



Atom Interferometry

**David E. Pritchard, Chris R.
Ekstrom, David Keith, Bruce G.
Oldaker, Quentin
Turchette, MASSACHUSETTS INST OF
TECH CAMBRIDGE RESEARCH LAB OF
ELECTRONICS.**

Atom Interferometry:

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 of 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.

Atom Interferometry Progress David E. Pritchard, Chris R. Ekstrom, David Keith, Bruce G. Oldaker, Quentin Turchette, MASSACHUSETTS INSTITUTE OF TECHNOLOGY, CAMBRIDGE RESEARCH LAB OF ELECTRONICS., 1990 An atom interferometer is constructed in which the atom waves are physically separated prior to being recombined. Fabricated transmission gratings are used as optical elements for the matter waves. Atom interferometers should be useful in studies of atomic properties, tests of basic quantum physics, for metrology, as rotation sensors, and perhaps ultimately as devices to make ultra-small structures using atom holograms. During the last year, our atom interferometer has evolved from a rough plan to an essentially complete device. At present, all the major components of the interferometer have been built and tested at least once. The system will be given its first real try in

the next year Our interferometer consists of three 0.2 microns period diffraction gratings equally spaced approx 0.65 m apart in our atomic beam machine The maximum separation of the beams will be approx 60 microns The first two gratings separate and redirect the atomic beam forming a standing wave interference pattern in the atomic flux at the third grating which acts like a mask to sample this pattern A principle technical obstacle is the mechanical vibrations of our machine which will blur the interference pattern jhd

Pushing the Frontiers of Atomic Physics Robin C[ot], Phillip L. Gould, Michael Rozman, 2009 This unique book highlights the state of the art of the booming field of atomic physics in the early 21st century It contains the majority of the invited papers from an ongoing series of conferences held every two years devoted to forefront research and fundamental studies in basic atomic physics broadly defined This conference held at the University of Connecticut in July 2008 is part of a series of conferences which began in 1968 and had its historical origins in the molecular beam conferences of the I I Rabi group It provides an archival and up to date summary of current research on atoms and simple molecules as well as their interactions with each other and with external fields including degenerate Bose and Fermi quantum gases and interactions involving ultrafast lasers strong field control of X ray processes and nanoscale and mesoscopic quantum systems The work of three recent Nobel Laureates in atomic physics is included beginning with a lecture by Eric Cornell on When Is a Quantum Gas a Quantum Liquid There are also papers by Laureates Steven Chu and Roy Glauber The volume also contains the IUPAP Young Scientist Prize lecture by Cheng Chin on Exploring Universality of Few Body Physics Based on Ultracold Atoms Near Feshbach Resonances

Current Trends in Atomic Physics Antoine Browaeys, Thierry Lahaye, Trey Porto, Charles S. Adams, Matthias Weidemüller, Leticia F. Cugliandolo, 2019-05-16 This book gathers the lecture notes of courses given at Session CVII of the summer school in physics entitled Current Trends in Atomic Physics and held in July 2016 in Les Houches France Atomic physics provides a paradigm for exploring few body quantum systems with unparalleled control In recent years this ability has been applied in diverse areas including condensed matter physics high energy physics chemistry and ultra fast phenomena as well as foundational aspects of quantum physics This book addresses these topics by presenting developments and current trends via a series of tutorials and lectures presented by international leading investigators

Laser Physics at the Limits Hartmut Figger, 2001-11-02 Published on the occasion of Theodor H nsch s 60th Birthday emphasis is placed on precision related to results in a variety of fields such as atomic clocks frequency standards and the measurement of physical constants in atomic physics Furthermore illustrations and engineering applications of the fundamentals of quantum mechanics are widely covered It has contributions by Nobel prize winners Norman F Ramsey Steven Chu and Carl E Wieman

Atom Interferometry Course 188 Proceedings of the International School of Physics «Enrico Fermi» G. Tino, M. Kasevich, 2014

Advances in Atomic, Molecular, and Optical Physics, 1995-03-01 Established in 1965 Advances in Atomic Molecular and Optical Physics continues its tradition of excellence with Volume 34 The latest volume includes nine reviews of topics related to the applications of atomic and molecular physics to

atmospheric physics and astrophysics *Handbook of Gravitational Wave Astronomy* Cosimo Bambi, Stavros Katsanevas, Konstantinos D. Kokkotas, 2022-07-02 This handbook provides an updated comprehensive description of gravitational wave astronomy In the first part it reviews gravitational wave experiments from ground and space based laser interferometers to pulsar timing arrays and indirect detection from the cosmic microwave background In the second part it discusses a number of astrophysical and cosmological gravitational wave sources including black holes neutron stars possible more exotic objects and sources in the early Universe The third part of the book reviews the methods to calculate gravitational waveforms The fourth and last part of the book covers techniques employed in gravitational wave astronomy data analysis This book represents both a valuable resource for graduate students and an important reference for researchers in gravitational wave astronomy 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

Hot Beats and Tune Outs Kayleigh Cassella, 2018 Ushered forth by advances in time and frequency metrology atom interferometry remains an indispensable measurement tool in atomic physics due to its precision and versatility A sequence of four $\pi/2$ beam splitter pulses can create either an interferometer sensitive to the atom's recoil frequency when the momentum imparted by the light reverses direction between pulse pairs or when constructed from pulses without such reversal sensitive to the perturbing potential from an external optical field Here we demonstrate the first atom interferometer with laser cooled lithium advantageous for its low mass and simple atomic structure We study both a recoil sensitive Ramsey-Bordé interferometer and interferometry sensitive to the dynamic polarizability of the ground state of lithium Recoil sensitive Ramsey-Bordé interferometry benefits from lithium's high recoil frequency a consequence of its low mass At an interrogation time of 10 ms a Ramsey-Bordé lithium interferometer could achieve sensitivities comparable to those realized at much longer times with heavier alkali atoms However in contrast with other atoms that are used for atom interferometry lithium's unresolved excited state hyperfine structure precludes the the cycling transition necessary for efficient cooling Without sub-Doppler cooling techniques As a result a lithium atomic gas is typically laser cooled to temperatures around 300 μ K above the Doppler limit and well above the recoil temperature of 6 μ K This higher temperature gas expands rapidly during the operation of an atom interferometer limiting the experimental interrogation time

and preventing spatially resolved detection In this work a light pulse lithium matter wave interferometer is demonstrated in spite of these limitation Two photon Raman interferometer pulses coherently couple the atom s spin and momentum and are thus able to spectrally resolve the outputs These fast pulses drive conjugate interferometers simultaneously which beat with a fast frequency component proportional to the atomic recoil frequency and an envelope modulated by the two photon detuning of the Raman transition We detect the summed signal at short experimental times preventing perturbation of the signal from vibration noise This demonstration of a sub recoil measurement with a super recoil sample opens the door to similar scheme with other particles that are difficult to trap and cool well like electrons An interferometer instead composed of pi 2 pulses with a single direction of momentum transfer can be sensitive to the dynamic polarizability of the atomic ground state By scanning the frequency of an external driving field such a measurement can be used to determine the atom s tune out wavelength This is the wavelength at which the frequency dependent polarizability vanishes due to compensating ac Stark shifts from other atomic states Lithium s simple atomic structure allows for a precise computation of properties with only em ab initio wave functions and spectroscopic data A direct interferometric measurement of lithium s red tune out wavelength at 670 971626 1 nm is a precise comparison to existing all order atomic theory computations It also provides another way to experimentally determine the S to P transitions matrix elements for which large correlations and small values complicate computations Finally a future measurement of lithium s ultraviolet tune out wavelength of at 324 192 2 nm would be sensitive to relativistic approximations in the atomic structure description Atom interferometry simultaneously verifies existing atomic theory with measurements of atomic properties and searches for exotic physics lurking in plain sight The techniques developed here broaden the applicability of interferometry and increase measurement sensitivity by simplifying cooling increasing atom number and reducing the cycle time Overcoming the current experimental limitations on interrogation time would allow for ultra precise measurements of both the tune out wavelength and the fine structure constant

New Developments in Atom Interferometry ,1992 The first true atom interferometer was demonstrated Using transmission gratings as optical elements for atom deBroglie waves a three grating atom interferometer was constructed which physically separates atom waves before recombining them This demonstration was closely followed by two demonstrations of atom interferometers which used laser light as the beam splitters Atom interferometers will make possible qualitatively new types of experiments involving inertial effects studies of atomic and molecular properties tests of basic quantum physics and may ultimately open the way to make ultra small structures using atom holograms *Atom Optics* Society of Photo-optical Instrumentation Engineers,United States. Defense Advanced Research Projects Agency,1997

Chemical Abstracts ,1922 New Techniques for Precision Atom Interferometry and Applications to Fundamental Tests of Gravity and of Quantum Mechanics Tim Kovachy,2016 Light pulse atom interferometry in which quantum mechanical atomic wave packets are split along two paths and later recombined and made to interfere by sequences of optical pulses is a

remarkably sensitive technique for measuring inertial forces allowing it to be a valuable tool for applications ranging from fundamental tests of gravity to geodesy and inertial navigation The inertial sensitivity of an atom interferometer is proportional to its enclosed spacetime area that is the product of the spatial separation between the two interferometer paths and the interferometer duration Therefore new techniques that allow this spacetime area to be increased are essential in order for atom interferometry to reach its full potential In this thesis I describe the development of such techniques We approach the problem of increasing the interferometer spacetime area on two fronts First we implement new methods to increase the momentum transferred by the beam splitters of the interferometer The velocity difference and therefore the spatial separation of the interferometer paths are proportional to this momentum transfer Conventional atom optics techniques involve beam splitters that transfer two photon momentum recoils $2 \hbar k$ to the atoms I will discuss our realization of large momentum transfer LMT beam splitters that transfer up to $100 \hbar k$ Second we have built a 10 m tall atomic fountain that allows the total interferometer duration to be increased to 2 s Ultimately we combined LMT atom optics with long duration atom interferometry in the 10 m atomic fountain leading to very large spacetime area atom interferometers In these very large area atom interferometers the separation between the two atomic wave packets that respectively travel along the two interferometer paths reaches distances of up to 54 cm Therefore in addition to offering greatly increased inertial sensitivity these interferometers probe the quantum mechanical wavelike nature of matter in a new macroscopic regime I will discuss the techniques we devised to overcome the many technical challenges associated with such interferometers which in other apparatus have prevented interference from being maintained for path separations larger than 1 cm I will also describe initial results from the use of our very large area interferometers to test the equivalence principle with Rb 85 and Rb 87 and our plans for further progress in this direction Very large area atom interferometry requires high laser power and extremely cold atom sources We have developed a novel high power frequency doubled laser source at 780 nm that is suitable for atom optics Also we have implemented a sequence of matter wave lenses to prepare and measure atomic ensembles with record low effective temperatures of 50 pK In addition to applications in atom interferometry we expect that such an atom source will be broadly useful for a wide range of experiments

Gravity Gradient Survey with a Mobile Atom Interferometer Xin'an Wu, 2009

Coherent Atomic Manipulation and Cooling Alexander J. Dunning, 2015-08-18 This work unites the concepts of laser cooling and matter wave interferometry to develop an interferometric laser cooling technique in an experimental system of cold rubidium atoms Serving as an introduction to graduate level coherent optical atomic manipulation the thesis describes the theory of stimulated Raman transitions and atom interferometry along with the experimental methods for preparing and manipulating cold atoms before building on these foundations to explore tailored optical pulse sequences and novel atomic cooling techniques Interferometric cooling originally proposed by Weitz and Hansch in 2000 is based upon the coherent broadband laser pulses of Ramsey

interferometry and in principle allows laser cooling of atomic and molecular species outside the scope of traditional Doppler laser cooling On the path toward cooling composite pulses quantum error correction methods developed by chemists to mitigate the effects of inhomogeneities in NMR spectroscopy are investigated with a view to improving the performance of atom interferometers Spin Squeezing and Non-linear Atom Interferometry with Bose-Einstein Condensates Christian Groß,2012-01-12 Interferometry the most precise measurement technique known today exploits the wave like nature of the atoms or photons in the interferometer As expected from the laws of quantum mechanics the granular particle like features of the individually independent atoms or photons are responsible for the precision limit the shot noise limit However this classical bound is not fundamental and it is the aim of quantum metrology to overcome it by employing entanglement among the particles This work reports on the realization of spin squeezed states suitable for atom interferometry Spin squeezing was generated on the basis of motional and spin degrees of freedom whereby the latter allowed the implementation of a full interferometer with quantum enhanced precision **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 **International Seminar on Novel Trends in Nonlinear Laser Spectroscopy and High-precision Measurements in Optics** Viktor Nikolaevich Zadkov,Sergeĭ Martirosovich Arakeliĭan,2001

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