PROBING THE NUCLEAR LANDSCAPE USING LASER SPECTROSCOPY

I.D. Moore

Abstract

THE STUDY of exotic nuclear matter and related radioactive ion beam technologies is at the forefront of modern subatomic physics. When exploring the nuclear landscape beyond the 300 or so stable nuclei a multitude of phenomena have been discovered. Almost 7000 nuclei are thought to exist, 2500 have been observed and detailed information is known for roughly half of them. The most poorly explored or undiscovered nuclear species are located on the neutron-rich side of the nuclear chart, forming the terra incognita for nuclear structure investigations. The results of such studies have an impact on the understanding of element synthesis in the Universe, to probes of fundamental symmetries and interactions. High-resolution optical measurements provide sensitive, model-independent nuclear structure data. Hyperfine structures and isotope shifts in electronic transitions exhibit readily accessible information on the size, shape, spin and moments of the nuclear charge distribution. Information on both bulk and valence nuclear properties are derived and an exceptional sensitivity to changes in nuclear deformation is achieved. Laser spectroscopy combined with on-line isotope separators and novel ion manipulation techniques provides the only mechanism for such studies in exotic nuclear systems.

In this talk I will review some of the most recent progress in the field of laser spectroscopy at radioactive ion beam facilities. I will present the specialized techniques utilized in order to probe different regions of the nuclear chart from light halo nuclei, to studies of medium-heavy nuclei towards the drip lines, to heavy elements such as Th and U. In all cases physics motivations and results will be presented. I will conclude with a look at the current limitations and gaps in the nuclear landscape and discuss where the field is proceeding in the future.
Learning physics in real world contexts

H. Joachim Schlichting

I AM a physicist receiving my PhD in physics from the University of Hamburg/Germany in 1974. I then specialized on topics in physics education and habilitated at the University of Osnabrück/Germany. I became a Full Professor of Didactics in 1991 at the University of Essen/Germany and later at the University of Münster/Germany, my present position.

My main research activities are concerned with several fields:

- Investigation of formation of physical concepts and their simplification in the formulation of strategies for the understanding of physics through the adaptation of suitable exemplary topics, e.g. the physics of everyday life
- Developing simplified, yet scientifically rigorous, theoretical and experimental representations of topics of modern physics (e.g. problems of non-linear physics (chaos and structure formation, physics of fractals) and investigating the corresponding concepts in the teaching and learning process
- Furthermore I was and I am engaged in professional organisations e.g. 1994 – 2000 Head of the Division of Didactics of Physics of the German Physical Society
- 2003 – 2009 member of ICPE (International Commission of Physics Education)
- About 400 publications in several journals of physics education and journals popularizing physics.
- 2008 Robert-Wichard-Pohl-Award of the German Physical Society “in recognition of his outstanding contributions to physics with interdisciplinary importance, for extraordinary achievements in the dissemination of scientific knowledge in teaching and in educational physics…”

Abstract

Learning physics in real world contexts

The typical procedure of teaching physics is to elaborate the physical fundamentals before they are applied to or detected in real world situations. To our observation in most cases there will be no real application at all in physics lessons. One reason is the tacit assumption that students disposing about the physical fundamentals are able to apply them to whatever it will be when it is demanded. This assumption misjudges that

- elements of physical knowledge which are not used at least from time to time in situations which concern the learners will decay and be forgotten,
- applying and integrating physical fundamentals to explain complex connections or even real situations are among the most demanding learning activities.

For these reasons we suggest to train to develop physical understanding in situations which are at least in some respects interesting for the students and are not only meaningful from a physical point of view. The important leaning target of general educating schools to contribute in a special way to general education of young people is another argument to go beyond pure physical topics.

Our arguments will be demonstrated by appropriate optical phenomena of the everyday life world.
Forging Light
Thomas Feurer

Thomas Feurer was born in Kempten, Germany, in September 1963. He received the Diploma in Physics from the University of Würzburg, Germany in 1990. He then moved to the Rice University in Houston, Texas, where he worked on optically induced percolative phase transitions. He earned his Ph.D. degree in Physics in 1994 at the University of Würzburg. In 1994 he went to the University of Jena and worked on ultrafast linear and nonlinear optics, femtosecond spectroscopy and coherent control of quantum systems, high-power short-pulse laser-matter interaction at relativistic intensities, generation of femtosecond hard x-rays and femtosecond time-resolved x-ray diffraction. He received the Habilitation in 2001 and moved to the M.I.T. in Cambridge, USA. His research interests were: high-frequency acoustics spectroscopy, ultrafast optics and pulse-shaping, nonlinear spectroscopy of liquids and solids, coherent control of collective excitation in solids, generation of phase-matched high harmonics, EUV nonlinear femtosecond spectroscopy. In 2002 he was appointed Research Associate at the M.I.T. and in 2004 he became full professor at the University of Bern, Switzerland. His current research interests are in ultrafast lasers and fiber optics, ultrafast coherent control and nonlinear spectroscopy. He has published more than 70 journal papers and holds 5 patents. In 1997, he received the Carl Zeiss Research Award, in 1999 the Werner-von-Siemens Medal and in 2001 he was awarded with a Max-Kade Fellowship. Thomas Feurer is a member of the Optical Society of America (OSA), the American Physical Society (APS) and the German Physical Society (DPG).

Abstract

INTERACTION of light with matter can be manipulated through tailoring the properties of light fields, such as wavelength, pulse duration, or spatial distribution to name but a few. Therefore, a substantial part of our past and ongoing research efforts have been dealing with the development of new sources of light. In the first part of my talk I will summarize recent developments in polarization shaping and temporal shaping of light fields and show applications thereof. Specifically, I will show laser oscillators designed to emit continuous wave or pulsed radially polarized beams and their application in material processing and metallic particle trapping. I will show recent progress in shaping the time-dependent electric field of classical light and the time-dependent wave function of non-classical light and their applications in nonlinear optics. In the second part of my talk I will present novel materials designed to shape light fields, i.e. so-called meta-materials. In order to understand the functionality of “meta-atoms” we have developed a platform at THz frequencies which allows for a sub-wavelength characterization of electromagnetic vector near-fields and from which we gain a detailed picture of the scattering properties of “meta-atoms” and, thus, of the different types of meta-materials. Finally, I will discuss whether the results obtained at THz frequencies can be transferred to optical frequencies.
Abstract

ONE OF the fields of experimental physics that has been revolutionised by the development of the laser in the past 50 years is the field of spectroscopy. Generally spectroscopy can be described as the study of the interaction of light and matter, and includes a multitude of specialised techniques facilitated by lasers. This presentation will focus on the role and advantages of lasers in the basic technique of measuring the unique spectrum of narrow spectral lines corresponding to wavelengths absorbed by a specific atomic or molecular species in gas phase. Spectroscopic measurements can be applied to identify and quantify the atomic or molecular species in a sample and to determine the temperature of the sample and speed of the atoms or molecules. This technique is of particular importance if the sample under study is not accessible in any other way, such as those in astrophysics and space science, including stars and the interstellar space.

A laser producing light in a narrow spectral range (i.e. light of one colour) of which the wavelength can be tuned is an ideal light source for spectroscopy, as it makes it possible to optimise both the spectral resolution and the signal strength, in contrast to conventional spectrometers where optimisation of one compromises the other. Pulsed lasers additionally offer the possibility to observe the time evolution of the sample after the laser pulse has interacted with the sample. In this presentation several important effects in the interaction between laser light and atoms or molecules will be introduced and subsequently the exploitation of these effects in two different high resolution laser spectroscopy experiments will be discussed.

In the first experiment a novel tuneable vacuum ultraviolet laser source is combined with a gas sample cooled in a supersonic gas jet. Every available mechanism is used to optimise the experiment to detect the weak absorption signals of rare carbon monoxide (CO) isotopomers and forbidden transitions of 12C16O. The results find direct application in astrophysics. In the second project the interaction of the light of tuneable external cavity diode lasers with rubidium atoms is investigated. It is discussed how a cold spectrum is obtained using a sample at room temperature, and how light is employed to cool and trap atoms in vacuum.
Abstract

The space surrounding the Earth is filled with hot electrons and protons, trapped in the Earth’s magnetic field, forming the Van Allen Radiation Belts. The particle fluxes in the belts can vary by many orders of magnitudes, with injections leading to huge increases in flux, much of which is slowly lost through precipitation into the Earth’s atmosphere. A relativistic electron in the “outer” belt is lost with an e-folding lifetime of a days to weeks, while the lifetimes in the “inner” belt are hundreds of days to years. In the last 10 years there has been increasing discussion as to practical human control of the energetic electron population in the radiation belts. This primarily comes from the perception that numerous valuable spacecraft might be endangered by injections of highly energetic electrons into the inner belt, and the realisation that such an injection could occur through a military or “terrorist” act (although smaller-scale injections can also take place in very large geomagnetic storms). Hence some US and European researchers have been investigating approaches to vastly increase the loss of these relativistic electrons, dumping them into the Earth’s atmosphere. The manmade control of the Van Allen belts has been termed “Radiation Belt Remediation” (RBR).

The RBR idea is on reason why there is increasing focus on understanding the natural processes which cause losses of radiation belt electrons. In this talk I will discuss the reasoning behind RBR-systems, and consider the atmospheric implications of the operation of such a system. I will go on to show that experimental measurements demonstrate that some powerful radio communications transmitters are currently driving the loss of rather high energy electrons (e.g., ~100-400 keV) into the atmosphere. While these very low frequency transmitters are intended for communications around the Earth, a small fraction of the broadcast energy leaks into space, undergoing cyclotron resonance with the trapped electrons, and precipitating them into the atmosphere. While one might view this as a form of pollution, modifying the “natural” space environment, these transmitters serve as an unintended experiment as to the practicalities of an RBR system – demonstrating that they are physically possible, but probably very difficult from a practical point of view.
A Rough Guide to Nanomagnetism

David Toyo Dekadjevi

My research programme concerns materials and devices for future information technology, in particular devices based on electron spin — so-called spintronics. This involves a wide ranging investigation of Magnetic Nanostructured Materials. Such materials are useful in the quest for ever more complex spin electronic devices — systems where the spin, as well as charge, of the electron is used in the storage and processing of information. Actually, I am concentrating my work in F nanoparticles and nanolayers coupled with antiferromagnetic and multiferroic materials in order to understand the temperature dependent static and dynamic (Giga-Hertz) properties. I am a regular referee (reviewer) for Physical Review B and have refereed more than 13 papers for Physical Review B. I am an occasional referee for Surface Science and other solid states review. I am also a subject of a biographical record in the Who's Who in the World 2008. Finally, I have published 20 papers in the last 10 years in the top ranked journal, including 6 Physical Review B, 2 Physical Review Letter, 4 Applied Physics Letter. The Physical Review papers and Applied Physics Letters were cited 70 times (cf. http://scitation.aip.org/). I have completed a Ph.D. in Solid State Physics at the University of Leeds (UK) in 2001. This project focused on understanding the correlation between the structure of magnetic multilayers with their magneto-transport properties. Then, I have occupied two Research Assistant positions. The first one was at the Institute of Material Research, located in the ST Microelectronics research site (Italy). The research project consisted of characterizing the structural and electrical properties of novel and relevant materials for the microelectronics industry. The second position was at the Rossendorf Beamline, Forschungszentrum Rossendorf (Germany). The research project consists of characterizing the structural properties of thin films (semiconductor, magnetic …), nanostructures and surfaces. I have then obtained a permanent position at the Université de Bretagne Occidentale (UBO), as a Senior Lecturer. I am now working at the Department of Physics of the University of Johannesburg where I carry my research on the temperature dependent properties of nanostructures.

Abstract

The information revolution, which has modified our way of living over the last few decades, has occurred due to the restless exponential growth of information amount that can be processed, stored, and transferred per unit time and unit area of relevant devices [1]. Nanomagnetism is becoming a very important research area in past decades due to its key role in this revolution. Its rapid development has its roots in the conviction that the progress that is being achieved by miniaturization of active elements such as high frequency transistors and memory cells will not continue forever. Therefore, the invention of future information technologies must involve new ideas. The main goal of Nanomagnetism is to gain knowledge on spin-dependent phenomena, and to exploit them for new functionalities. This talk will present a review of some of the current developments of nanomagnetism and expose some of the future trends.

Research on nanomagnetism involves virtually all material families, the most mature being studies on magnetic multilayers, in which spin-dependent scattering and tunneling are being successfully applied in reading heads of high-density hard-discs. We should introduce the concept of nanomagnetism through the magnetic properties of single and multilayer thin film systems. In particular, the interfacial exchange coupling between ferromagnetic (F) and antiferromagnetic (AF) nanostructures will be discussed, not only because of its key role in applications such as giant magnetoresistive heads for high density recording systems, nonvolatile memory, and sensors, but also for its possible application in high frequency devices [2]. The magnetic properties of coupled Ni/NiO bilayers will be presented to illustrate challenges in exchange coupled systems. Beyond thin films and multilayers, nanoparticles have also received a load of interest due to their peculiar electronic and magnetic properties. The magnetic properties of NiFe nanoparticles will also be discussed to illustrate challenges and future trends in nanomagnetism.