Cover image:
Journal of Physics B: Atomic, Molecular and Optical Physics highlights of 2009 offer you a representative cross section regarding breadth, quality and diversity of papers and fast track communications published last year in J. Phys. B.

In our era of seemingly objective and quantitative indicators such as citations and downloads, this year we have simply asked our board members: what was your favorite J. Phys. B article in 2009 and why do you like it? Enjoy reading their highlights and find out if you agree with the selection - and if not, there are many more excellent articles to be found in J. Phys. B.

I thank all authors and referees who contribute to the journal and support its vision: to be an intellectual market place for exchanging interesting results and creative ideas.


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Experimental 5-site optical dark ring lattices generated using an acousto-optical modulator and corresponding least-squares theoretical fits

The density evolution of an exact Floquet state of a driven Bose-Einstein condensate in a 1D optical lattice with a spatiotemporal driving field

Contour plot of nuclear probabilities obtained from the time-dependent Schrödinger equation for an H₂ molecule
Journal of Physics B: Atomic, Molecular and Optical Physics

Published twice-monthly (24 issues per year), Journal of Physics B: Atomic, Molecular and Optical Physics covers the study of atoms, ions, molecules and clusters, and their structure and interactions with particles, photons or fields. The journal also publishes articles dealing with those aspects of spectroscopy, quantum optics and non-linear optics, laser physics, astrophysics, plasma physics, chemical physics, optical cooling and trapping and other investigations where the objects of study are the elementary atomic, ionic or molecular properties of processes.

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J. Phys. B publishes Research Papers and Fast Track Communications (FTCs). FTCs are outstanding short articles reporting new and timely developments. They are processed quickly, free to publish, and are open access.

The journal also publishes Special Issues, Topical Reviews and PhD Tutorials, details of which can be found on pages 7, 8 and 9, respectively.

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30 most downloaded articles

Taken from all of the articles published by the journal in 2009, below is a list of the 30 most popular articles in terms of downloads.


High-resolution electron attachment to the molecules CCl\textsubscript{4} and SF\textsubscript{6} over extended energy ranges with the (EX)LPA method, M Braun, S Marienfeld, M-W Ruf and H Hotop, J. Phys. B: At. Mol. Opt. Phys. 42 (2009) 125202


2009 Special Issues

All these special issues can be accessed via www.iop.org/journals/jphysb

Resonances: from few-body to many-body phenomena

**Guest Editors:** Lorenz S Cederbaum, Jan-Michael Rost and Hossein R Sadeghpour


Resonances are a recurring and timeless theme in almost all fields of research, and just within physics, resonances cover a vast spread of phenomena. This special issue contains original research articles covering current topics in atomic, molecular and ultracold atomic physics.

Few-photon optics

**Guest Editors:** Gaetan Messin, Barry C Sanders, David Petrosyan and John Rarity


Light is composed of photons, but only recently has it become relatively common, albeit still challenging, to manipulate single or few photons. This special issue presents state-of-the-art theory and experiment concerning the production of few-photon states of light, processing the states, and performing highly sensitive low-noise detection at the single-photon level.

Attosecond and x-ray free-electron laser physics

**Guest Editors:** Robert Moshammer and Joachim Ullrich


Currently, we are witnessing a revolution in photon science, driven by the vision to time-resolve ultra-fast electronic motion in atoms, molecules, and solids as well as by the quest for the characterization of time-dependent structural changes in large molecules and solids. Quantum jumps in the development of light sources are the key technologies for this emerging field of research. Thus, high harmonic radiation bursts now penetrate the attosecond ($10^{-18}$ s) regime and free-electron lasers (fELs) deliver ultra-brilliant femtosecond, coherent VUV and x-ray pulses. This special issue presents a snapshot of this ongoing revolution and brings together, for the first time, pioneering results in both of these fields that are expected to evolve synergetically in the future.

Modern applications of trapped ions

**Guest Editors:** Martina Knoop, Laurent Hilico and Jürgen Eschner


Ion traps are fantastic tools to explore the world of electrons, atomic and molecular ions, or charged clusters, in the classical as well as in the quantum regime. Extremely long storage times allow probing even of single particles with very high precision. This special issue presents state-of-the-art theory and experiments in a variety of tutorials, reviews and research papers.
Topical Reviews and PhD Tutorials

Topical reviews present a snapshot of recent progress in a particular field. Written by leading researchers in their respective fields, these articles present the background to a particular field and the current state of the art.

PhD Tutorials are of a pedagogical nature. Designed to guide newcomers into rapidly developing fields where textbooks are still lacking, they allow interested researchers from more distant fields to gain an insight into what they see as a new subject. PhD Tutorials are generally based on either an excellent PhD thesis or an outstanding lecture series at a graduate Winter/Summer School.

Both Topical Reviews and PhD Tutorials are normally commissioned by the Editorial Board. However, if you have a suggestion for an article, the J. Phys. B team would be happy to pass your idea on to the Editorial Board, so please contact us at jphysb@iop.org.

2009 Topical Reviews

Engineering atomic Rydberg states with pulsed electric fields
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3 Department of Physics, University of Tennessee, Knoxville, TN 37996, USA
4 Institute for Theoretical Physics, Vienna University of Technology, Vienna, Austria

Abstract
Atoms in high-lying Rydberg states with large values of the principal quantum number \( n \), \( n \geq 300 \), form a valuable laboratory in which to explore the control and manipulation of quantum states of mesoscopic size using carefully tailored sequences of short electric field pulses whose characteristic times (duration and/or rise/fall times) are less than the classical electron orbital period. Atoms react to such pulse sequences very differently than to short laser or microwave pulses providing the foundation for a number of new approaches to engineering atomic wavefunctions. The remarkable level of control that can be achieved is illustrated with reference to the generation of localized wavepackets in Bohr-like near-circular orbits, and the production of non-dispersive wavepackets under periodic driving and their transport to targeted regions of phase space. The testing of these control schemes, together with their reversibility, through the creation of electric dipole echoes in Stark wavepackets, is also described. New protocols continue to be developed that will allow even tighter control with the promise of new insights into quantum-classical correspondence, information storage in mesoscopic systems, physics in the ultra-fast ultra-intense regime and nonlinear dynamics in driven systems.

2009 PhD Tutorials

Concepts in x-ray physics
Robin Santra
Argonne National Laboratory, Argonne, IL 60439, USA and Department of Physics, University of Chicago, Chicago, IL 60637, USA

Abstract
A basic introduction to the theory underlying x-ray processes is provided. After general remarks on the practical advantages of using x-rays for probing matter, the derivation of the minimal-coupling Hamiltonian within nonrelativistic quantum electrodynamics is outlined. Perturbation theory is reviewed and applied to describe x-ray-induced processes. In connection with x-ray absorption, inner-shell binding energies and the photon energy dependence of the x-ray absorption cross section are discussed. In the context of x-ray scattering, atomic and molecular scattering factors are introduced, the complex index of refraction is derived, and the nonrelativistic theory of Compton scattering is described. The final topic is x-ray fluorescence and Auger decay of inner-shell-excited systems.
Investigation of carrier to envelope phase and repetition rate: fingerprints of mode-locked laser cavities

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² Department of Physics, Texas A & M University, College Station, USA
³ Center for High Technology Materials, Albuquerque, NM, USA

Abstract
We use mode locked lasers in a non-conventional way, as a sensor to perform intracavity measurements. To understand this new technique of intracavity phase interferometry (IPI), one should take a detailed look at the characteristics of the frequency comb and its sensitivity to its parent cavity. The laser cavity provides a means to perform phase interferometry while outside the cavity one can only observe amplitude interference. Many physical quantities such as nonlinear index, Earth rotation, magnetic field, Fresnel drag, etc are converted to phase. IPI is performed by designing laser cavities in which two pulses circulate independently, generating two pulse trains that can have a phase difference that will be converted to frequency. We also explore repetition rate spectroscopy in Rb⁸⁷ by tailoring a laser wavelength, power and bandwidth. Coherent population trapping is observed when the laser repetition rate matches submultiples of hyperfine splitting.

Dynamical decoherence control of multi-partite systems

Goren Gordon
Department of Chemical Physics, Weizmann Institute of Science, 76100 Rehovot, Israel

Abstract
A unified theory is given of dynamically modified decay and decoherence of field-driven multipartite systems. When this universal framework is applied to two-level systems or qubits experiencing either amplitude or phase noise due to their coupling to a thermal bath, it results in completely analogous formulae for the modified decoherence rates in both cases. The spectral representation of the modified decoherence rates underscores the main insight derived from this approach, namely, that the decoherence rate is the spectral overlap of the noise and modulation spectra. This allows us to come up with general recipes for modulation schemes for the optimal reduction of decoherence under realistic constraints. An extension of the treatment to multilevel and multipartite systems exploits intra-system symmetries to dynamically protect multipartite entangled states. Another corollary of this treatment is that entanglement, which is very susceptible to noise and can die, i.e., vanish at finite times, can be resuscitated by appropriate modulations prescribed by our universal formalism. This dynamical decoherence control is also shown to be advantageous in quantum computation setups, where control fields are applied concurrently with the gate operations to increase the gate fidelity.
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Two-photon double ionization of Ne by free-electron laser radiation: a kinematically complete experiment

M Kurka1, A Rudenko2, I Foucar3, K U Kühnel1, Y H Jiang1, Th Ergler1, T Havermeier1, M Smolarski3, S Schössler3, K Cole1, MSchöffler3, R Dörner1, M Gensch4,9, S Düsterer4, R Treusch4, S Fritzsche5,6, A N Grum-Grzhimailo7, E V Gryzlova7, N M Kabachnik7,8, C D Schröter1, R Moshammer1,2 and J Ullrich1,2

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Abstract

We present kinematically complete data on two-photon double ionization of Ne induced by short (~25 fs) intense (~5 × 10^13 W cm^{-2}) free-electron laser pulses at 44 eV. The observed electron energy spectrum points to the dominance of 'sequential' ionization. We analyse state-selective angular distributions as well as the two-electron angular correlation function, and suggest a method to determine the time delay between both ionization steps. The measured angular asymmetry (\(\beta\)) parameters significantly deviate from the results of an earlier non-coincident experiment providing benchmark data for theory.

Board member's comments

"The paper is a very detailed study of two-photon double ionization and as such an important publication in a rapidly growing field. The measured angular asymmetry parameters significantly deviate from the results of an earlier non-coincident experiment providing benchmark data for theory." Thomas Möller, Technische Universität Berlin, Germany
Exploring temporal and rate limits of laser-induced electron emission

S A Hilbert1, A Neukirch1,2, C J G J Uiterwaal1 and H Batelaan4
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2 Present address: Department of Physics and Astronomy, University of Rochester, Rochester, NY 14627-0171, USA


Abstract
To achieve high temporal resolution for ultrafast electron diffraction, Zewail (Proc. Natl Acad. Sci. USA 102 7069 (2005)) has proposed to use high repetition rate, ultrafast electron sources. Such electron sources emitting one electron per pulse eliminate Coulomb broadening. High repetition rates are necessary to achieve reasonable data acquisition times. We report laser-induced emission from a nanometre-sized tip at one electron per pulse with a 1 kHz repetition rate in the femtosecond regime. This source, combined with 1 MHz repetition rate lasers that are becoming available, will be a primary candidate for next generation ultra fast, high-coherence electron diffraction experiments. We also report that the measured energy bandwidth of our electron source does not support sub-cycle electron emission. This result addresses a current debate on ultrafast nanotip sources. Regardless of the limited bandwidth, this source may be used in conjunction with a recently proposed active dispersion compensation technique (Proc. Natl Acad. Sci. USA 104 18409 (2007)) to deliver attosecond electron pulses on a target.

Board member’s comments
“In a beautiful experimental paper, Hilbert et al consider laser-induced electron ejection from nanometer scale metal tips. I like this paper because it addresses whether attosecond ideas (my own area of research) can be extended to metal tips. Hilbert et al measure that a single electron can be ejected per laser pulse, synchronized with their 45 fs laser pulse. They show from the energy spectrum of the electron that the ejection is not broad enough for the ejection to be sub-cycle. The continuum electron wave packet emerges over a 5 fs (or longer) time window. A good paper makes you want more. I cannot help but wonder if the ejection would be sub-cycle for longer wavelength light, or if a shorter excitation pulse were used, or with a sharper tip. The paper ends as it began: by pointing out the importance of highly coherent femtosecond electrons for laser-pump electron-probe experiments for ultrafast science.”
Paul Corkum, NRC, Steacie Institute for Molecular Sciences, Canada

Ion momentum spectroscopy of N2 and O2 molecules irradiated by EUV free-electron laser pulses

H Fukuzawa1,2, K Motomura1,2, X-J Liu1,2, G Prümper1,2, M Okunishi1, K Ueda1,2, N Saito1,2, H Iwayama1,4, K Nagaya1,4, M Yao1,4, M Nagasono1, A Higashiya1, M Yabashi1, T Ishikawa1, H Ohashi1,5 and H Kimura1,5
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4 Department of Physics, Kyoto University, Kyoto 606-8502, Japan
5 Japan Synchrotron Radiation Research Institute, Sayo, Hyogo 679-5198, Japan


Abstract
We have investigated dissociative ionization of N2 and O2 molecules by 52 nm extreme-ultraviolet light pulses at the free-electron laser facility in Japan. Distributions of kinetic energy release were measured at two different laser power densities below 3 × 1013 W cm−2 and intermediate and final states of the sequential two photon transitions were identified.
The generalized geometrical model for the photoionization of polarized atoms: application to linear dichroism in the 2p photoemission from Na $3^2S$ and Na* $3^2P$ initial states

A N Grum-Grzhimailo$^{1,3}$, E V Gryzlova$^1$, D Cubaynes$^2$, E Heinecke$^3$, M Yalçinkaya$^4$, P Zimmermann$^2$ and M Meyer$^2$

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$^4$ Science Faculty, Physics Department, Istanbul University, 34118 Vezneciler/ Istanbul, Turkey


Abstract

The generalized geometrical model utilized for the interpretation of photoelectron spectra is extended to the photoionization from polarized atoms. Within this model, the linear magnetic and the linear alignment dichroisms in the photoemission are calculated. The theoretical results are compared to those obtained from high-resolution angle-resolved photoelectron spectra, which were recorded upon 2p$^{-1}$ photoionization of sodium atoms oriented in the Na 2p$^63s^2\, S_{1/2}$ ground and Na* 2p$^63p^2\, P_{1/2,3/2}$ laser-excited states or aligned in the Na* 2p$^63p^2\, P_{3/2}$ state. Good overall agreement is found between theory and experiment.

Femtosecond isomerization dynamics in the ethylene cation measured in an EUV-pump NIR-probe configuration

J van Tilborg$^1$, T K Allison$^{1,2}$, J W Wright$^1$, M P Hertlein$^1$, R W Falcone$^{1,2}$, Y Liu$^1$, H Merdji$^3$ and A Belkacem$^1$

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$^3$ Service des Photons, Atomes et Molécules, CEA-Saclay, 91191 Gif-sur-Yvette, France


Abstract

Dynamics in the excited ethylene cation C$_2$H$_2^+$ lead to isomerization to the ethylidene configuration (HC-CH$_3^+$), which is predicted to be a transient configuration for electronic relaxation. With an intense femtosecond extreme ultraviolet pump pulse to populate the excited state, and a near infrared probe pulse to produce the fragments CH$^+$ and CH$_3^+$ (which provides a direct signature of ethylidene), we measure optimum fragment yields at a probe delay of 80 fs. Also, an H$_2$-stretch transient configuration, yielding H$_2^+$ upon probing, is found to succeed the ethylidene configuration. We find that a single simple- or double-decay model does not match the data, and we present a modified model (introduction of an isomerization delay of 50 ± 25 fs) that does provide agreement.

Board member’s comments

“Van Tilborg and coworkers have employed pump-probe spectroscopy to measure the isomerisation dynamics of the ethylene cation on a sub-100 fs timescale. An extreme ultraviolet (EUV) light pulse (20-25 eV) excites the ethylene molecule high into the ionisation continuum creating an ethylene cation in very highly excited electronic states. Excess vibrational energy is redistributed within the cation on a femtosecond timescale and an intense infrared probe pulse (800 nm) is employed to fragment the cation at different points along its excited state potential energy surfaces. The fragmentation products (CH$^+$, CH$_3^+$, H$_2^+$) are detected by time-of-flight mass-spectrometry and the observed dynamics are consistent with the idea that the ethylene cation isomerises to form ethylidene [HCC(H)$_2^+$]. There has been a lot of discussion about how modern EUV technology can be applied to photochemistry and this paper illustrates very nicely that this really is possible.”

Helen Fielding, University College London, UK

Study of the dynamics in the EUV-pump (20-25 eV) excited ethylene cation (C$_2$H$_2^+$) leading to formation of the transient ethylidene configuration (HC-CH$_3^+$). Application of an NIR probe (1.5 eV) resulted in ethylidene fragmentation to (CH$^+$) and (CH$_3^+$), which occurred favorably at a 80 fs probe delay. The fragment (H$_2^+$) was measured predominantly at a 110 fs probe delay, consistent with the concept of the ethylidene population decaying into the (H$_2^+$) yielding configuration through a H$_2$ stretch.
Momentum space tomographic imaging of photoelectrons

C Smeenk¹, L Arissian¹,², A Staudte¹, D M Villeneuve¹ and P B Corkum¹

¹ Joint Laboratory for Attosecond Science, University of Ottawa and National Research Council, 100 Sussex Drive, Ottawa, Canada
² Department of Physics, Texas A&M University, College Station, TX, USA


Abstract
We apply tomography, a general method for reconstructing 3D distributions from multiple projections, to reconstruct the momentum distribution of electrons produced via strong field photoionization. The projections are obtained by rotating the electron distribution via the polarization of the ionizing laser beam and recording a momentum spectrum at each angle with a 2D velocity map imaging spectrometer. For linearly polarized light, the tomographic reconstruction agrees with the distribution obtained using an Abel inversion. Electron tomography, which can be applied to any polarization, will simplify the technology of electron imaging. The method can be directly generalized to other charged particles.

Fabricating atom chips with femtosecond laser ablation

C H Wolff, S Whitlock, R M Lowe, A I Sidorov and B V Hall

ARC Centre of Excellence for Quantum-Atom Optics and Centre for Atom Optics and Ultrafast Spectroscopy, Swinburne University of Technology, Hawthorn, Victoria 3122, Australia


Abstract
We report on the microfabrication of atom chips using a femtosecond laser ablation technique to arbitrarily sculpture both thin conductive metal films and permanent magnetic materials. We have measured the threshold fluences for a variety of materials relevant to atom chip development (Au, Ag, Cr, Ni, TbGdFeCo, SmCo, CoCr). The quality of the ablation process is investigated by extracting the power spectral density of the edge roughness from composite scanning electron microscope images and through the use of a magnetoresistance microscope to measure the associated magnetic field noise. Finally, we present results from a sculptured wire which produces an array of tunable double wells designed for near-surface force sensing with Bose–Einstein condensates.

Tomographic imaging of the electron velocity spectrum in elliptically polarized light, showing the reconstructed distribution in the plane of polarization. The colour code represents the relative number of electrons.

Comparison of the magnetic field topology above a sculptured wire. (a) Finite element analysis mesh indicating the dual edge fabrication pattern, (b) numerical simulation of the Bz magnetic field component evaluated at a height of 17 μm above the wire for 150 mA current and (c) experimental map of Bz produced using the MR microscope to map the field above the laser ablated sculptured wire.
Narrow absorptive resonances in a four-level atomic system

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**Abstract**
We study the effect of a control beam on a $^8$Rb electromagnetically induced transparency (EIT) system. The control beam couples one ground state to another excited state forming a four-level $\Lambda$-system. Phase coherent laser beams to drive the $\Lambda$-system are produced using a double injection locking scheme. We show that the control beam can be used to Stark shift or split the EIT resonance. Finally, we show that, when the control beam is on resonance, one observes a Doppler-free and sub-natural absorptive resonance with a width of order 100 kHz. Crucially, this narrow absorptive resonance only occurs when atoms with a range of velocities are present, as is the case in a room-temperature vapor.

**Board member’s comments**
“Currently the spectroscopy in thermal vapor cells is seeing a revival after the focus of research has been on ultracold atoms for many years. This paper shows not only sub-Doppler but also a sub-natural spectroscopic feature that will not be present in a cold atomic ensemble, reminding us that thermal cells sometimes have even more to offer than cold atoms.”

Tilman Pfau, Universität Stuttgart, Germany

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Scattering resonances and two-particle bound states of the extended Hubbard model

M Valiente and D Petrosyan
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**Abstract**
We present a complete derivation of two-particle states of the one-dimensional extended Bose–Hubbard model involving attractive or repulsive on-site and nearest-neighbour interactions. We find that this system possesses scattering resonances and two families of energy-dependent interaction-bound states which are not present in the Hubbard model with the on-site interaction alone.

**Board member’s comments**
“I believe it merits being on the Highlights List for its novel and timely results concerning a basic model in quantum physics and for the authors’ elegant analytical derivation.”

Gershon Kurizki, Weizmann Institute of Science, Rehovot, Israel

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Change in transmission of a 780 nm probe beam propagating through a thermal Rb vapor cell. In the presence of a coupling beam a EIT resonance is produced, as in the blue trace. The black trace corresponds to the application of both coupling and control beams, producing an absorptive resonance.
Radiative lifetimes of neutral cerium

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Abstract
Radiative lifetimes, accurate to ±5%, have been measured for 153 levels of neutral cerium using time-resolved laser-induced fluorescence (TRLIF) on a slow beam of cerium atoms. Of the 153 levels studied, 150 are even parity and 3 are odd parity. The levels range in energy from 16 869 to 28 557 cm⁻¹. This set of Ce I lifetimes is much more extensive than others published to date, and will provide the absolute calibration for a very large set of measured Ce I transition probabilities. Accurate transition probabilities for lines in the visible and ultraviolet are needed both in astrophysics, for the determination of elemental abundances, and by the lighting community, for research and development of metal halide high-intensity discharge lamps.

Board member’s comments
“The spectra of the rare-earth elements are well known for their extreme complexity. This feature is well appreciated in applications such as high-intensity discharges (HID); however it also hinders experimental and theoretical efforts to analyze such spectra. The recent work by Den Hartog et al provides researchers with a large set of exceptionally accurate (< 5%) measurements of radiative lifetimes for more than 150 levels in neutral cerium. This atom is extensively used in HIDs and its spectra are quite prominent in stars. The measured lifetimes form a set of benchmark results that will provide absolute calibration for a large set of measured Ce I transition probabilities.”
Yuri Ralchenko, NIST, Gaithersburg, USA

Effect of directional energetic electrons on the density diagnostic of hot plasmas

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Abstract
We have theoretically investigated how a small fraction of energetic beamed electrons influences the diagnostics of the electron density in hot plasmas, based on the intensity ratio $R$ of the helium-like forbidden line to the intercombination lines. Elaborate calculations of the intensity ratio $R$ have been performed for Ne⁸⁺ ions over the range of electron densities $10^9 – 10^{13}$ cm⁻³ using an electron distribution (model) that includes both Maxwellian isotropic and monoenergetic beam components. By taking into account all important transitions among the 117 magnetic sublevels of the 1s² $nl$ ($n = 2–4$) configurations, a collisional-radiative model has been applied for determining the populations of the upper-magnetic sublevels of lines. The required collision strengths due to both electron components were computed semi-relativistically in the complementary distorted-wave and Coulomb–Bethe methods. The results are given for temperatures $T_e$ of the Maxwellian electron component in the range 2–5 × 10⁶ K and for kinetic energies $e_0$ of the monoenergetic electron component between 0.95 and 4 keV. At low $T_e$ and $e_0$ not too high, the anisotropy of the intensity angular distribution of lines is found to have an appreciable effect on the $R$ ratio. The electron density inferred from the intensity ratio $R$ without including the beam effect can be significantly overestimated or underestimated depending upon the emission angle relative to the electron beam direction.

Comparison of the anisotropy of the intensity angular distribution ($I(\theta)/I(\theta=0)$) of the two lines $x$ (dotted lines) and $y$ (full lines) calculated for an electron density of $n_e = 10^{10}$ cm⁻³, beam fraction of $f = 5\%$, and for three different pairs of parameters ($T_e, e_0$).
Bell-inequality violations with single photons entangled in momentum and polarization

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2 Departamento de Ciencias, Sección Física, Pontificia Universidad Católica del Perú, Apartado 1761, Lima, Peru

Abstract
We present a violation of the Clauser–Horne–Shimony–Holt and the Clauser–Horne inequalities using heralded single photons entangled in momentum and polarization modes. A Mach–Zehnder interferometer and polarization optics are used to rotate the spatial and polarization bases, respectively. With this setup we were able to test quantum mechanics with the original formulation of the Clauser–Horne inequality. The results rule out a wide class of realistic non-contextual hidden-variable theories. It is interesting to note that by enabling another degree of freedom to the photon, e.g., by using the spatial modes of the light, which carry orbital angular momentum, we could perform the all-or-nothing Greenberger–Horne–Zeilinger test with a single particle. This would open new doors to tests of non-contextual HV theories with single particles.

Data (symbols) obtained from the experiments that were used to compute the correlation parameter $S_{\text{ClaSH}}$ that violated the CHSH inequality. The solid line is a single parameter fit to the data.

Entanglement evolution of two remote and non-identical Jaynes–Cummings atoms

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2 ARC Centre of Excellence for Quantum-Atom Optics and Centre for Atom Optics and Ultrafast Spectroscopy, Swinburn University of Technology, Melbourne, VIC 3122, Australia

Abstract
A detailed treatment of the entanglement dynamics of two distant but non-identical systems is presented. We study the entanglement evolution of two remote atoms interacting independently with a cavity field, as in the double Jaynes–Cummings model. The four-qubit pairwise concurrences are studied, allowing for asymmetric atom–cavity couplings and off-resonant interactions. Counter to intuition, imperfect matching can prove advantageous to entanglement creation and evolution. For two types of initial entanglement, corresponding to spin-correlated and anti-correlated Bell states $\Phi^-$ and $\psi^-$, a full, periodic and directed transfer of entanglement into a specific qubit pair is possible, for resonant interactions, depending on the choice of relative couplings. Furthermore, entanglement transfer and sudden death (ESD) can be prevented using off-resonant interactions, although for some initial states, detunings will trigger an otherwise frozen entanglement, to allow a full entanglement transfer.

Effect of detuning on the entanglement evolution of the Bell state $\psi^-$. The concurrence measure $C_R$ is plotted as a function of time and detuning $\Delta$. Here $g_1 = g_2 = g$. Detuning stabilizes the entanglement between atoms and decreases the period of entanglement revival.

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Analytic formulae for high harmonic generation

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² Department of Physics and Astronomy, The University of Nebraska, Lincoln, NE 68588-0111, USA


Abstract
Analytic formulae describing harmonic generation by a weakly bound electron are derived quantum mechanically in the tunnelling limit. The surprisingly simple analytic formulae (involving a single Airy function) for the amplitudes and rates of harmonics generated by an electron bound in a short-range potential provide excellent agreement with exact TdEr results over the high energy part of the HHG plateau (and beyond). The formulae confirm the classical three-step model and provide an analytic explanation for oscillatory structures on the harmonic generation plateau.

Pulse measurements by randomly quasi phase matched second harmonic generation in the regime of total internal reflection

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² Department of Physics, Sofia University ‘St Kl Ohridski’, 1164 Sofia, Bulgaria


Abstract
We demonstrate experimentally the frequency doubling in disordered quadratic nonlinear media in the regime of total internal reflection of the fundamental beam. We show how the transversely emitted second harmonic can be employed for an efficient characterization of short laser pulses.

Board member’s comments
“Wavelength conversion of light via second-harmonic generation is probably one of the most important nonlinear optical process which is at the basis of several optical techniques to measure the duration of ultrashort optical pulses. In this article the authors propose and experimentally demonstrate a novel pulse measurement scheme, which relies on transverse frequency doubling in a nonlinear crystal with a random distribution of its ferroelectric domains under the regime of total internal reflection. As compared to most common pulse characterization methods, the suggested geometry is very simple and enables non-destructive pulse monitoring, making it very appealing for its integration in lasers or optical systems without disturbing their operation.”

Stefano Longhi, Politecnico di Milano, Italy

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High-resolution electron attachment to the molecules CCl$_4$ and SF$_6$ over extended energy ranges with the (EX)LPA method

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Abstract
Using a variant of the laser photoelectron attachment (LPA) method with an extended energy range (EXLPA), we have studied low-energy electron attachment to the molecules CCl$_4$ (Cl$^-$ formation) and SF$_6$ (SF$_5^-$ and SF$_5^-$ formation) in a diffuse gas target ($T_g = 300$ K) from 0 eV up to 2 eV at energy widths down to 14 meV. In the EXLPA method, pulses of near-zero energy photoelectrons are produced in a guiding magnetic field, accelerated by a weak electric field, brought to the energy of interest prior to their traversal through the target region and subsequently accelerated and deflected onto a detecting plate. Anions due to electron attachment are extracted by a pulsed electric field, during which the photoelectron current is interrupted, and detected by a quadrupole mass spectrometer. The EXLPA anion yields are combined with absolute cross sections, obtained at very high resolution ($≈ 1$ meV) with the LPA method over the range 0–0.17 eV, to yield new recommended absolute partial and total attachment cross sections over the range 0–2 eV at the well-defined gas temperature $T_g = 300$ K. Our cross sections show characteristic deviations from previously reported results. At least in part, these differences can be attributed to the fact that in the earlier electron beam experiments the gas temperature was higher than 300 K. For SF$_5^-$, the branching fractions for SF$_5^-$ formation at electron energies 0.002–0.43 eV and for different initial rovibrational distributions are compared with those recently predicted from kinetic modelling within the framework of statistical unimolecular rate theory. Satisfactory agreement is observed, but our data provide evidence that an additional path for producing SF$_5^-$ and SF$_6^-$ ions is available at electron energies above about 0.3 eV.

Deep interference minima in non-coplanar triple differential cross sections for the electron-impact ionization of small atoms and molecules

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Abstract
The time-dependent close-coupling method and a distorted-wave approach are used to explore deep minima discovered in the non-coplanar triple differential cross sections for the electron-impact ionization of helium. This phenomenon has been well studied experimentally but so far has not been investigated by a non-perturbative theoretical approach. We find that our time-dependent calculations reproduce very well the experimental minima, and that the distorted-wave calculations also confirm this phenomenon. Further investigations reveal that the minima appear to be due to deep destructive interference between the partial wave contributions which make up the cross sections. We also show that similar minima may be found in triple differential cross sections arising from the electron-impact ionization of atomic and molecular hydrogen.

The branching fractions $R(E; T_g)$ for SF$_5^-$ formation over the electron energy range $E = 0.002–0.43$ eV at gas temperatures from 200 K to 600 K. The results of a previous kinetic modeling study are shown by the full and broken curves while the open squares denote the present experimental results.

Triple differential cross sections for the electron-impact ionization of molecular hydrogen at an incident energy of 35.4 eV, for equal energy sharing outgoing electrons. Experimental data (dots) are compared with TDCC calculations (red line) which are averaged over all molecular orientations and two sets of 3dW calculations. The calculations labelled 3dW (with CP) include a correlation-polarization term, while the calculation labelled 3dW (no CP) omits the correlation-polarization term. Both sets of 3dW calculations are divided by 6.3 to allow a better comparison with other results. The double-dashed purple line indicates the TDCC calculation for a specific molecular orientation ($\phi = 50^\circ$, $\phi = 0^\circ$), where it can be seen that a deep interference minimum is predicted.
Environment assisted electron capture

Kirill Gokhberg and Lorenz S Cederbaum

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Abstract

Electron capture by isolated atoms and ions proceeds by photorecombination. In this process, a species captures a free electron by emitting a photon which carries away the excess energy. It is shown here that in the presence of an environment a competing non-radiative electron capture process can take place due to long range electron correlation. In this interatomic (intermolecular) process the excess energy is transferred to neighbouring species. The asymptotic expression for the cross section of this process is derived. We demonstrate by explicit examples that under realizable conditions, the cross section of this interatomic process can clearly dominate that of photorecombination.

Board member’s comments

“What do I expect from a good theoretical paper? First of all, it should transport an interesting and appealing idea. Secondly, the authors should be able to explain that idea in a simple yet concise way. To this end, an approximate analytical result is very helpful because it triggers my own creative thinking and allows me to estimate quickly whether the new and appealing idea would be relevant in a context of research which occupies my own thinking. Finally, I would like to be able to judge how relevant the idea is, of course ideally in direct comparison to an experiment, or, if not possible, at least compared to a full numerical result with as few approximations as possible.

This wish list I have for a theory paper is almost completely fulfilled by the FTC “Environment assisted electron capture” co-authored by Kirill Gokhberg and Lorenz Cederbaum. Environment assisted electron capture is a general and simple concept, where the energy, which is generated through recombining a free electron into a bound state, is not released in the form of a photon but transferred to other bound electrons in the neighborhood of the ion under consideration. The authors give an analytical formula which is asymptotically (for large distances) valid and relates directly the cross section of the competing radiative recombination to the presently discussed case.”

Jan-Michael Rost, Max-Planck-Institut für Physik komplexer Systeme, Germany

Classical versus quantum dynamics of the atomic Josephson junction

G J Krahn and D H J O’Dell

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Abstract

We compare the classical (mean-field) dynamics with the quantum dynamics of atomic Bose–Einstein condensates in double-well potentials. The quantum dynamics are computed using a simple scheme based on the Raman–Nath equations. Two different methods for exciting a non-equilibrium state are considered: an asymmetry between the wells which is suddenly removed and a periodic time oscillating asymmetry. The first method generates wave packets that lead to collapses and revivals of the expectation values of the macroscopic variables, and we calculate the time scale for these revivals. The second method permits the excitation of a single energy eigenstate of the many-particle system, including Schrödinger cat states. We also discuss a band theory interpretation of the energy level structure of an asymmetric double well, thereby identifying analogies to Bloch oscillations and Bragg resonances. Both the Bloch and Bragg dynamics are purely quantum and are not contained in the mean-field treatment.

Photorecombination cross sections of the Br atom and interatomic Coulombic electron capture cross sections of Br with Cl− as its neighbour at different interatomic separations (top). Photorecombination cross section of the Cl atom and interatomic Coulombic electron capture cross sections of Cl with Br− as its neighbour at different interatomic separations (bottom).
Modified transmission spectrum induced by two-mode interference in a single silica microsphere

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Abstract

We theoretically and experimentally study the resonant transmission spectrum of light in a fibre taper coupled with a single silica microsphere cavity system, where two whispering-gallery modes (WGMs) are simultaneously excited. By changing the taper position (correspondingly, tuning the resonant frequencies of the two WGMs and modulating their coupling conditions with the fibre taper), a sharp electromagnetically-induced transparency-like window can be observed in the transmission spectrum. This line shape originates from the taper-mediated interference between two co-existing WGMs in a single microsphere. This measurement result agrees well with the theoretical analysis.

Experimental transmission spectra (black lines) and theoretical calculation (red lines) with detuning $\delta_{\omega_{1}^{\prime}}/2\pi = 0$. Inset: Schematic illustration of a two-mode microcavity coupled to a waveguide.

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