

Y. Yamamoto  
F. Tassone  
H. Cao

# **Semiconductor Cavity Quantum Electrodynamics**



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# Semiconductor Cavity Quantum Electrodynamics

**Frank Jahnke**



## **Semiconductor Cavity Quantum Electrodynamics:**

Semiconductor Cavity Quantum Electrodynamics Y. Yamamoto, F. Tassone, H. Cao, 2003-07-01 This monograph is the first to give a comprehensive account of the theory of semiconductor cavity quantum electrodynamics for such systems in the weak coupling and strong coupling regimes It presents the important concepts together with relevant recent experimental results

Semiconductor Cavity Quantum Electrodynamics Y. Yamamoto, F. Tassone, H. Cao, 2014-03-12 This monograph is the first to give a comprehensive account of the theory of semiconductor cavity quantum electrodynamics for such systems in the weak coupling and strong coupling regimes It presents the important concepts together with relevant recent experimental results

*1D and 2D Photonic Crystal Nanocavities for Semiconductor Cavity QED*. Benjamin Colby Richards, 2011 The topic of this dissertation is photonic crystal nanocavities for semiconductor cavity quantum electrodynamics For the purposes of this study these nanocavities may be one dimensional 1D or two dimensional 2D in design The 2D devices are active and contain embedded InAs quantum dots QDs whereas the 1D devices are passive and contain no active emitters The 2D photonic crystal nanocavities are fabricated in a slab of GaAs with a single layer of InAs QDs embedded in the slab When a cavity mode substantially overlaps the QD ensemble the dots affect the linewidths of the observed modes leading to broadening of the linewidth at low excitation powers due to absorption and narrowing of the linewidths at high excitation powers due to gain when the QD ensemble absorption is saturated We observe lasing from a few QDs in such a nanocavity A technique is discussed which allows us to tune the resonance wavelength of a nanocavity by condensation of an inert gas onto the sample which is held at cryogenic temperatures The structural quality at the interfaces of epitaxially grown semiconductor heterostructures is investigated and a growth instability is discovered which leads to roughness on the bottom of the GaAs slabs Adjustment of MBE growth parameters leads to the elimination of this roughness and the result is higher nanocavity quality factors A number of methods for optimizing the fabrication of nanocavities is presented which lead to higher quality factors It is shown that some fundamental limiting factor not yet fully understood is preventing high quality factors at wavelengths shorter than 950 nm Silicon 1D devices without active emitters are investigated by means of a tapered microfiber loop and high quality factors are observed This measurement technique is compared to a cross polarized resonant scattering method The quality factors observed in the silicon nanocavities are higher than those observed in GaAs consistent with our observation that quality factors are in general higher at longer wavelengths

*Semiconductor Cavity QED and Related Devices* Hui Cao, 1997      **Cavity Quantum Electrodynamics in**

**Semiconductor Laser** Y. Yamamoto, R. Horowicz, S. Machida, G. Bjoerk, W. H. Richardson, NIPPON TELEGRAPH AND TELEPHONE CORP TOKYO., 1992 A one dimension planar microcavity structure shown in can increase the coupling efficiency Beta of spontaneous emission into a single cavity resonant mode if the spontaneous emission spectral width  $\Delta\omega$  is smaller than the microcavity resonance width  $\Delta\omega_c$  and if the refractive index difference  $\Delta n$  is fairly large The loss of

spontaneous emission into spurious modes 1 Beta are clue to the two degenerate orthogonal polarization modes and the leaky guided modes propagating in a plane of the microcavity A three dimensional waveguide microcavity structure shown in features several advantages over the one dimensional structure The increase in Beta is realized without requiring  $\delta\omega_{\text{sub } e} \delta\omega_{\text{sub } c}$  and large  $\delta n$  The degeneracy of the two orthogonal polarization mode s can be lifted and the leaky guided modes can be made cut off by the waveguide structure Therefore the spurious spontaneous emission into these modes can be suppressed The spontaneous emission lifetime T can be also decreased in the three dimensional microcavity On the other hand the one dimensional microcavity cannot decrease  $\tau_{\text{sub } \delta}$  but can only increase  $\tau_{\text{sub } \delta}$

Quantum Optics with Semiconductor Nanostructures Frank Jahnke, 2012-07-16 An understanding of the interaction between light and matter on a quantum level is of fundamental interest and has many applications in optical technologies The quantum nature of the interaction has recently attracted great attention for applications of semiconductor nanostructures in quantum information processing Quantum optics with semiconductor nanostructures is a key guide to the theory experimental realisation and future potential of semiconductor nanostructures in the exploration of quantum optics Part one provides a comprehensive overview of single quantum dot systems beginning with a look at resonance fluorescence emission Quantum optics with single quantum dots in photonic crystal and micro cavities are explored in detail before part two goes on to review nanolasers with quantum dot emitters Light matter interaction in semiconductor nanostructures including photon statistics and photoluminescence is the focus of part three whilst part four explores all solid state quantum optics crystal nanobeam cavities and quantum dot microcavity systems Finally part five investigates ultrafast phenomena including femtosecond quantum optics and coherent optoelectronics with quantum dots With its distinguished editor and international team of expert contributors Quantum optics with semiconductor nanostructures is an essential guide for all those involved with the research development manufacture and use of semiconductors nanodevices lasers and optical components as well as scientists researchers and students A key guide to the theory experimental realisation and future potential of semiconductor nanostructures in the exploration of quantum optics Chapters provide a comprehensive overview of single quantum dot systems nanolasers with quantum dot emitters and light matter interaction in semiconductor nanostructures Explores all solid state quantum optics crystal nanobeam cavities and quantum dot microcavity systems and investigates ultrafast phenomena

**Semiconductor Interfaces, Microstructures and Devices** Zhe Chuan Feng, 1993-01-01 A semiconductor interface is the contact between the semiconductor itself and a metal The interface is a site of change and it is imperative to ensure that the semiconducting material is sealed at this point to maintain its reliability This book examines various aspects of interfaces showing how they can affect microstructures and devices such as infrared photodetectors as used in night sights and blue diode lasers It presents various techniques for examining different types of semiconductor material and suggests future potential commercial applications for different semiconductor devices Written by experts in their fields and focusing

on metallic semiconductors Cadmium Telluride and related compounds this comprehensive overview of recent developments is an essential reference for those working in the semiconductor industry and provides a concise and comprehensive introduction to those new to the field

**Optical Generation and Control of Quantum Coherence in Semiconductor Nanostructures** Gabriela Slavcheva, Philippe Roussignol, 2010-06-01 The fundamental concept of quantum coherence plays a central role in quantum physics cutting across disciplines of quantum optics atomic and condensed matter physics Quantum coherence represents a universal property of the quantum systems that applies both to light and matter thereby tying together materials and phenomena Moreover the optical coherence can be transferred to the medium through the light-matter interactions Since the early days of quantum mechanics there has been a desire to control dynamics of quantum systems The generation and control of quantum coherence in matter by optical means in particular represents a viable way to achieve this longstanding goal and semiconductor nanostructures are the most promising candidates for controllable quantum systems Optical generation and control of coherent light-matter states in semiconductor quantum nanostructures is precisely the scope of the present book Recently there has been a great deal of interest in the subject of quantum coherence We are currently witnessing parallel growth of activities in different physical systems that are all built around the central concept of manipulation of quantum coherence The burgeoning activities in solid state systems and semiconductors in particular have been strongly driven by the unprecedented control of coherence that previously has been demonstrated in quantum optics of atoms and molecules and is now taking advantage of the remarkable advances in semiconductor fabrication technologies A recent impetus to exploit the coherent quantum phenomena comes from the emergence of the quantum information paradigm

**Semiconductor Photonics of Nanomaterials and Quantum Structures** Arash Rahimi-Iman, 2021-04-23 This book introduces the wider field of functional nanomaterials sciences with a strong emphasis on semiconductor photonics Whether you are studying photonic quantum devices or just interested in semiconductor nanomaterials and their benefits for optoelectronic applications this book offers you a pedagogical overview of the relevant subjects along with topical reviews The book discusses different yet complementary studies in the context of ongoing international research efforts delivering examples from both fundamental and applied research to a broad readership In addition a hand full of useful optical techniques for the characterization of semiconductor quantum structures and materials are addressed Moreover nanostructuring methods for the production of low dimensional systems which exhibit advantageous properties predominantly due to quantum effects are summarized Science and engineering professionals in the interdisciplinary domains of nanotechnology photonics materials sciences and quantum physics can familiarize themselves with selected highlights with eyes towards photonic applications in the fields of two dimensional materials research light-matter interactions and quantum technologies

**Physics of Semiconductor Microcavities** Benoit Deveaud, 2007-02-27 Electron and photon confinement in semiconductor nanostructures is one of the most active areas in solid state research Written by

leading experts in solid state physics this book provides both a comprehensive review as well as a excellent introduction to fundamental and applied aspects of light matter coupling in microcavities Topics covered include parametric amplification and polariton liquids quantum fluid and non linear dynamical effects and parametric instabilities polariton squeezing Bose Einstein condensation of microcavity polaritons spin dynamics of exciton polaritons polariton correlation produced by parametric scattering progress in III nitride distributed Bragg reflectors using AlInN GaN materials high efficiency planar MCLEDs exciton polaritons and nanoscale cavities in photonic crystals and MBE growth of high finesse microcavities

**The Physics of Semiconductors** Marius Grundmann, 2015-12-24 The 3rd edition of this successful textbook contains ample material for a comprehensive upper level undergraduate or beginning graduate course guiding readers to the point where they can choose a special topic and begin supervised research The textbook provides a balance between essential aspects of solid state and semiconductor physics on the one hand and the principles of various semiconductor devices and their applications in electronic and photonic devices on the other It highlights many practical aspects of semiconductors such as alloys strain heterostructures nanostructures that are necessary in modern semiconductor research but typically omitted in textbooks Coverage also includes additional advanced topics such as Bragg mirrors resonators polarized and magnetic semiconductors nanowires quantum dots multi junction solar cells thin film transistors carbon based nanostructures and transparent conductive oxides The text derives explicit formulas for many results to support better understanding of the topics The Physics of Semiconductors requires little or no prior knowledge of solid state physics and evolved from a highly regarded two semester course In the third edition several topics are extended and treated in more depth including surfaces disordered materials amorphous semiconductors polarons thermopower and noise More than 1800 references guide the reader to historic and current literature including original and review papers and books

*Electronic Quantum Transport in Mesoscopic Semiconductor Structures* Thomas Ihn, 2004-09-09 The physics of semiconductors has seen an enormous evolution within the last fifty years Countless achievements have been made in scientific research and device applications have revolutionized everyday life We have learned how to customize materials in order to tailor their optical as well as electronic properties The ongoing trend toward device miniaturization has been the driving force on the application side and it has fertilized fundamental research Nowadays advanced processing techniques allow the fabrication of sub micron semiconductor structures in many university research laboratories At the same time experiments down to millikelvin temperatures allow researchers to anticipate the observation of quantum phenomena so far hidden at room temperature by the large thermal energy and strong dephasing The field of mesoscopic physics deals with systems under experimental conditions where several quantum length scales for electrons such as system size and phase coherence length or phase coherence length and elastic mean free path are comparable Intense research over the last twenty years has revealed an enormous richness of quantum effects in mesoscopic semiconductor physics which is typically characterized by an interplay of quantum

interference and many body interactions The most famous phenomena are probably the integer and fractional quantum Hall effects the quantization of conductance through a quantum point contact the Aharonov Bohm effect and single electron charging of quantum dots      Quantum Optics of Confined Systems M. Ducloy, Daniel Bloch, 1996-03-31 In the last few years it was seen the emergence of various new quantum phenomena specifically related with electronic or optical confinement on a sub wavelength size Fast developments simultaneously occurred in the field of Atomic Physics notably through various regimes of Cavity Quantum Electrodynamics and in Solid State Physics with advances in Quantum Well technology and Nanooptoelectronics Simultaneously breakthroughs in Near Field Optics provided new tools which should be widely applicable to these domains However the key concepts used to describe these new and partly related effects are often very different and specific of the Community involved in a given development It has been the ambition of the Meeting held at Centre de Physique des Houches to give an opportunity to specialists of different Communities to deepen their understanding of advances more or less intimately related to their own field while presenting the basic concepts of these different fields through pedagogical Introductions The audience comprised advanced students postdocs and senior scientists with a balanced participation of Atomic Physicists and Solid State Physicists and had a truly international character The considerable efforts of the lecturers in order to present exciting new results in a language accessible to the whole audience were the essential ingredients to achieve successfully what was the main goal of this School      *Semiconductor Quantum Science and Technology* ,2020-11-28 Semiconductor quantum science and technology is exploring the exciting and emerging prospects of integrating quantum functionality on semiconductor platforms to convert current information technology into quantum information technology The past twenty years have led to incredible advances in this field This book brings together the leading scientists who present the main achievements and challenges by reviewing and motivating the state of the art at a tutorial level The key challenges include creating quantum light sources quantum information processing via strong light matter interaction discovering new quantum materials as well as quasiparticles and determining new quantum spectroscopic methodologies for superior control of quantum phenomena As an important step integration of these solutions on a semiconductor chip is discussed and outlook for the future of semiconductor quantum science and technology is given Leading experts present their vision on semiconductor quantum science and technology All aspects needed to realize semiconductor quantum science and technology are explained Quantum semiconductors from overviewed a tutorial introduction to the state of the art      **Spatio-Temporal Dynamics and Quantum Fluctuations in Semiconductor Lasers** Edeltraud Gehrig, Ortwin Hess, 2003-09-22 Presents fundamental theories and simulations of the spatio temporal dynamics and quantum fluctuations in semiconductor lasers The dynamic interplay of light and matter is theoretically described by taking into account microscopic carrier dynamics spatially dependent light field propagation and the influence of spontaneous emission and noise      Investigations of a Coherently Driven Semiconductor Optical Cavity QED System

,2008 Chip based cavity quantum electrodynamics QED devices consisting of a self assembled InAs quantum dot QD coupled to a high quality factor GaAs microdisk cavity are coherently probed through their optical channel using a fiber taper waveguide We highlight one particularly important aspect of this all fiber measurement setup which is the accuracy to which the optical coupling level and optical losses are known relative to typical free space excitation techniques This allows for precise knowledge of the intracavity photon number and measurement of absolute transmitted and reflected signals Resonant optical spectroscopy of the system under both weak and strong driving conditions are presented which when compared with a quantum master equation model of the system allows for determination of the coherent coupling rate between QD exciton and optical cavity mode the different levels of elastic and inelastic dephasing of the exciton state and the position and orientation of the QD within the cavity Pump probe measurements are also performed in which a far off resonant red detuned control laser beam is introduced into the cavity Rather than producing a measurable ac Stark shift in the exciton line of the QD we find that this control beam induces a saturation of the resonant system response The broad photoluminescence spectrum resulting from the presence of the control beam the cavity points to sub band gap absorption in the semiconductor and the resulting free carrier generation as the likely source of system saturation

*Handbook of Self Assembled Semiconductor Nanostructures for Novel Devices in Photonics and Electronics* Mohamed Henini,2011-07-28 The self assembled nanostructured materials described in this book offer a number of advantages over conventional material technologies in a wide range of sectors World leaders in the field of self organisation of nanostructures review the current status of research and development in the field and give an account of the formation properties and self organisation of semiconductor nanostructures Chapters on structural electronic and optical properties and devices based on self organised nanostructures are also included Future research work on self assembled nanostructures will connect diverse areas of material science physics chemistry electronics and optoelectronics This book will provide an excellent starting point for workers entering the field and a useful reference to the nanostructured materials research community It will be useful to any scientist who is involved in nanotechnology and those wishing to gain a view of what is possible with modern fabrication technology Mohamed Henini is a Professor of Applied Physics at the University of Nottingham He has authored and co authored over 750 papers in international journals and conference proceedings and is the founder of two international conferences He is the Editor in Chief of Microelectronics Journal and has edited three previous Elsevier books Contributors are world leaders in the field Brings together all the factors which are essential in self organisation of quantum nanostructures Reviews the current status of research and development in self organised nanostructured materials Provides a ready source of information on a wide range of topics Useful to any scientist who is involved in nanotechnology Excellent starting point for workers entering the field Serves as an excellent reference manual

[Semiconductor Nanolasers](#) Qing Gu,Yeshaiahu Fainman,2017-02-16 A unique and comprehensive resource covering the fundamentals of nanolasers with



details of design fabrication and applications      **Electroweak Symmetry Breaking** Wolfgang Kilian, 2003-09-02 The systematic bottom up approach provides the appropriate framework for interpreting measurements that will be performed to better understand the physics of mass generation in the universe No knowledge of quantum field theory is required other than familiarity with effective Lagrangians and Feynmann diagrams      Compton Scattering Frank Wissmann, 2003-12-03 A comprehensive summary of experiments on Compton scattering from the proton and neutron performed at the electron accelerator MAMI The experiments cover a photon energy range from 30 MeV to 500 MeV The reader is introduced to the theoretical concepts of Compton scattering followed by a description of the experiments on the proton their analysis and results

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