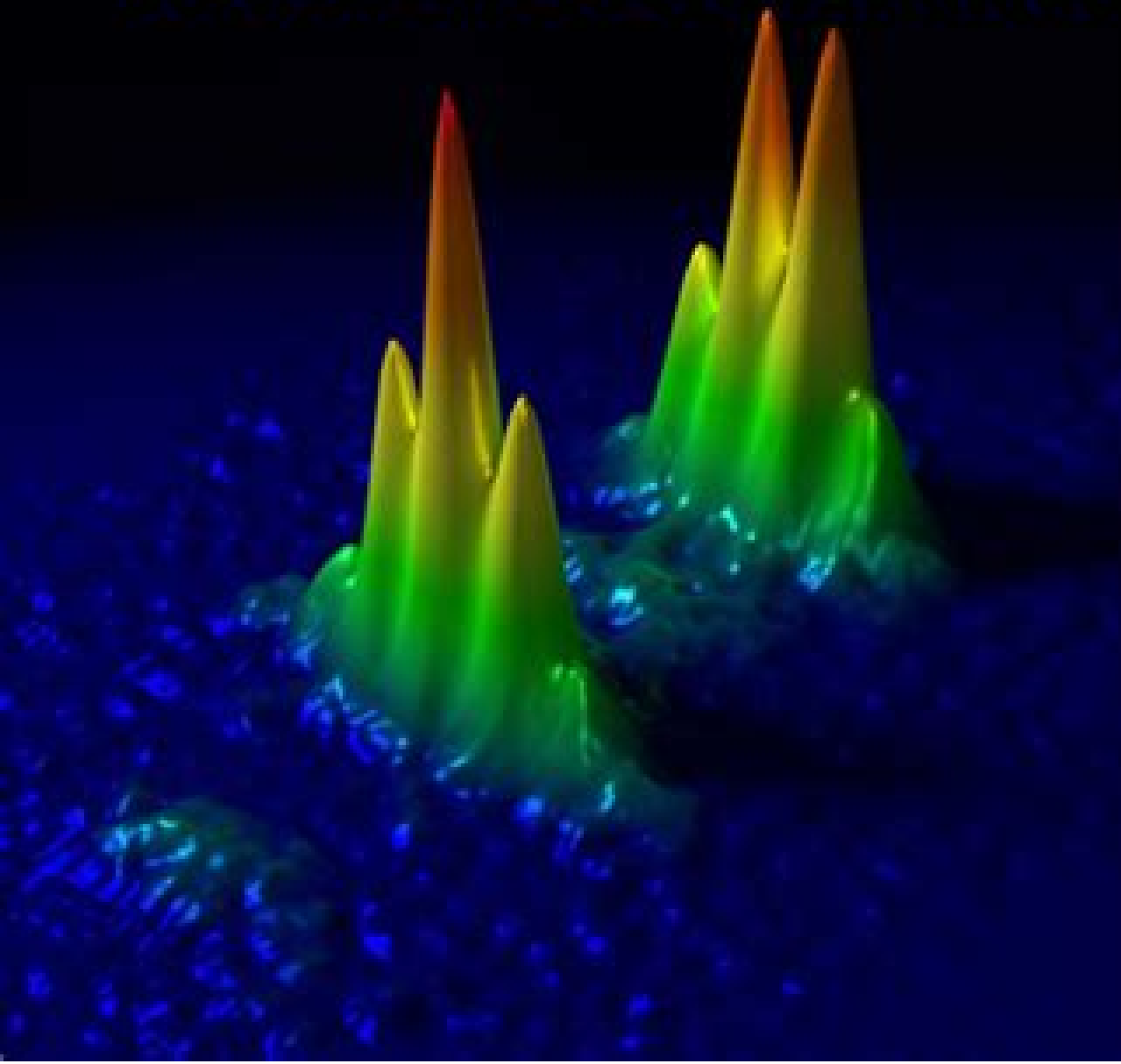


Atom interferometry for fundamental physics and gravitational wave detection



CERN

Jason Hogan
Stanford University
September 12, 2019

Atom Interferometry Proceedings Of The International School Of Physics

Tarik Berrada



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

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

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

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

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

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

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

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

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 *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 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

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

Civil and Environmental Engineering for the Sustainable Development Goals Manuela Antonelli, Gabriele Della Vecchia, 2022-05-14 This open access volume collects emerging issues in Environmental and Civil Engineering originating from outstanding doctoral dissertations discussed at Politecnico di Milano in 2021 The advanced innovative insights provided are presented with reference to the relevant sustainable development goals SDGs hoping that scientists technicians and decision makers will find them as a valid support to face future sustainability challenges Indeed the fast evolution of our society often falls short in properly taking into consideration its relationship with

the environment which is not only the primary source of any resource and the sink of all the wastes we generate throughout our activities but also the cause of most of the loading and constraints applied to structures and infrastructures. The lack of a proper consideration of the relationship between the needs of both the society and the environment may lead to strong disequilibria generating a large amount of threats for a robust resilient and continuous development. In this perspective the SDGs set by the United Nations represent the criteria to revise our development model towards the ability to conjugate different needs to build a safe relation between anthropic activities and the environment. Civil and Environmental Engineering plays a relevant role in providing methods, approaches, risk and impact assessments as well as technologies to fulfil the SDGs. Research in these fields may in fact provide technical knowledge and tools to support decision makers and technicians in: i) planning mitigation and adaptation actions to climate change, extreme weather, earthquakes, drought, flooding and other natural disasters; ii) designing efficient and sustainable strategies for resources exploitation, minimizing the impact and the unequal distributions; iii) increasing the safety of structures and infrastructures under exceptional loadings and against the deterioration due to their lifecycle; iv) adopting a holistic risk management approach and appropriate technologies to reduce pollution and environment deterioration which increase vulnerability; v) providing a safe drinking water and sanitation system to protect human health.

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.

Advances in Atomic, Molecular, and Optical Physics Susanne Yelin, Louis F. Dimauuro, Hélène Perrin, 2021-07-09. *Advances in Atomic Molecular and Optical Physics* Volume 70 provides a comprehensive compilation of recent developments in a field that is in a state of rapid growth as new experimental and theoretical techniques are used on many problems, both old and new. Topics covered include related applied areas such as atmospheric science, astrophysics, surface physics and laser physics, with timely articles written by distinguished experts. Presents the work of international experts in the field. Contains comprehensive articles that compile recent developments in a field that is experiencing rapid growth with new experimental and theoretical techniques emerging. Ideal for users interested in optics, excitons, plasmas and thermodynamics. Covers atmospheric science, astrophysics and surface and laser physics amongst other topics.

Principles of Laser Spectroscopy and Quantum

Optics Paul R. Berman, Vladimir S. Malinovsky, 2011-01-02. *Principles of Laser Spectroscopy and Quantum Optics* is an

essential textbook for graduate students studying the interaction of optical fields with atoms. It also serves as an ideal reference text for researchers working in the fields of laser spectroscopy and quantum optics. The book provides a rigorous introduction to the prototypical problems of radiation fields interacting with two and three level atomic systems. It examines the interaction of radiation with both atomic vapors and condensed matter systems, the density matrix and the Bloch vector and applications involving linear absorption and saturation spectroscopy. Other topics include hole burning, dark states, slow light and coherent transient spectroscopy as well as atom optics and atom interferometry. In the second half of the text, the authors consider applications in which the radiation field is quantized. Topics include spontaneous decay, optical pumping, sub-Doppler laser cooling, the Heisenberg equations of motion for atomic and field operators and light scattering by atoms in both weak and strong external fields. The concluding chapter offers methods for creating entangled and spin-squeezed states of matter. Instructors can create a one-semester course based on this book by combining the introductory chapters with a selection of the more advanced material. A solutions manual is available to teachers. Rigorous introduction to the interaction of optical fields with atoms. Applications include linear and nonlinear spectroscopy, dark states and slow light. Extensive chapter on atom optics and atom interferometry. Conclusion explores entangled and spin-squeezed states of matter. Solutions manual available only to teachers.

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