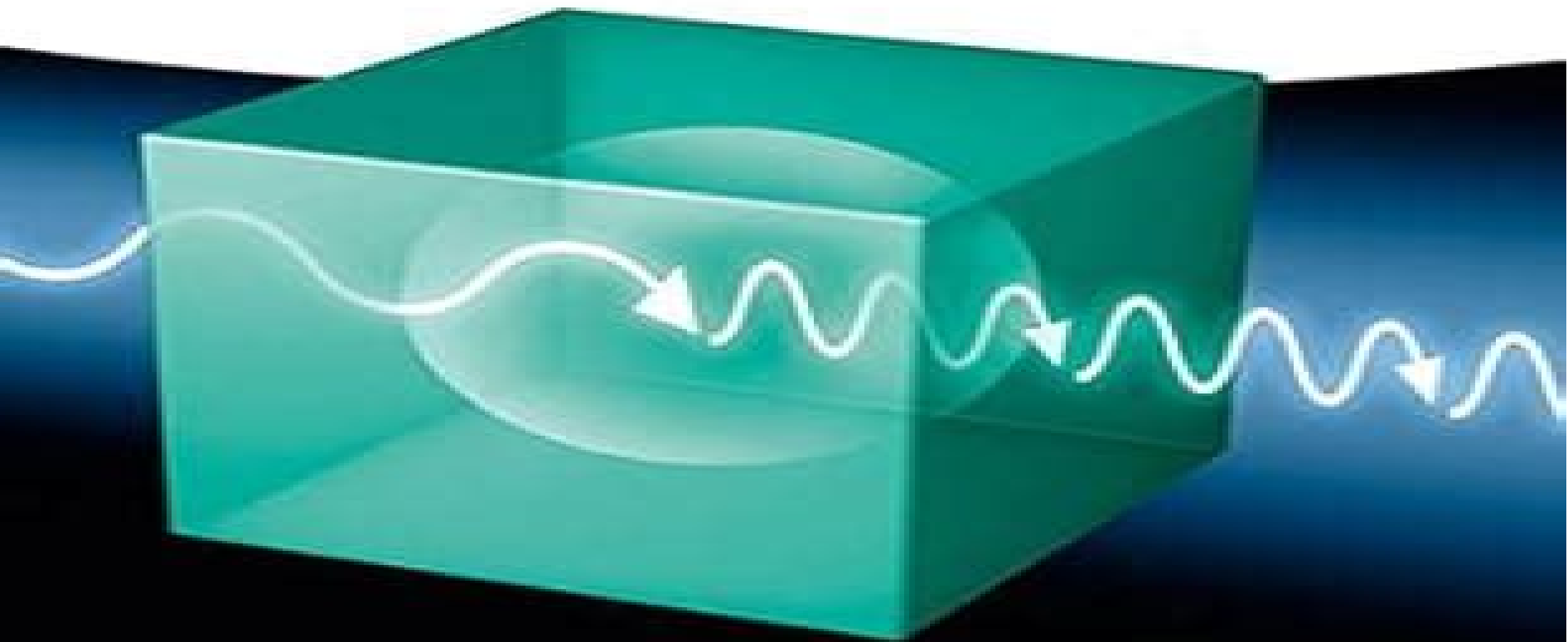


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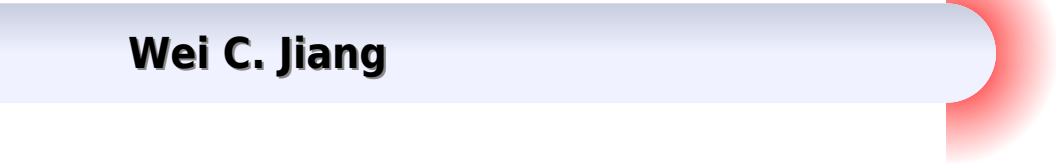
Nonlinear Optical Cavity Dynamics

From Microresonators to Fiber Lasers



Nonlinear Optical Cavity Dynamics Microresonators Ebook

Wei C. Jiang



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Nonlinear Optical Cavity Dynamics Philippe Grelu, 2015-12-23 By recirculating light in a nonlinear propagation medium the nonlinear optical cavity allows for countless options of light transformation and manipulation In passive media optical bistability and frequency conversion are central figures In active media laser light can be generated with versatile underlying dynamics Emphasizing on ultrafast dynamics the vital arena for the information technology the soliton is a common conceptual keyword thriving into its modern developments with the closely related denominations of dissipative solitons and cavity solitons Recent technological breakthroughs in optical cavities from micro resonators to ultra long fiber cavities have entitled the exploration of nonlinear optical dynamics over unprecedented spatial and temporal orders of magnitude By gathering key contributions by renowned experts this book aims at bridging the gap between recent research topics with a view to foster cross fertilization between research areas and stimulating creative optical engineering design **Novel Nonlinear Interactions and Synchronization Dynamics in Micro-resonators** Yanan Henry Wen, 2015 This thesis investigates two systems in chip based nonlinear optical microresonators First is the generation of broadband frequency combs through parametric four wave mixing and the associated phenomenon of cavity soliton formation in micro resonators We begin by investigating the relationship between cavity soliton based modelocking and traditional saturable absorber based modelocking We find that a saturable absorber based modelocked laser with stimulated emission gain on only one cavity mode is dynamically equivalent to a parametrically driven cavity soliton comb We also study the phase dynamics of the cavity soliton formation process for which we derive a set of phase equations from the governing Lugiato Lefever equation which exhibit synchronization mechanisms akin to the Kuramoto model for coupled oscillators These equations predict that phase anti symmetrization precedes phase synchronization in the cavity soliton formation process and explains the origin of the pump phase offset seen in parametrically driven cavity solitons We then extend the concept of synchronization to systems of multiple cavity soliton frequency combs We show that cavity solitons in evanescently coupled micro resonators can synchronize to one another generating synchronized pulses in the time domain and frequency locked combs lines in the spectral domain Second is the demonstration of all optical switching using nonlinear loss in micro resonators We achieve this through two means The first is through the stimulated Raman response of silicon Here we fabricate a silicon micro ring that is co resonant with both a pump field and the anti Stokes field of the silicon material The presence of the pump field stimulates optical loss at the antiStokes field modulating the cavity resonance across all three regimes of coupling and demonstrating a single resonance all optical switch Secondly we use the two photon absorption process of highly nonlinear organic dye molecules embedded in a polymer host We achieve nonlinear loss induced decoupling of a cavity resonance of more than 7 dB and demonstrate the on chip nonlinear loss of 18 cm GW of the organic polymer **Novel Dynamics of Driven Nonlinear Resonators** Ian Hendry, 2020 This Thesis is comprised of theoretical and experimental investigations

designed to shed light on novel dynamics of nonlinear optical resonators. The theoretical investigations focus on cavity soliton CS dynamics in the presence of pulsed or amplitude modulated driving fields while the experimental investigation focusses on frequency comb generation in second order nonlinear microresonators. First we describe theoretical investigations into the dynamics of CSs in the presence of amplitude inhomogeneities of the driving field such as pulsed driving where the repetition rate of the inhomogeneity and the soliton are synchronised. We show that in contrast to phase inhomogeneities CSs are attracted towards and trapped to specific values of the driving field. We link our findings to a spontaneous symmetry breaking instability that physically arises from a competition between coherent driving and nonlinear propagation effects. We then consider the impact due to the presence of desynchronization between the CS and the repetition rate of the inhomogeneity. We show that the trapping positions can be manipulated and even erased such that single soliton operation can be assured. Further investigation into the interplay of this desynchronization and stimulated Raman scattering has allowed us to explain recent experimental observations. The experimental portion of this Thesis focusses on the demonstration of internally pumped optical parametric oscillations in a lithium niobate microresonator. We demonstrate through numerical simulations that frequency combs can form around the pump and the second harmonic in a doubly resonant second order nonlinear microresonator. We then report on our experimental method for comb generation in a naturally phase matched lithium niobate microresonator by thermally tuning the birefringence of the crystal. Our observations of cascaded internally pumped optical parametric oscillation producing sidebands around the pump and the second harmonic bring us one step closer to achieving full comb generation in quadratically nonlinear optical microresonators.

Applications of High-Q

Microresonators in Cavity Optomechanics and Nonlinear Photonics Wei C. Jiang, 2016. Optical microresonators confining light to small volumes are indispensable for a great variety of studies and applications. This thesis is devoted to a study of cavity optomechanical and nonlinear optical phenomena in high Q microresonators with different materials and structures. Based on that it proposes and demonstrates several novel schemes and device platforms that exhibit great potential for various applications ranging from frequency metrology and quantum photonics to information processing and sensing. The thesis starts with a demonstration of a high frequency above 1 GHz regenerative optomechanical oscillator based on a 2 mm radius high Q silicon microdisk resonator in the silicon on insulator platform with an ultra low threshold pump power at room temperature and atmosphere. It then continues to explore the cavity optomechanics in single crystal lithium niobate. A compact lithium niobate microdisk optomechanical resonator with high optical and mechanical qualities, large optomechanical coupling and high mechanical frequency is achieved enabling the demonstration of regenerative oscillation in the ambient. Meanwhile I propose and investigate a novel approach for single molecule detection that utilizes the optical spring effect in a high Q coherent optomechanical oscillator to dramatically enhance the sensing resolution by orders of magnitude compared with conventional resonator based approaches. In particular a high Q silica microsphere is

employed to experimentally demonstrate the detection of single Bovine Serum Albumin proteins with a molecular weight of 66 kDalton at a signal to noise ratio of 16.8. On the other hand the thesis focuses on the theoretical and experimental investigation of the generation of high purity bright photon pairs in a silicon microdisk based on the cavity enhanced four wave mixing. The device is able to produce multiple photon pairs at different wavelengths in the telecom band with a high spectral brightness of 6.24×10^7 pairs/s/mW/2 GHz and photon pair correlation with a coincidence to accidental ratio of 1386/278 while pumped with a continuous wave laser. Finally an intriguing approach is proposed for dispersion dynamic tuning and micro engineering by taking advantage of the optical forces in nano optomechanical structures. The proposed approach exhibits great potential for broad applications in dispersion sensitive processes which not only offer a new root towards versatile tunable nonlinear photonics but may also open up a great avenue towards a new regime of nonlinear dynamics coupling between nonlinear optical and optomechanical effects. Pages xi xii

Optical Microresonators John Heebner, Rohit Grover, Tarek A. Ibrahim, 2008. Optical Micro Resonators are an exciting new field of research that has gained prominence in the past few years due to the emergence of new fabrication technologies. This book is the first detailed text on the theory, fabrication and applications of optical micro resonators and will be found useful by both graduate students and researchers in the field.

Practical Applications of Microresonators in Optics and Photonics Andrey B. Matsko, 2018-09-03. Assembling an international team of experts this book reports on the progress in the rapidly growing field of monolithic micro and nanoresonators. The book opens with a chapter on photonic crystal based resonators, nanocavities. It goes on to describe resonators in which the closed trajectories of light are supported by any variety of total internal reflection in curved and polygonal transparent dielectric structures. The book also covers distributed feedback microresonators for slow light, controllable dispersion and enhanced nonlinearity. A portion of coverage is dedicated to the unique properties of resonators which are extremely efficient tools when conducting multiple applications.

Nonlinear Optics for the Information Society Alfred Driessen, 2001-11-30. Proceedings of the Third Annual Meeting of the COST Action P2 held in Enschede, The Netherlands, 26-27 October 2000.

Microresonators for Nonlinear Quantum Optics Zachary Vernon, 2017. In this thesis I study in detail the quantum dynamics of several nonlinear optical processes in microresonator systems. A Heisenberg picture input output formalism is developed from first principles that includes the effects of scattering losses and independent quality factors and coupling ratios for different resonances. The task of calculating the device output is then reduced to solving a set of driven damped ordinary differential equations for the resonator mode operators alone. This theoretical framework is used to study photon pair generation via spontaneous four wave mixing in the weakly pumped regime on which the effects of scattering losses are appraised. A more strongly driven regime is studied for continuous wave pumps demonstrating when self and cross phase modulation and multi photon pair generation become important and their effects on the spectral and power scaling properties of the system are examined. A detuning strategy is presented that

compensates for some of these effects The results of the weak pump regime are applied to study microresonator based heralded single photon sources The impact of scattering losses is studied revealing that typical systems suffer from low heralding efficiency due to these losses A technique to improve heralding efficiency is presented through over coupling the resonator channel system and a resultant trade off between heralding rate and heralding efficiency is uncovered Limitations to the spectral purity of the heralded single photon output for conventional microresonator systems are also analysed and a more sophisticated coupling scheme presented to overcome the upper bound for spectral purity of 93% that exists in typical systems permitting the generation of single photons with spectral purity arbitrarily close to 100% without spectral filtering or sophisticated phase matching techniques The theory of quantum frequency conversion in microresonators using four wave mixing is then developed in detail and the spectral conversion probability and conversion efficiency studied Efficiencies exceeding 90% using less than 100 mW of pump power are predicted to be achievable with current technology A dressed mode picture is developed to better understand the conversion dynamics Rabi like spectral splitting and temporal oscillations of the intracavity mean photon number are predicted exhibiting a novel regime of strongly coupled photonic modes

Nonlinear Optical Whispering Gallery Microresonators for Photonics John E. Heebner, 2003 *Cavity Optomechanics*

Markus Aspelmeyer, Tobias J. Kippenberg, Florian Marquardt, 2014-07-05 During the last few years cavity optomechanics has emerged as a new field of research This highly interdisciplinary field studies the interaction between micro and nano mechanical systems and light Possible applications range from novel high bandwidth mechanical sensing devices through the generation of squeezed optical or mechanical states to even tests of quantum theory itself This is one of the first books in this relatively young field It is aimed at scientists engineers and students who want to obtain a concise introduction to the state of the art in the field of cavity optomechanics It is valuable to researchers in nano science quantum optics quantum information gravitational wave detection and other cutting edge fields Possible applications include biological sensing frequency comb applications silicon photonics etc The technical content will be accessible to those who have familiarity with basic undergraduate physics

This book delves into Nonlinear Optical Cavity Dynamics Microresonators Ebook. Nonlinear Optical Cavity Dynamics Microresonators Ebook is an essential topic that must be grasped by everyone, ranging from students and scholars to the general public. The book will furnish comprehensive and in-depth insights into Nonlinear Optical Cavity Dynamics Microresonators Ebook, encompassing both the fundamentals and more intricate discussions.

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