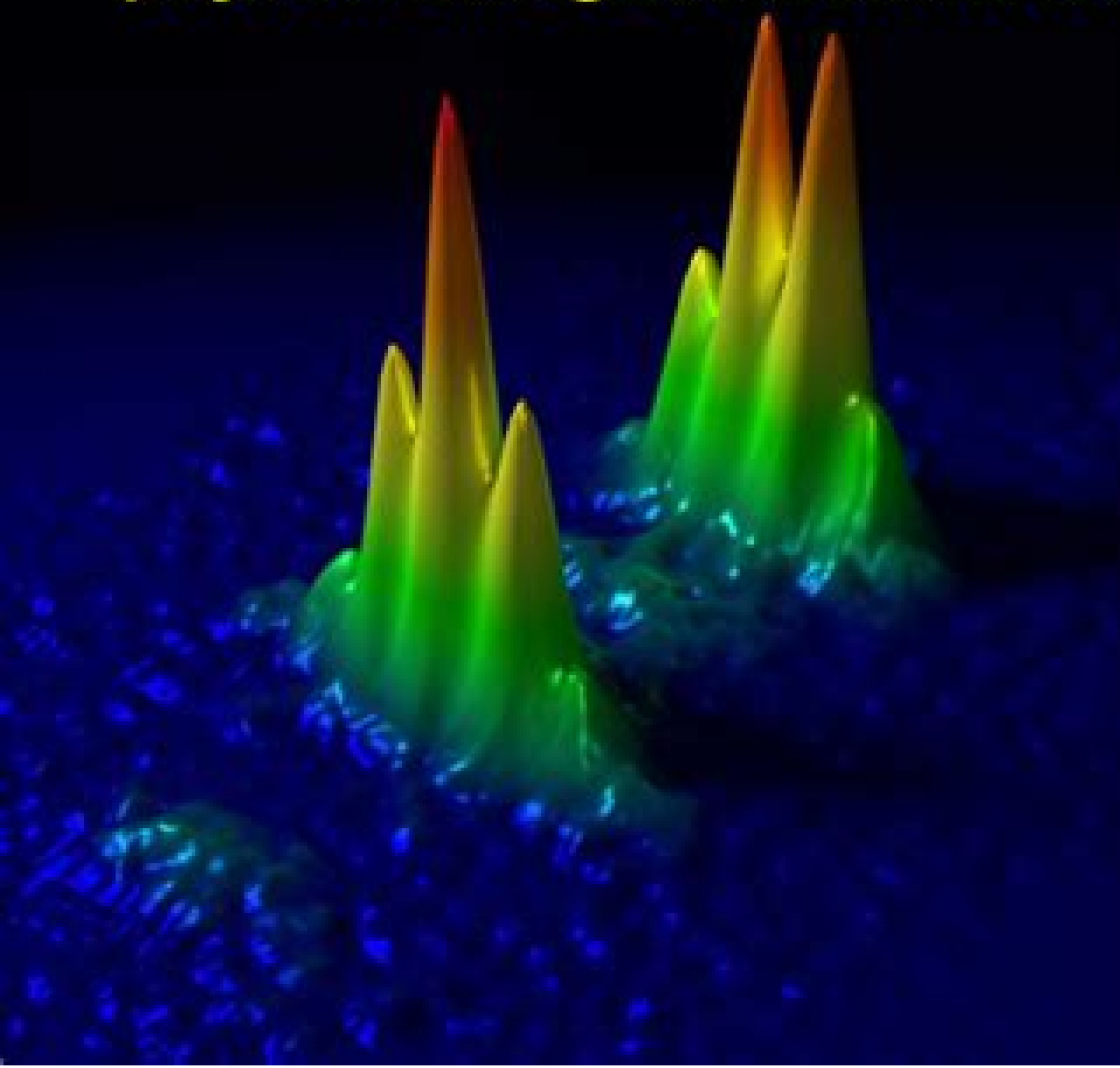


# Atom interferometry for fundamental physics and gravitational wave detection



CERN

Jason Hogan  
Stanford University  
September 12, 2019

# Atom Interferometry Proceedings Of The International School Of Physics

**Reiner Rummel**



## **Atom Interferometry Proceedings Of The International School Of Physics:**

Atom Interferometry Guglielmo M. Tino, M. A. Kasevich, 2014 Since atom interferometers were first realized about 20 years ago atom interferometry has had many applications in basic and applied science and has been used to measure gravity acceleration rotations and fundamental physical quantities with unprecedented precision Future applications range from tests of general relativity to the development of next generation inertial navigation systems This book presents the lectures and notes from the Enrico Fermi school Atom Interferometry held in Varenna Italy in July 2013 The aim of the school was to cover basic experimental and theoretical aspects and to provide an updated review of current activities in the field as well as main achievements open issues and future prospects Topics covered include theoretical background and experimental schemes for atom interferometry ultracold atoms and atom optics comparison of atom light electron and neutron interferometers and their applications high precision measurements with atom interferometry and their application to tests of fundamental physics gravitation inertial measurements and geophysics measurement of fundamental constants interferometry with quantum degenerate gases matter wave interferometry beyond classical limits large area interferometers atom interferometry on chips and interferometry with molecules The book will be a valuable source of reference for students newcomers and experts in the field of atom interferometry

**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

**Long Baseline Atom Interferometry** David Marvin Slaughter Johnson, 2011 Due to its impressive sensitivity long baseline atom interferometry is an exciting tool for tests of fundamental physics We are currently constructing a 10 meter scale apparatus to test the Weak Equivalence Principle WEP using co located Rb85 and Rb87 atom interferometers This apparatus aims to improve the current limit on WEP violation 100 fold which illustrates the power of this technique This scientific goal sets stringent requirements on the kinematic preparation of the atomic test masses the interferometer laser wavefront and stability as well as the electromagnetic and gravitational field homogeneity of the interferometer region The efforts to control these sources of systematic error are discussed Additionally applications of long

baseline atom interferometry to space based sensors for geodesy and gravitational wave detection are presented *A Guide to Experiments in Quantum Optics* Hans-A. Bachor, Timothy C. Ralph, 2019-10-28 Provides fully updated coverage of new experiments in quantum optics This fully revised and expanded edition of a well established textbook on experiments on quantum optics covers new concepts results procedures and developments in state of the art experiments It starts with the basic building blocks and ideas of quantum optics then moves on to detailed procedures and new techniques for each experiment Focusing on metrology communications and quantum logic this new edition also places more emphasis on single photon technology and hybrid detection In addition it offers end of chapter summaries and full problem sets throughout Beginning with an introduction to the subject *A Guide to Experiments in Quantum Optics* 3rd Edition presents readers with chapters on classical models of light photons quantum models of light as well as basic optical components It goes on to give readers full coverage of lasers and amplifiers and examines numerous photodetection techniques being used today Other chapters examine quantum noise squeezing experiments the application of squeezed light and fundamental tests of quantum mechanics The book finishes with a section on quantum information before summarizing of the contents and offering an outlook on the future of the field Provides all new updates to the field of quantum optics covering the building blocks models and concepts latest results detailed procedures and modern experiments Places emphasis on three major goals metrology communications and quantum logic Presents fundamental tests of quantum mechanics Schrodinger Kitten multimode entanglement photon systems as quantum emulators and introduces the density function Includes new trends and technologies in quantum optics and photodetection new results in sensing and metrology and more coverage of quantum gates and logic cluster states waveguides for multimodes discord and other quantum measures and quantum control Offers end of chapter summaries and problem sets as new features *A Guide to Experiments in Quantum Optics* 3rd Edition is an ideal book for professionals and graduate and upper level students in physics and engineering science **Laser**

**Spectroscopy - Proceedings Of The Xxii International Conference** Kai Dieckmann, 2016-10-14 ICOLS features the latest developments in the area of laser spectroscopy and related topics in atomic molecular and optical physics and other disciplines The talks covered a broad range of exciting physics such as precision tests of fundamental symmetries with atoms and molecules atomic clocks quantum many body physics with ultra cold atoms atom interferometry quantum information science with photons and ions quantum optics and ultra fast atomic and molecular dynamics The conference program comprised 14 sessions with 9 keynote addresses 25 invited talks and 3 hot topic talks The speakers came from 15 different countries Ever since the ICOLS conference series originated in 1973 its proceedings have been highly valued by many for capturing important developments in the field and offering the room to represent various aspects of specific research topics The present volume contains some of the invited talks delivered at the conference **Atom Optics and Space Physics** E. Arimondo, W. Ertmer, Wolfgang Schleich, E. M. Rasel, 2009 The goal of this volume is to discuss the rapidly moving field of

atom optics and interferometry with all its intricate aspects ranging from fundamental physics to applications and the theory of relativity The breathtaking success in manipulating atoms using lasers has encouraged these two so far disjunct communities to move closer together and begin collaborations After an introduction to atom optics and Bose Einstein condensation the theoretical foundations of cold atom interferometers their use to test gravity and their implementation in laboratory measurements of the Earth rotation and of Newton s gravitational constant are discussed Several papers discuss the characteristics of gyroscopes and interferometers as sensors for inertial forces starting from gyroscopes based on light waves and comparing their sensitivity to those based on matter waves The final topic is the variation of fundamental constants a subject that during the last years has attracted a lot of attention from different communities of physics

Expanding Frontier Of Atomic Physics, The - Proceedings Of The Xviii International Conference On Atomic Physics

Hossein R Sadeghpour, Eric J Heller, David E Pritchard, Pierre Agostini, 2003-04-29 This important proceedings volume highlights the major scientific achievement of the last decade in atomic physics namely the creation of the gaseous Bose Einstein condensate which was featured prominently at the XVIII International Conference on Atomic Physics ICAP2002 Two recipients of the 2001 Nobel Prize delivered lectures at the meeting Among the topics discussed were novel processes leading to degenerate Fermi gases in atom traps creation of cold molecules condensates in optical lattices atoms in intense fields tests of fundamental symmetries quantum control and information time and frequency standards **Atom**

**Interferometry** Paul R. Berman, 1997-01-08 The field of atom interferometry has expanded rapidly in recent years and today's research laboratories are using atom interferometers both as inertial sensors and for precision measurements Many researchers also use atom interferometry as a means of researching fundamental questions in quantum mechanics Atom Interferometry contains contributions from theoretical and experimental physicists at the forefront of this rapidly developing field Editor Paul R Berman includes an excellent balance of background material and recent experimental results providing a general overview of atom interferometry and demonstrating the promise that it holds for the future Includes contributions from many of the research groups that have pioneered this emerging field Discusses and demonstrates new aspects of the wave nature of atoms Explains the many important applications of atom interferometry from a measurement of the gravitational constant to atom lithography Examines applications of atom interferometry to fundamentally important quantum mechanics problems **Atom Interferometry**

Guglielmo M. Tino, Mark A. Kasevich, 2014-10-15 Since atom interferometers were first realized about 20 years ago atom interferometry has had many applications in basic and applied science and has been used to measure gravity acceleration rotations and fundamental physical quantities with unprecedented precision Future applications range from tests of general relativity to the development of next generation inertial navigation systems This book presents the lectures and notes from the Enrico Fermi school Atom Interferometry held in Varenna Italy in July 2013 The aim of the school was to cover basic experimental and theoretical aspects and to provide an

updated review of current activities in the field as well as main achievements open issues and future prospects Topics covered include theoretical background and experimental schemes for atom interferometry ultracold atoms and atom optics comparison of atom light electron and neutron interferometers and their applications high precision measurements with atom interferometry and their application to tests of fundamental physics gravitation inertial measurements and geophysics measurement of fundamental constants interferometry with quantum degenerate gases matter wave interferometry beyond classical limits large area interferometers atom interferometry on chips and interferometry with molecules The book will be a valuable source of reference for students newcomers and experts in the field of atom interferometry *Current Trends in Atomic Physics* Antoine Browaeys,Thierry Lahaye,Trey Porto,Charles S. Adams,Matthias Weidemüller,Leticia F. Cugliandolo,2019 Atomic physics provides a paradigm for exploring few body quantum systems with unparalleled control Recently this has been applied in diverse areas including condensed matter physics high energy physics and foundations of quantum physics This book addresses these topics by presenting developments and current trends Exploring the World with the Laser Dieter Meschede,Thomas Udem,Tilman Esslinger,2018-01-02 This edition contains carefully selected contributions by leading scientists in high resolution laser spectroscopy quantum optics and laser physics Emphasis is given to ultrafast laser phenomena implementations of frequency combs precision spectroscopy and high resolution metrology Furthermore applications of the fundamentals of quantum mechanics are widely covered This book is dedicated to Nobel prize winner Theodor W H nsch on the occasion of his 75th birthday The contributions are reprinted from a topical collection published in Applied Physics B 2016 Selected contributions are available open access under a CC BY 4 0 license via link [springer.com](https://www.springer.com) Please see the copyright page for further details **Metrology and Fundamental Constants** Theo W. Hänsch,2007 One of the exciting characteristics of metrology is its intimate relationship between fundamental physics and the leading edge of technology which is needed to perform advanced and challenging experiments and measurements This title includes a set of lectures which present the relevant progress in Metrology **Progress in Optics: A Tribute to Emil Wolf**,2020-04-24 Progress in Optics Volume 65 A Tribute to Emil Wolf provides the latest release in a series that presents an overview of the state of the art in optics research In this update readers will find timely chapters on Specular mirror interferometer Maximum Likelihood Estimation in the Context of an Optical Measurement Surface Plasmons The Development of Coherence Theory and much more **Molecular Beams in Physics and Chemistry** Bretislav Friedrich,Horst Schmidt-Böcking,2021-06-19 This Open Access book gives a comprehensive account of both the history and current achievements of molecular beam research In 1919 Otto Stern launched the revolutionary molecular beam technique This technique made it possible to send atoms and molecules with well defined momentum through vacuum and to measure with high accuracy the deflections they underwent when acted upon by transversal forces These measurements revealed unforeseen quantum properties of nuclei atoms and molecules that became the basis for our current understanding of

quantum matter This volume shows that many key areas of modern physics and chemistry owe their beginnings to the seminal molecular beam work of Otto Stern and his school Written by internationally recognized experts the contributions in this volume will help experienced researchers and incoming graduate students alike to keep abreast of current developments in molecular beam research as well as to appreciate the history and evolution of this powerful method and the knowledge it reveals Interferometry with Interacting Bose-Einstein Condensates in a Double-Well Potential Tarik Berrada,2015-12-17

This thesis demonstrates a full Mach Zehnder interferometer with interacting Bose Einstein condensates confined on an atom chip It relies on the coherent manipulation of atoms trapped in a magnetic double well potential for which the author developed a novel type of beam splitter Particle wave duality enables the construction of interferometers for matter waves which complement optical interferometers in precision measurement devices both for technological applications and fundamental tests This requires the development of atom optics analogues to beam splitters phase shifters and recombiners Particle interactions in the Bose Einstein condensate lead to a nonlinearity absent in photon optics This is exploited to generate a non classical state with reduced atom number fluctuations inside the interferometer This state is then used to study the interaction induced dephasing of the quantum superposition The resulting coherence times are found to be a factor of three longer than expected for coherent states highlighting the potential of entanglement as a resource for quantum enhanced metrology **Advances in Atomic, Molecular, and Optical Physics** ,2005-05-10 This series established in 1965 is concerned with recent developments in the general area of atomic molecular and optical physics The field is in a state of rapid growth as new experimental and theoretical techniques are used on many old and new problems Topics covered include related applied areas such as atmospheric science astrophysics surface physics and laser physics Articles are written by distinguished experts who are active in their research fields The articles contain both relevant review material and detailed descriptions of important recent developments Reviews timely fields of atomic physics Articles written by world leaders in those fields In depth review of the subject with relevant literature Suitable for researchers in other fields Only book series of this kind

**Non-equilibrium Dynamics of Tunnel-Coupled Superfluids** Marine Pigneur,2020-08-28 The relaxation of isolated quantum many body systems is a major unsolved problem of modern physics which is connected to many fundamental questions However realizations of quantum many body systems which are both well isolated from their environment and accessible to experimental study are scarce In recent years the field has experienced rapid progress partly attributed to ultra cold atoms This book presents the experimental study of a relaxation phenomenon occurring in a one dimensional bosonic Josephson junction The system consists of two 1D quasi Bose Einstein condensates of  $^{87}\text{Rb}$  magnetically trapped on an atom chip Using radio frequency dressing the author deforms a single harmonic trap in which the atoms are initially condensed into a double well potential and realizes a splitting of the wave function A large spatial separation and a tilt of the double well enable the preparation of a broad variety of initial states by precisely adjusting the initial population

and relative phase of the two wave packets while preserving the phase coherence By re coupling the two wave packets the author investigates tunneling regimes such as Josephson plasma oscillations and macroscopic quantum self trapping In both regimes the tunneling dynamics exhibits a relaxation to a phase locked equilibrium state contradicting theoretical predictions The experimental results are supported with an empirical model that allows quantitative discussions according to various experimental parameters These results illustrate how strongly the non equilibrium dynamics differ from the equilibrium one which is well described by thermodynamics and statistical physics

**Atom Optics** Pierre Meystre, 2001-09-21 Quantum mechanics does away with the distinction between particles and waves and one of the more interesting implications of the wave particle duality the discovery that atoms may be manipulated in ways analogous to the manipulation of light with lenses and mirrors has formed the basis for the relatively new field of atom optics Pierre Meystre's Atom Optics is the first book entirely devoted to this exciting area of research Reference links to the leading journals in the field links to research sites graphics and updates can be found online

**Erdmessung und Satellitengeodäsie** Reiner Rummel, 2017-08-18 Das Handbuch der Geodäsie ist ein hochwertiges wissenschaftlich fundiertes Werk über die Geodäsie unserer Zeit und bietet anhand von in sechs Bänden zusammengestellten Einzelthemen ein repräsentatives Gesamtbild des Fachgebiets Satelliten führten zu einer Revolution in der Geodäsie Erst mit Hilfe von Satelliten wurde die Erdmessung tatsächlich global und dreidimensional Ozeane und Eisschilde stellen keine Hindernisse mehr dar sie lassen sich heute mit gleicher Präzision vermessen wie die Kontinente Verfeinerungen resultieren aus der Kombination von Raumverfahren mit terrestrischen Messmethoden Damit gelingt es der Erdmessung fundamentale Beiträge zum Verständnis des Erdsystems und des Klimawandels zu liefern Voraussetzung für diese Entwicklung sind sehr moderne Messverfahren und Auswertemethoden und deren extrem genaue Verknüpfung in einem globalen erd- und raumfesten Referenzsystem Im Band Erdmessung und Satellitengeodäsie werden exemplarisch die historischen Wurzeln methodischen Grundlagen verwendeten Messverfahren sowie die Forschungstrends vorgestellt

**Laser Spectroscopy - Proceedings Of The Xii International Conference** Massimo Inguscio, M Allegrini, A Sasso, 1996-03-20 The book includes all the recent major advances in the field of Laser Spectroscopy Major results span from the control of matter by electromagnetic fields trapping and cooling to high precision measurements on simple atomic systems and to quantum optics with single atoms As an outstanding contribution the reader will find in the book the first report of the Bose Einstein condensation achieved by laser cooling of rubidium atoms Achievements in the technology of tunable sources in particular of miniaturized solid state devices are also reported Most recent advances in molecular spectroscopy are illustrated with emphasis on cooled spectra clusters and high accuracy frequency references Topics such as atomic interferometry and microcavity quantum optics are also covered



The Top Books of the Year Atom Interferometry Proceedings Of The International School Of Physics The year 2023 has witnessed a remarkable surge in literary brilliance, with numerous engrossing novels captivating the hearts of readers worldwide. Lets delve into the realm of popular books, exploring the engaging narratives that have captivated audiences this year. The Must-Read : Colleen Hoovers "It Ends with Us" This heartfelt tale of love, loss, and resilience has captivated readers with its raw and emotional exploration of domestic abuse. Hoover expertly weaves a story of hope and healing, reminding us that even in the darkest of times, the human spirit can succeed. Uncover the Best : Taylor Jenkins Reids "The Seven Husbands of Evelyn Hugo" This intriguing historical fiction novel unravels the life of Evelyn Hugo, a Hollywood icon who defies expectations and societal norms to pursue her dreams. Reids captivating storytelling and compelling characters transport readers to a bygone era, immersing them in a world of glamour, ambition, and self-discovery. Atom Interferometry Proceedings Of The International School Of Physics : Delia Owens "Where the Crawdads Sing" This captivating coming-of-age story follows Kya Clark, a young woman who grows up alone in the marshes of North Carolina. Owens weaves a tale of resilience, survival, and the transformative power of nature, entrancing readers with its evocative prose and mesmerizing setting. These popular novels represent just a fraction of the literary treasures that have emerged in 2023. Whether you seek tales of romance, adventure, or personal growth, the world of literature offers an abundance of engaging stories waiting to be discovered. The novel begins with Richard Papen, a bright but troubled young man, arriving at Hampden College. Richard is immediately drawn to the group of students who call themselves the Classics Club. The club is led by Henry Winter, a brilliant and charismatic young man. Henry is obsessed with Greek mythology and philosophy, and he quickly draws Richard into his world. The other members of the Classics Club are equally as fascinating. Bunny Corcoran is a wealthy and spoiled young man who is always looking for a good time. Charles Tavis is a quiet and reserved young man who is deeply in love with Henry. Camilla Macaulay is a beautiful and intelligent young woman who is drawn to the power and danger of the Classics Club. The students are all deeply in love with Morrow, and they are willing to do anything to please him. Morrow is a complex and mysterious figure, and he seems to be manipulating the students for his own purposes. As the students become more involved with Morrow, they begin to commit increasingly dangerous acts. The Secret History is a brilliant and gripping novel that will keep you speculating until the very end. The novel is a cautionary tale about the dangers of obsession and the power of evil.

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