

Special Issue: Artificial Gauge Fields

Artificial Gauge Fields with Ultracold Atoms in Optical Lattices

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Artificial Ultracold Optical Lattices Springer

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Kumar Khandai**



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Artificial Gauge Fields with Ultracold Atoms in Optical Lattices Monika Aidelsburger, 2015-12-14 This work reports on the generation of artificial magnetic fields with ultracold atoms in optical lattices using laser assisted tunneling as well as on the first Chern number measurement in a non electronic system It starts with an introduction to the Hofstadter model which describes the dynamics of charged particles on a square lattice subjected to strong magnetic fields This model exhibits energy bands with non zero topological invariants called Chern numbers a property that is at the origin of the quantum Hall effect The main part of the work discusses the realization of analog systems with ultracold neutral atoms using laser assisted tunneling techniques both from a theoretical and experimental point of view Staggered homogeneous and spin dependent flux distributions are generated and characterized using two dimensional optical super lattice potentials Additionally their topological properties are studied via the observation of bulk topological currents The experimental techniques presented here offer a unique setting for studying topologically non trivial systems with ultracold atoms **Springer Handbook of Atomic, Molecular, and Optical Physics** Gordon W. F. Drake, 2023-02-09 Comprises a comprehensive reference source that unifies the entire fields of atomic molecular and optical AMO physics assembling the principal ideas techniques and results of the field 92 chapters written by about 120 authors present the principal ideas techniques and results of the field together with a guide to the primary research literature carefully edited to ensure a uniform coverage and style with extensive cross references Along with a summary of key ideas techniques and results many chapters offer diagrams of apparatus graphs and tables of data From atomic spectroscopy to applications in comets one finds contributions from over 100 authors all leaders in their respective disciplines Substantially updated and expanded since the original 1996 edition it now contains several entirely new chapters covering current areas of great research interest that barely existed in 1996 such as Bose Einstein condensation quantum information and cosmological variations of the fundamental constants A fully searchable CD ROM version of the contents accompanies the handbook **Proceedings of the National Workshop on Recent Advances in Condensed Matter and High Energy Physics** Kusum Lata Pandey, Pradip Kumar Priya, Umesh Kumar Yadav, Prashanta Kumar Khandai, 2022-09-01 This book presents peer reviewed articles from the National Workshop on Recent Advances in Condensed Matter and High Energy Physics 2021 CMHEP 2021 This workshop was held in the Department of Physics Ewing Christian College ECC Prayagraj in collaboration with National Academic of Sciences NASI Prayagraj India in 2021 The book highlights recent theoretical and experimental developments in condensed matter and high energy physics which include novel phases of matter namely crystalline and non crystalline phases unconventional superconducting phases magnetic phases and Quark Gluon plasma phases along with searches of neutrino and dark matter This book provides a good resource for beginners as well as advanced researchers in the field of condensed matter and high energy physics **High Performance Computing in Science and Engineering '21** Wolfgang E. Nagel, Dietmar H. Kröner, Michael M.

Resch,2023-01-30 This book presents the state of the art in supercomputer simulation It includes the latest findings from leading researchers using systems from the High Performance Computing Center Stuttgart HLRS in 2021 The reports cover all fields of computational science and engineering ranging from CFD to computational physics and from chemistry to computer science with a special emphasis on industrially relevant applications Presenting findings of one of Europe s leading systems this volume covers a wide variety of applications that deliver a high level of sustained performance The book covers the main methods in high performance computing Its outstanding results in achieving the best performance for production codes are of particular interest for both scientists and engineers The book comes with a wealth of color illustrations and tables of results Fluctuations and Non-Equilibrium Phenomena in Strongly-Correlated Ultracold Atoms Kazuma

Nagao,2020-08-25 This book discusses non equilibrium quantum many body dynamics recently explored in an analog quantum simulator of strongly correlated ultracold atoms The first part presents a field theoretical analysis of the experimental observability of the Higgs amplitude mode that emerges as a relativistic collective excitation near a quantum phase transition of superfluid Bose gases in an optical lattice potential The author presents the dynamical susceptibilities to external driving of the microscopic parameters taking into account a leading order perturbative correction from quantum and thermal fluctuations and shows clear signatures of the Higgs mode in these observables This is the first result that strongly supports the stability of the Higgs mode in three dimensional optical lattices even in the presence of a spatially inhomogeneous confinement potential and paves the way for desktop observations of the Higgs mode In the second part the author applies the semi classical truncated Wigner approximation TWA to far from equilibrium quantum dynamics Specifically he considers the recent experiments on quantum quench dynamics in a Bose Hubbard quantum simulator A direct comparison shows remarkable agreement between the numerical results from TWA and the experimental data This result clearly indicates the potential of such a semi classical approach in reliably simulating many body systems using classical computers The book also includes several chapters providing comprehensive reviews of the recent studies on cold atomic quantum simulation and various theoretical methods including the Schwinger boson approach in strongly correlated systems and the phase space semi classical method for far from equilibrium quantum dynamics These chapters are highly recommended to students and young researchers who are interested in semi classical approaches in non equilibrium quantum dynamics *Advances in Quantum Mechanics* Alessandro Michelangeli,Gianfausto Dell'Antonio,2017-08-01 This

volume collects recent contributions on the contemporary trends in the mathematics of quantum mechanics and more specifically in mathematical problems arising in quantum many body dynamics quantum graph theory cold atoms unitary gases with particular emphasis on the developments of the specific mathematical tools needed including linear and non linear Schr dinger equations topological invariants non commutative geometry resonances and operator extension theory among others Most of contributors are international leading experts or respected young researchers in mathematical physics

PDE and operator theory All their material is the fruit of recent studies that have already become a reference in the community Offering a unified perspective of the mathematics of quantum mechanics it is a valuable resource for researchers in the field

Physics and Technology of Ultracold Atomic Gases Roberto Onofrio, Luca Salasnich, 2025-01-27 This book is based on lecture notes originally developed for introductory graduate courses offered by the authors at Dartmouth College and the University of Padova The first two chapters analyze quantum degenerate gases and various cooling and trapping techniques for atoms The remaining three chapters discuss ultracold atoms as weakly interacting strongly interacting and non interacting coherent systems The third chapter presents multiple pieces of evidence for quantum degeneracy in Bose and Fermi gases followed by peculiar features such as superfluidity and the formation of topological defects The fourth chapter addresses strongly correlated systems discussing the BCS BEC crossover in fermionic gases and quantum phase transitions including their dependence on effective dimensionality The fifth chapter offers a more specific discussion of quantum coherence in ultracold atoms and their potential as a platform for quantum metrology and quantum emulation Four appendices provide more quantitative details of theoretical tools used in the last two chapters Each chapter concludes with problems and a list of more specialized material The main goal is to introduce interested students to ultracold atom physics research topics and expose scientists working in other areas of frontier physics to this novel and exciting research direction This book is also intended to complement existing textbooks in standard courses on condensed matter physics demonstrating how some general elements of the latter can be understood by continuously increasing the interactions between ultracold and quantum degenerate atoms under controlled external conditions

Quantum Many-Body Physics of Ultracold Molecules in Optical Lattices Michael L. Wall, 2015-04-20 This thesis investigates ultracold molecules as a resource for novel quantum many body physics in particular by utilizing their rich internal structure and strong long range dipole dipole interactions In addition numerical methods based on matrix product states are analyzed in detail and general algorithms for investigating the static and dynamic properties of essentially arbitrary one dimensional quantum many body systems are put forth Finally this thesis covers open source implementations of matrix product state algorithms as well as educational material designed to aid in the use of understanding such methods

High Performance Computing in Science and Engineering ' 17 Wolfgang E. Nagel, Dietmar H. Kröner, Michael M. Resch, 2018-02-16 This book presents the state of the art in supercomputer simulation It includes the latest findings from leading researchers using systems from the High Performance Computing Center Stuttgart HLRS in 2017 The reports cover all fields of computational science and engineering ranging from CFD to computational physics and from chemistry to computer science with a special emphasis on industrially relevant applications Presenting findings of one of Europe s leading systems this volume covers a wide variety of applications that deliver a high level of sustained performance The book covers the main methods in high performance computing Its outstanding results in achieving the best performance for production codes are of particular interest for both

scientists and engineers The book comes with a wealth of color illustrations and tables of results *Enhanced Optical and Electric Manipulation of a Quantum Gas of KRb Molecules* Jacob P. Covey, 2018-10-01 This thesis describes significant advances in experimental capabilities using ultracold polar molecules While ultracold polar molecules are an idyllic platform for quantum chemistry and quantum many body physics molecular samples prior to this work failed to be quantum degenerate were plagued by chemical reactions and lacked any evidence of many body physics These limitations were overcome by loading molecules into an optical lattice to control and eliminate collisions and hence chemical reactions This led to observations of many body spin dynamics using rotational states as a pseudo spin and the realization of quantum magnetism with long range interactions and strong many body correlations Further a quantum synthesis technique based on atomic insulators allowed the author to increase the filling fraction of the molecules in the lattice to 30% a substantial advance which corresponds to an entropy per molecule entering the quantum degenerate regime and surpasses the so called percolations threshold where long range spin propagation is expected Lastly this work describes the design construction testing and implementation of a novel apparatus for controlling polar molecules It provides access to high resolution molecular detection and addressing large versatile static electric fields and microwave frequency electric fields for driving rotational transitions with arbitrary polarization Further the yield of molecules in this apparatus has been demonstrated to exceed 10^5 which is a substantial improvement beyond the prior apparatus and an excellent starting condition for direct evaporative cooling to quantum degeneracy Quantum Gas Experiments: Exploring Many-body States Paivi Torma, Klaus Sengstock, 2014-09-16 Quantum phenomena of many particle systems are fascinating in their complexity and are consequently not fully understood and largely untapped in terms of practical applications Ultracold gases provide a unique platform to build up model systems of quantum many body physics with highly controlled microscopic constituents In this way many body quantum phenomena can be investigated with an unprecedented level of precision and control and models that cannot be solved with present day computers may be studied using ultracold gases as a quantum simulator This book addresses the need for a comprehensive description of the most important advanced experimental methods and techniques that have been developed along with the theoretical framework in a clear and applicable format The focus is on methods that are especially crucial in probing and understanding the many body nature of the quantum phenomena in ultracold gases and most topics are covered both from a theoretical and experimental viewpoint with interrelated chapters written by experts from both sides of research Graduate students and post doctoral researches working on ultracold gases will benefit from this book as well as researchers from other fields who wish to gain an overview of the recent fascinating developments in this very dynamically evolving field Sufficient level of both detailed high level research and a pedagogical approach is maintained throughout the book so as to be of value to those entering the field as well as advanced researchers Furthermore both experimentalists and theorists will benefit from the book close collaboration between the two are continuously driving the

field to a very high level and will be strengthened to continue the important progress yet to be made in the field **Hybrid Quantum Systems** Yoshiro Hirayama,Koji Ishibashi,Kae Nemoto,2022-01-06 This book presents state of the art research on quantum hybridization manipulation and measurement in the context of hybrid quantum systems It covers a broad range of experimental and theoretical topics relevant to quantum hybridization manipulation and measurement technologies including a magnetic field sensor based on spin qubits in diamond NV centers coherently coupled superconductor qubits novel coherent couplings between electron and nuclear spin photons and phonons and coherent coupling of atoms and photons Each topic is concisely described by an expert at the forefront of the field helping readers quickly catch up on the latest advances in fundamental sciences and technologies of hybrid quantum systems while also providing an essential overview

From Atom Optics to Quantum Simulation Sebastian Will,2012-12-15 This thesis explores ultracold quantum gases of bosonic and fermionic atoms in optical lattices The highly controllable experimental setting discussed in this work has opened the door to new insights into static and dynamical properties of ultracold quantum matter One of the highlights reported here is the development and application of a novel time resolved spectroscopy technique for quantum many body systems By following the dynamical evolution of a many body system after a quantum quench the author shows how the important energy scales of the underlying Hamiltonian can be measured with high precision This achievement its application and many other exciting results make this thesis of interest to a broad audience ranging from quantum optics to condensed matter physics A lucid style of writing accompanied by a series of excellent figures make the work accessible to readers outside the rapidly growing research field of ultracold atoms *Entanglement in Spin Chains* Abolfazl Bayat,Sougato Bose,Henrik Johannesson,2022-09-26 This book covers recent developments in the understanding quantification and exploitation of entanglement in spin chain models from both condensed matter and quantum information perspectives Spin chain models are at the foundation of condensed matter physics and quantum information technologies and elucidate many fundamental phenomena such as information scrambling quantum phase transitions and many body localization Moreover many quantum materials and emerging quantum devices are well described by spin chains Comprising accessible self contained chapters written by leading researchers this book is essential reading for graduate students and researchers in quantum materials and quantum information The coverage is comprehensive from the fundamental entanglement aspects of quantum criticality non equilibrium dynamics classical and quantum simulation of spin chains through to their experimental realizations and beyond into machine learning applications Solid-State Physics James D. Patterson,Bernard C.

Bailey,2019-02-20 This book teaches solid state physics in a comprehensive way covering all areas It begins with three broad topics how and why atoms bind together to form solids lattice vibrations and phonons and electrons in solids It then applies this knowledge to interactions especially those between electrons and phonons metals the Fermi surface and alloys semiconductors magnetism superconductivity dielectrics and ferroelectrics optical properties defects layered materials

quantum Hall effect mesoscopics nanophysics and soft condensed matter Further important topics of the book are the evolution of BEC to BCS phenomena conducting polymers graphene iron pnictide superconductors light emitting diodes N V centers nanomagnetism negative index of refraction optical lattices phase transitions phononics photonics plasmonics quantum computing solar cells spin Hall effect and spintronics In this 3rd edition topics such as topological insulators quantum computing Bose Einstein transitions highly correlated electron systems and several others have been added New material on magnetism in solids as well as a discussion of semiconductors and a changed set of problems with solutions are also included The book also discusses folk theorems to remind readers of the essence of the physics without mathematics and includes 90 mini biographies of prominent solid state physicists of the past and present to put a human face on the subject An extensive solutions manual rounds out the book

Advances in Precision Laser Spectroscopy Kelin Gao, Wuming Liu, Jianping Yin, Jin Wang, Mingsheng Zhan, 2022-06-21 Provides extensive and thoroughly exhaustive coverage of precision laser spectroscopy Presents chapters written by recognized experts in their individual fields Topics covered include cold atoms cold molecules methods and techniques for production of cold molecules optical frequency standards based on trapped single ions etc Applicable for researchers and graduate students of optical physics and precision laser spectroscopy

Quantum Collisions and Confinement of Atomic and Molecular Species, and Photons P. C. Deshmukh, E. Krishnakumar, Stephan Fritzsche, M. Krishnamurthy, Sonjoy Majumder, 2019-09-28 This book comprises selected peer reviewed papers presented at the 7th Topical Conference of the Indian Society of Atomic and Molecular Physics jointly held at IISER Tirupati and IIT Tirupati India The contributions address current topics of interest in atomic and molecular physics both from the theoretical and experimental perspective The major focus areas include quantum collisions spectroscopy of atomic and molecular clusters photoionization Wigner time delay in collisions laser cooling Bose Einstein condensates atomic clocks quantum computing and trapping and manipulation of quantum systems The book also discusses emerging topics such as ultrafast quantum processes including those at the attosecond time scale This book will prove to be a valuable reference for students and researchers working in the field of atomic and molecular physics

Universal Themes of Bose-Einstein Condensation Nick P. Proukakis, David W. Snoke, Peter B. Littlewood, 2017-04-27 Covering general theoretical concepts and the research to date this book demonstrates that Bose Einstein condensation is a truly universal phenomenon

Utilization of Renormalized Mean-Field Theory upon Novel Quantum Materials Wei-Lin Tu, 2019-05-08 This book offers a new approach to the long standing problem of high T_c copper oxide superconductors It has been demonstrated that starting from a strongly correlated Hamiltonian even within the mean field regime the competing orders revealed by experiments can be achieved using numerical calculations In the introduction readers will find a brief review of the high T_c problem and the unique challenges it poses as well as a comparatively simple numerical approach the renormalized mean field theory RMFT which provides rich results detailed in the following chapters With an additional phase picked up by the original Hamiltonian

some behaviors of interactive fermions under an external magnetic field which have since been experimentally observed using cold atom techniques are also highlighted

Photoassociation of Ultracold CsYb Molecules and Determination of Interspecies Scattering Lengths Alexander Guttridge, 2019-06-01 This thesis lays the groundwork for producing a new class of ultracold molecule by associating an alkali metal atom and a closed shell alkaline earth like atom specifically Cs and Yb. Such molecules exhibit both a magnetic dipole moment and an electric dipole moment in their ground state. This extra degree of freedom opens up new avenues of research including the study of exotic states of matter, the shielding of molecular collisions and the simulation of lattice spin models. In detail, the thesis reports the first and only ultracold mixture of Cs and Yb in the world, giving details of the methods used to cool such contrasting atomic species together. Using sensitive two colour photoassociation measurements to measure the binding energies of the near threshold CsYb molecular levels in the electronic ground state has allowed the previously unknown scattering lengths to be accurately determined for all the Cs Yb isotopic combinations. As part of this work, the one photon photoassociation of ultracold Cs Yb is also studied, yielding useful information on the excited state potential. Knowledge of the scattering lengths enables a strategy to be devised to cool both species to quantum degeneracy and crucially determines the positions of interspecies Feshbach resonances required for efficient association of ground state CsYb molecules. With these results, the prospect of bringing a new molecule into the ultracold regime has become considerably closer.

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