}). In SQR due to the interfacial triangular potential at the interface the movement of electron or hole or both restricted and the exciton localisation is sharp. In PQR, the parabolic trough facilitates to and fro motion of carrier and moreover there is no such triangular interface. Hence these interfacial effects have a major role in determining the χ_{dia}.

Thus, the interfacial effect of any heterojunctions which greatly influences the mobility of exciton can be made minimal if the ring is designed with a parabolic confinement. Analysis of χ_{dia} in QR structures will pave way for improvement of magneto-electronic and opto-electronic devices.

CHAPTER-IV

Geometrical Effects on the Donor States in Concentric Double Quantum Rings

The possibility of tailoring III-V GaAs/$Al_{0.3}Ga_{0.7}As$ Concentric Double Quantum Ring (CDQR) by tuning the ring dimension brings out carrier confinement in different regimes which make them suitable for specific applications.

i) Central barrier criticality for tunneling of donor

The additional stacking of barrier material between the two rings act as a channel for carrier tunneling. Narrow central barrier couples the two rings and the carrier tunnels through this narrow barrier, reach the outer ring and again tunnels back to the inner ring. Thus, the carrier oscillates between the inner and outer rings and it sustains until C_B reaches its criticality, i.e., the value above which the barrier blocks the carrier from tunneling. Larger barrier completely isolates the two rings.

ii) Selective occupancy of the donor in the rings: Effect of geometry

a) In the coupled regime: Dominance of centrifugal force

Localisation of the carrier in the coupled rings is due to the interplay between (i) spatial confinement given by the dimension of the materials (ii) the centrifugal force and (iii) Coulomb interaction of the parent donor. Though the Coulomb interaction favors occupancy in a wider ring, the centrifugal force overplays and forces the carrier to the inner ring in certain ring dimensions. The carrier seeks the outer ring when the outer ring approaches the dimension of the inner ring.

b) In the decoupled regime: Observation of nano to bulk transition

In the decoupled regime for $C_B \geq 50$ Å, on reaching $I_R=O_R$ (Inner ring width=Outer ring width), there is a sudden fall in BE and it saturates at 5.83 meV which is the bulk limit of a GaAs semiconductor. Thus, one can observe a sudden transition from nanoscale to bulk. Another interesting observation is, though the inner ring dimension is in the nanoscale regime (I_R=100Å), BE value reaches the bulk limit in the prevailing condition. This transition occurs only when the barrier is very large.

iii) Effect of height of the ring on donor confinement

When the heights of the two rings are the same ($H_I=H_O$ = 40 Å) and when $I_R=O_R$, the energy states in the two rings are in the resonant mode. When H_I = 40 Å and H_O = 60 Å i. e. when the height of the outer ring is larger than that of the inner ring, though the outer ring becomes deeper and wider than the inner ring, the carrier seeks only the inner ring because of the centrifugal force that arises due to the geometry of the system. Variation in the height of the rings plays a major role in the emission energy. This result will throw more light on the design of quantum rings for specific applications.

The selective occupancy of the carrier in either of the rings and the tunneling effect of the carrier will be of high use in designing many electronic devices. Since the carrier in the inner ring enhances persistent current, the aforesaid geometry is suitable for such applications. CDQR with an outer ring width larger than that of the inner ring promotes carrier confinement only in outer ring which can be used for X-OR gate applications. Only a proper design of CDQR will serve the purpose of using them for specific applications.

CHAPTER-V

Stability of Direct and Indirect Excitons in Concentric Double Quantum Rings Embedded in SiO_2 Matrix

Exciton states of CDQR heterostructures embedded in SiO_2 matrix under the influence of electric field has been calculated theoretically using variational technique.

i) Influence of electric field on exciton localisation and exciton diamagnetism

Electric field changes the polarizability of the carrier through band tilting which directs the carriers relatively in the opposite direction to each other. Band tilting modifies the shape of the axial potential profile from square to triangular. Hence the carriers which were in a wide, shallow square confinement are now in a deep, thin triangular confinement. This enables tunneling of carriers and the interaction between them is gradually reduced and this significantly reduces the BE. Strengthening the electric field can even change a direct exciton into an indirect exciton. Thus the electric field sensitizes the energy of the carriers and this in turn brings out considerable changes in the properties of the carriers confined in the system.

Application of electric field reduces χ_{dia} because of the charge separation through band tilting. When $O_R < I_R$ χ_{dia} value is larger and when $O_R \sim I_R$ χ_{dia} falls. Hence the bound electron hole pair now travels as individual particles and the exciton loses its excitonic nature. Electron and hole located in different layers of heterostructures reduces the χ_{dia} of an indirect exciton. The influence of electric field on exciton localisation and exciton diamagnetism gives a very good perception to understand the stability of exciton.

ii) Direct to indirect exciton transition: Through spatial dimension

Apart from external electric field, tuning the ring dimension can convert a Direct Exciton (DX) to Indirect Exciton (IDX). When the rings are coupled, effect of electric field on both DX and IDX are similar except at $I_R \sim O_R$. DXs get transformed into IDXs at $I_R \sim O_R$. When the outer ring approaches the dimension of the inner ring there is a sudden fall in BE. When the rings are decoupled the carriers are localised either in one of the rings. Exciton is highly localised in inner ring when the rings are coupled and it is highly localised in the outer ring when the rings are decoupled.

iii) Effect of carrier location

Subjecting a QR to electric field change the shape of the confining potential and this can be observed by varying the location of the exciton from one end to the other end which gradually increases the BE. The improvement is more prominent for larger electric field. The carriers seek the lower potential and confined in the triangular potential at the edge offered by the electric field and this improves the excitonic BE at the edge. This study suggests that the external electric field induces a change in the wavefunction of the carriers by breaking the symmetry of the system and opening a venue for new applications.

iv) Interband transition energy

Interband Transition Energy (IBTE) which directly gives information about emission decides the optical properties. It has been calculated for various ring dimensions for both DXs and IDXs. Lower value of IBTE indicates higher stability of excitons.

v) Effect of SiO_2 ligand matrix on direct excitons

Embedding a quantum heterostructure in a SiO_2 matrix will be of greater use when they find their utility in device applications. SiO_2 being an insulator has a larger band gap and provides a stronger barrier which confines the carriers stronger than $Al_{0.3}Ga_{0.7}As$ barrier. The difference in BE with and without ligand for both coupled and decoupled rings are more conspicuous which confirms that the effect of SiO_2 matrix on exciton localisation in a nonmagnetic system is very large. The behavior of semiconductor QR surrounded by an insulator can be understood with this type of hybrid structures.

Part B - Theoretical Investigation on the Donor and Exciton States in Semimagnetic CdTe/CdMnTe Quantum Ring

Since several works on the donor and excitons states in single semimagnetic QRs have been reported already, this thesis focusses on the investigations of donor and exciton states in semimagnetic double QRs.

CHAPTER-VI

Combined Effect of Ring Dimension and Magnetic Field on Donor States in Diluted Magnetic Double Quantum Rings

Rigorous analysis on the donor states in $CdTe/Cd_{1-x}Mn_xTe$ DMCDQR under various magnetic field has been made using variational method.

i) Donor bound electron in coupled and decoupled double quantum ring

(Radially Symmetric and Asymmetric Rings)

Application of magnetic field is found to be an effective tool to control the carrier dynamics in semimagnetic QRs. Both (Inner Ring Donor) IRD and (Outer Ring Donor) ORD in Narrow Symmetric Ring (NSR) possess larger BE because of the specific ring dimension which is close to the effective Bohr radius. In contrast to that of the radially symmetric ring, BE of radially asymmetric rings shows a reversal behaviour for IRD and ORD. The strength of binding is larger for a decoupled ring. When the asymmetric rings are decoupled, at lower magnetic field, the probability of carrier localisation is more in the wider ring, no matter whether the ring is inner or outer. Another interesting behavior is BE increases with increase of magnetic field for NAR (Narrow Asymmetric Ring). This is mainly because of the centrifugal force due to the ring structure. BE of weakly coupled NAR with H_I=40Å and H_O=60Å at γ=0.05 is smaller than a strongly coupled NAR. This is reversal to the trend obtained for H_I=60Å and H_O=40Å which may be due to the confinement given by the height of the inner ring where the donor is lodged.

ii) Stability of bound magnetic polaron

The exchange interaction which depends on the overlap between the orbital of the conduction electron and the orbital of the 3d electrons responsible for the Mn^{2+} spin can be calculated using Spin Polaranic Shift (SPS). Spin polarisation within the hydrogenic orbit of the donor and the energy required to flip the spin of the magnetic ions are estimated for various ring dimensions. This SPS acts as a correction for BE while exchange interaction is taken into consideration.

This work gives an insight for the proper choice of external magnetic field and ring dimension of DMCDQR so that they can be used for the design of specific magnetic and spintronic applications.

CHAPTER-VII

Effect of Ion Concentration on Bound Magnetic Polaron in Diluted Magnetic Double Quantum Rings

Effect on Mn^{2+} ion concentration on the formation of Bound Magnetic Polaron (BMP) in $Cd_{1-x1}Mn_{x1}Te/Cd_{1-x2}Mn_{x2}Te$ DMCDQR under various magnetic fields has been studied by estimating Spin Polaronic Shift (SPS).

i) Under zero magnetic field

Random distribution of magnetic ions over the cation leads to exchange interaction which is a significant magnetic effect on DMS systems. Increasing the concentration of magnetic ions cancels the spins of the nearest neighbours due to antiferromagnetic interaction and this reduces the number of ions contributing to the total magnetic moment. Therefore, only an optimum concentration of Mn^{2+} ions contributes effectively to the total magnetic moment. This peculiarity is observed in the zero magnetic field case.

ii) Under weak magnetic field

Application of magnetic field gives additional confinement to the carrier which results in larger SPS value for larger concentration of Mn^{2+} ions. Formation of ferromagnetic cloud is favoured by this external perturbation through the alignment of the spins of the magnetic ions in the vicinity of the carrier. This stimulates the energy and spin transfer between the ion and carrier which confirms that the spin can be effectively controlled by the magnetic field and this can be exploited in spintronic applications.

Only very few antiferromagnetically coupled pairs are available at the interface and this can effectively contribute to a larger $\langle S_z \rangle$. Therefore, the magnetization of the material becomes larger since these ions can easily be aligned in the external magnetic field. The number of such interface ions is larger for ultra-thin barrier and this effect is prominent for barrier centered impurities.

iii) Under strong magnetic field

Larger magnetic field do not have much influence over the deep embedded ions inside the barrier where the carrier cannot penetrate. Thus, the SPS increases only for the decoupled rings and this appears to be a perfect tool for interface studies.

iv) Under critical magnetic field

Even at the critical magnetic field one can observe a larger polaronic shift for all the ring dimensions and concentrations. These results confirm that spin alignment retains over a long range of magnetic field and hence to attain a spin saturation, QR structure requires a larger magnetic field.

All these magnetic field and concentration effect on SPS concludes that even at higher magnetic field and concentration QR experiences high degree of confinement. Dissolution of spin pairs hardly occur in DMCDQR heterostructures.

CHAPTER- VIII

Effect of Electric Field on the Exciton Localisation in Diluted Magnetic Double Quantum Rings Embedded in SiO_2 Ligand Matrix

This chapter deals with the excitonic states in symmetric and asymmetric DMCDQR embedded in SiO_2 ligand matrix under electric field.

i) Stability of exciton under external electric field

As already mentioned the application of electric field polarizes the carrier in different direction and this destroys the excitonic nature even at low field by largely separating the carriers. Introduction of electric field to a semimagnetic system does not suddenly reduce the BE but rather it requires a larger field. Thus a nonmagnetic system is more sensitive to electric field compared to a semimagnetic system.

ii) Exciton localisation in symmetric and asymmetric quantum rings

In nonmagnetic system beyond a particular C_B value BE remains constant for all O_R values. But for DMCDQR even for larger C_B value a sudden transition in BE occurs beyond a particular O_R value. This confirms that the central barrier has to be tuned further to completely decouple the semimagnetic rings. The behavior of carriers trapped inside a nonmagnetic and semimagnetic ring greatly differs in certain aspects.

iii) Effect of SiO_2 ligand matrix on the exciton localisation

In case of a semimagnetic system the presence of SiO_2 matrix significantly alters the localisation of outer ring exciton. For the Inner Ring Excitons (IRE), the difference in BE with and without ligand is very small. The effect of ligand is insignificant for IRE when the rings are decoupled.

CHAPTER-IX

Summary and Suggestions for Future Work

The donor and exciton states in a single and concentrically coupled double quantum ring under the effect of magnetic field and electric field has been investigated. Efficient carrier transport from inner ring to outer ring in both non-magnetic and semimagnetic QR is observed through proper choice of ring and barrier dimension. Stability of DX and IDX in both symmetric and asymmetric rings has been determined using χ_{dia}. Formation of BMP inside DMCDQR for various magnetic field and ion concentration and the shift in BMP from one ring to other ring for certain ring dimensions has also been calculated.

The selective occupancy of the carriers in either of the rings and the tunneling effect of the carrier will be of high use in designing many electronic devices. Investigations and measurement of χ_{dia} is a useful direct tool to evaluate exciton dipole moment and exciton polarizability and also for the choice of suitable confinement for appropriate applications. Effect of magnetic field and concentration on highly confined DMS offers the possibility of zooming in spin phenomena to contribute in spintronic applications. External electric field has the ability to tune the electronic properties which has many advantages over optoelectronic applications. All these works are specially intended to convey the fundamentals of physical phenomena of quantum rings.

Scope for Future Work

Theoretical estimation of exciton diamagnetism in single and double Quantum Rings can be made by considering the carriers in the low-lying excited states which will be useful to study the optical transition properties. All these works may be extended in presence of other external perturbations like pressure and temperature. Dynamics of direct and indirect exciton states can be explored in hybrid quantum structures as in Dot in a Ring and also in quantum rings of different confinements. More work is needed to further explore the unique physical properties associated with their special ring-shape and their applications in devices.

List of Publications

International Journals

1. Tailoring the Electronic Properties of Concentric Double Quantum Rings in the Presence of a Donor Impurity.
   I. Janet Sherly, *A. Esther Lidiya and P. Nithiananthi,* Journal of Applied Physics 125, 165707 (2019).

2. Influence of Electric Field on Direct and Indirect Exciton in a Concentrically Coupled Quantum Ring Heterostructure Embedded in SiO_2 Matrix.
   I. Janet Sherly *and P. Nithiananthi,* Superlattices and Microstructures 137, 106334 (2020).

3. Effect of Confining Potential on the Exciton Stability at Various Locations in a Parabolic and Square Quantum Ring.
   I. Janet Sherly *and P. Nithiananthi,* Physica Scripta 95, 055102 (2020).

4. Tuning the Dynamics of Bound Magnetic Polaron in Asymmetric $Cd_{1-x1}Mn_{x1}Te/Cd_{1-x2}Mn_{x2}Te$ Semimagnetic Concentric Double Quantum Rings: Through Magnetic Ion Concentration and Magnetic Field.
   I. Janet Sherly *and P. Nithiananthi,* Physica B 600, 412615 (2021).

5. Carrier Dynamics in Quantum Ring in a Quantum Well: Magnetic Field and Non-Parabolicity Effects.
   S. Lilly Angel, ***I. Janet Sherly*** *and P. Nithiananthi,* AIP Conference Proceedings 2265, 030063 (2020).

6. Stability of Indirect and Direct Excitons Through Diamagnetic Susceptibility in a Concentric Double Quantum Ring Structure.
   I. Janet Sherly, *G. Vignesh and P. Nithiananthi,* AIP Conference Proceedings 2265, 030064 (2020).

7. Tuning Carrier Dynamics and Spin Polaronic Shift in $CdTe/Cd_{0.9}Mn_{0.1}Te$ Concentric Double Quantum Rings: Effect of Magnetic Field.
   I. Janet Sherly *and P. Nithiananthi* (Communicated).

8. Influence of Electric Field on Direct and Indirect Exciton in a Diluted Magnetic Concentrically Coupled Quantum Ring Heterostructure Embedded in SiO_2 Matrix
   I. Janet Sherly *and P. Nithiananthi* (Communicated).

International Journals (Not included in the thesis)

9. Combined Effect of Stress and Nonparabolicity on the Diamagnetic Susceptibility of Donor States in a Double Quantum Well.
   I. Janet Sherly *and P. Nithiananthi*, AIP Conference Proceedings 1942, 050085 (2018).

International Conferences

1. Effect of Geometry on the Exciton Binding Energy in a Quantum Ring.
   I. Janet Sherly*, K. Jayakumar, P. Nithiananthi.*
   Second International Conference on Materials science and Technology, St. Thomas College, 5th -8th June 2016, Palai, Kerala.

2. Binding Energy of a Donor in a Concentric Double Quantum Ring.
   A. Esther Lidiya, ***I. Janet Sherly****, P. Nithiananthi.*
   International Conference on Renewable Energy Science and Technology, 10th -11th March 2017, Alagappa University, Karaikudi.

3. Binding Energy of a Donor in a Concentric Double Quantum Ring Structure.
   A. Esther Lidiya, ***I. Janet Sherly****, P. Nithiananthi.*
   International Conference on Nanoscience and Nanotechnology, 9th -11th August 2017, SRM University, Kattankulathur, India.

4. Effect of Magnetic Field on the Binding Energy of a Donor in a Single Quantum Ring.
   S. Lilly Angel, ***I. Janet Sherly****, P. Nithiananthi.*
   International Conference on Recent Advances in Materials, 22nd-23rd March 2018, National College, Tiruchirappalli.

5. Excitonic States in a Concentric Double Quantum Ring Structures.
   I. Janet Sherly *and P. Nithiananthi.*
   International Conference on Advanced Nanomaterials for Energy and Healthcare Applications, 31st August – 1st September 2018, KSR College of Arts and Science for Women, Thiruchengodu, Tamilnadu, India.

6. Theoretical Investigation on the Interband Transition Energy of an Exciton in a Double Quantum Ring for Solar Cell Applications.
   I. Janet Sherly *and P. Nithiananthi.*
   International Conference on Exploring Nanostructures for Enhanced Power Conversion Efficiency of Solar Cells, 7th -8th January 2019, The Gandhigram Rural Institute- Deemed to be University, Gandhigram.

7. Influence of Electric Field of Exciton in a Concentric Double Quantum Ring Embedded in SiO_2 Matrix.
   I. Janet Sherly *and P. Nithiananthi.*
   International Conference on Nanoscience and Nanotechnology, 28th -30th January 2019, SRM University, Kattankulathur, India

National Conferences

1. Effect of Stress and Nonparabolicity on the Diamagnetic Susceptibility of a Donor in a Double Quantum Well.
   I. Janet Sherly*, K. Ponrasu, G. Vignesh, P. Nithiananthi.*

National Conference on Advanced materials for Energy and Environmental Applications, 18th-20th March 2015, Bharathiar University, Coimbatore.

2. Localisation of a Donor in a Double Quantum Well Through Diamagnetic Susceptibility.
   *K. Ponrasu, **I. Janet Sherly**, G. Vignesh, P. Nithiananthi.*
   National Conference on Advanced materials for Energy and Environmental Applications, 18th-20th March 2015, Bharathiar University, Coimbatore.

3. Exciton Confined in a Quantum Ring: An Ideal One Dimensional Structure.
   ***I. Janet Sherly** and P. Nithiananthi.*
   National Conference on Advances in Material Science, February 12th, 2016, Dindigul.

4. Effect of Ring Width on Binding Energy of Donor in a Quantum Ring
   ***I. Janet Sherly** and P. Nithiananthi*
   National Conference on Recent Advances in the Applications of Macromolecular Materials, 2nd -3rd March 2017, Gandhigram Rural Institute, Gandhigram.

5. Oscillator Strength of an Exciton in a Single Parabolic Quantum Ring.
   ***I. Janet Sherly** and P. Nithiananthi.*
   26th DAE-BRNS National Laser Symposium, 20th –23rd December, 2017, BARC, Mumbai, India.

6. Combined Effect of Stress and Nonparabolicity on the Diamagnetic Susceptibility of Donor States in a Double Quantum Well.
   ***I. Janet Sherly**, P. Nithiananthi.*
   62nd DAE-Solid State Physics Symposium, 26th-30th December, 2017, BARC, Mumbai, India.

7. Stability of Indirect and Direct Excitons Through Diamagnetic Susceptibility in a Concentric Double Quantum Ring Structure.
   ***I. Janet Sherly**, G. Vignesh and P. Nithiananthi.*
   64th DAE-Solid State Physics Symposium, 18th – 22nd, December, 2019, IIT, Jodhpur, India.

8. Carrier Dynamics in Quantum Ring in a Quantum Well: Magnetic Field and Non-Parabolicity Effects.
   *S. Lilly Angel, **I. Janet Sherly** and P. Nithiananthi.*
   62nd DAE-Solid State Physics Symposium, 18th – 22nd, December, 2019, IIT, Jodhpur, India.