Resonant nonlinear interaction of light in photonic crystal cavity-quantum dot systems

A THESIS

submitted by

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(Enrollment No: D10017)

for the award of the degree

of

DOCTOR OF PHILOSOPHY

School of Basic Sciences
INDIAN INSTITUTE OF TECHNOLOGY MANDI
KAMAND, MANDI-175005, INDIA

March 2019

dedicated to

my parents

and

my aunt (Bua)

for their love, care and inspiration.....

Certificate

This is to certify that the thesis entitled "**Resonant nonlinear interaction of light in photonic crystal cavity-quantum dot systems**", submitted by Mr. Jitendra Kumar Verma to the Indian Institute of Technology Mandi for the award of Doctor of Philosophy is a bonafide record of research work carried out by him under my supervision. The contents of this thesis, in full or in parts, have not been submitted to any other institute or university for the award of any degree or diploma.

Dr. Pradyumna Kumar Pathak
March 2019

Declaration

I hereby declare that except where specific reference is made to the work of others, the contents of this thesis are original and have not been submitted in whole or in part for consideration for any other degree or qualification in this, or any other university. This thesis is my own work and contains nothing which is the outcome of work done in collaboration with others, except as specified in the text and Acknowledgements. The thesis contains total five chapters.

Jitendra Kumar Verma
March 2019

Acknowledgements

I feel a great pleasure to express my gratitude to my thesis guide Dr. Pradyuman Kumar Pathak for his excellent guidance and help throughout my research work, without his help this work was not possible. His guidance helped me in all the time of research and writing of this thesis. His deep insight and an elegant approach to the subject as well as exceptional capacity to work have been a great source of inspiration for me. I could not have imagined having a better advisor and mentor for my Ph.D. study.

I would like to thank my doctorol committee: Dr. Hari Varma, Dr. Anil Kumar Sao, Dr. Rahul Vaish and Dr. B. S. Rajpurohit for their fruitful discussions, suggestions, and encouragement during my research work. My sincere thanks also goes to my teachers Dr. Mahendra Singh Chauhan and Dr. Sachin Gihar who inspired me for higher study. I also acknowledge IIT Mandi for providing me financial support. I thank all staff members of IIT Mandi for their kind cooperation and friendly behaviour. The life passed in IIT Mandi hostel was wonderful and unforgettable, specially tea time, lunch time, and dinner time in mess. I feel the life passed in the lap of Himalaya was unforgettable and best time till now. The natural beauty of Himachal Pradesh attracts me much more.

My thanks also goes to my research group members Mr. Manoj Das and Mr. Harmanpreet Singh for discussing the quantum optics and research problems.

My heartfelt thanks to Dr. Jalim Singh for his help in programming language and discussing the personal problems as well, to Dr. Rajiv Maurya for being a classmate, roommate as well as a good friend since 9th class to till now, to Dr. Sohan Lal for sharing the ideas on personal as well as academic problems, to Dr. Mohit Sharma for encouraging me during in my bad time and depression, to Dr. Avdhesh for discussing spirituality, and to Dr. Atendra Kumar for his help during my illness.

I would also like to thank all of my friends with whom I shared most beautiful moments of life as well as tough times too in particular Dr. Pushpendra, Dr. Jay Prakash, Dr. Lakshman, Dr. Vishal Maurya, Dr. Ashish, Dr. Anna, Mr. Nishith Mohan, Miss. Subhanjali, Dr.

Atendra, Dr. Pankaj Narula, Dr. Chander, Dr. Harivansh, Dr. Sindhu, Dr. Anshul,Dr. Anand, Dr. Sunil Kumar (Hamirpur), Mr. Vikas Kharwar, Mr. Prabal Singh, and Mr. Vineet Yadav.

I would like to express my special thanks to Miss. Neha Thakur for her care and emotional support.

Finally, I must remember my family members for their love and affection, in particular, my father Mr. Ramnath Verma, my mother Smt. Kalawati, my aunt(Bua) smt. Shakuntala Verma, my younger brothers Rahul Rajput and Dharmendra Verma, my sister Pratibha Rajput, my grandmother, and my uncle (taaya) Mr. Mohan Lal Verma. Further, I can not forget to remember my brother late Mr. Pushpendra Kumar Rajput and uncle (taaya) late Mr. Lekhraj Verma.

Jitendra Kumar Verma

Abstract

The work presented in this thesis concerns cavity quantum electrodynamics techniques for generating the photon pairs and entangled states using the quantum dots and photonic cavities for quantum information applications, such as quantum computation, quantum teleportation, and quantum cryptography.

We have presented the schemes to realize a highly efficient solid state source of photon pairs, cooperative emission of two photons, and generation of entangled states. For highly efficient solid state source of photon pairs, a semiconductor quantum dot is embedded in a photonic crystal microcavity and is coherently pumped from its ground state using a Gaussian pulse and a continuous wave laser which makes it innovative. The photon pair emission takes place either by four wave-mixing process (FWM) or by stimulated Raman adiabatic passage (STIRAP) depending on the applied continuous wave laser between exciton and biexciton state. The efficiency of generating the photon pair by FWM is higher than 0.9 and by STIRAP process is around 0.77. For cooperative two photon emission, two quantum dots are coupled with a single mode and two mode photonic crystal cavity. The cooperative two photon emission occurs when excitons in two off-resonantly coupled quantum dots decay simultaneously. Also, we bring out the role of exciton- phonon coupling on two-photon cooperative emission. The interaction of two quantum dots with common cavity fields leads to cavity induced two-photon emission which is strongly inhibited by electron phonon coupling. The interaction with common phonon bath produces phonon induced two-photon emission. For generating entangled states, a quantum dot in a bimodal cavity is prepared in the biexciton state. The cascaded biexciton-exciton decay of quantum dot produces either a two photon NOON state or a polarization entangled state. We also study the effect of phonon coupling on the generated entangled states. We find that the concurrence which measures the entanglement decreases on increasing the temperature in both cases.

Table of contents

List of figures