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Erratum

In the article *"Study of atom-surface interactions employing ultra-cold atoms and Bose-Einstein condensates"* (Vol. 1, issue 6), $\nabla \cdot (\mathbf{m} \cdot \mathbf{B})$ on page 13, left column, line no. 2 should be read as $\nabla (\mathbf{m} \cdot \mathbf{B})$.

Error is regretted.

EDITOR, ISAMP NL

FROM THE EDITORS' DESK

"Mirror, mirror on the wall who is the fairest of all?" A question for an intelligent mirror. Scientifically unviable but probably not without an underlying meaning of consequence. In this issue of news letter we have a report prepared by an Engineering and Physical Sciences Research Council (EPSRC) funded team from UK. It is based on their visits to several educational and research establishments in India, and interaction with subject experts. The team also interacted with the participants of the **XV NCAMP**, 2004 which was held in **PRL**. Coming back to the mirror, one may live a hundred years and yet, one shall never have a glimpse of one's own visage without a reflecting surface. Perhaps the same applies in other contexts too, and this report could be considered as a reflection of the atomic, molecular and chemical physics research in India from a learned team.

In the regular sections, this edition of the news letter has three abstracts, which are all related to molecular calculations. The first two are on the lineshape calculations, whereas the third concerns studies on diatomic molecular wave packet revivals. The third abstract also carries a very vivid image which adorned the cover page of March 14, 2006 issue of Journal of Physics B and the image does speak thousand words atleast.

The news letter also carries an article on **Fractional Statistics**, which provides a very lucid introduction to the topic. It later proposes using anyons, which follow **fractional statistics**, for **quantum computation**.

Wish you a happy reading!

K.P. Subramanian
EDITOR, ISAMP Newsletter

Dilip Angom
Guest Editor

April 21, 2006

Modified complex Robert-Bonamy formalism calculations for strong to weak interacting systems

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In 1979 Robert and Bonamy published a complex formalism (CRB) for the calculations of the pressure broadened half-width and collision-induced line shifts [1]. Application of the linked cluster theorem produced expressions that no longer needed the cut-off procedure that plagued earlier line shape theories. Recently Ma-Tipping-Boulet (MTB) [2] have suggested that the application of the linked cluster theorem in their derivation of Robert and Bonamy was based on an invalid assumption. In their work MTB have given the modified expressions and state that the effect of the modification is more important for strong interaction systems. Here the effect of the MTB modification to the formalism of Robert-Bonamy is studied for systems which range in interaction strength from strong to weak. In particular, complex Robert-Bonamy calculations [1, 3] and calculations based on the modified formalism are made in the mean-relative thermal velocity approximation for the systems: H_2O-H_2O, H_2O-N_2, H_2O-O_2, O_2-N_2, O_2-O_2, and CH_4-N_2 and the results from the formalisms compared for both the pressure-broadened half-width and pressure-induced line shift. The results of the two methods of computation are compared with the measurement database [4]. It is shown that the difference between the two methods of computation is proportional to the strength of the radiator-perturber interaction and for some systems is larger than the uncertainty desired by the spectroscopy and remote sensing communities. Comparison with the measurement database shows better agreement with the CRB calculations.

[1] D. Robert and J. Bonamy, *J. Phys. Paris.*, **40**, 923 (1979)
[2] Q. Ma, R. H. Tipping and C. Boulet, *J. Quant. Spectrosc. Radiat. Transfer., in press*, (2006)
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Status: Communicated to Mol. Phys. (2006)

Calculation of lineshape parameters for self-broadening of water vapor transitions via complex Robert-Bonamy theory

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Water vapor in the Earth's atmosphere is being studied in the 3.2-17.76mm spectral region by the atmospheric infrared sounder (AIRS) on Aqua, the troposphere emission spectrometer (TES) and the high-resolution dynamics limb sounder (HIRDLS) on Aura both part of the NASA EOS mission [1]. However, the lack of sufficient data on spectral parameters will hamper the prospect of accurate retrievals of temperature and concentration profiles. The spectral parameters for thousands of water vapor transitions are required, which are hard to determine by measurements alone. As reported previously [2], of the 10 602 measurements of H_2O self-broadening half-widths only 440 intercomparisons with more than 3 data points have estimated uncertainty less than 10%. In this work, we have employed the mean relative thermal velocity approximation of the complex implementation of Robert-Bonamy formalism [3, 4] to obtain the self-broadened half-widths and self induced line shifts for 5442 water vapor transitions in the 3.2-17.76mm region. From these calculations a number of hidden aspects of broadening and shifting mechanisms can be understood. Here we consider the dependence of the line shape parameters on rotational state, vibrational state, temperature, intermolecular potential, collision dynamics, and method of calculation.

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[3] D. Robert and J. Bonamy, *J. Phys. Paris.*, **40**, 923 (1979)
[4] R. R. Gamache, *J. Mol. Spectrosc.*, **229**, 9-18 (2005)

To be presented in the International Symposium on Molecular Spectroscopy, 61st Meeting, Ohio (2006)

The role of ro-vibrational coupling in the revival dynamics of diatomic molecular wave packets

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We study the revival and fractional revivals of a diatomic molecular wave packet of circular states whose weighting coefficients are peaked about a vibrational quantum number $\bar{v}$ and a rotational quantum number $\bar{j}$. Furthermore, we show that the interplay between the rotational and vibrational motion is determined by a parameter $\gamma = \sqrt{D/C}$ where D is the dissociation energy and C is inversely proportional to the reduced mass of the two nuclei. Using I_2 and H_2 as examples, we show, both analytically and visually (through animations), that for $\gamma >> \bar{v}, \bar{j}$, the rotational and vibrational time scales are so far apart that the ro-vibrational motion gets decoupled and the revival dynamics depends essentially on one time scale. For $\gamma \sim \bar{v}, \bar{j}$, on the other hand, the evolution of the wave packet depends crucially on both the rotational and vibrational time scales of revival. In the latter case, an interesting rotational vibrational fractional revival is predicted and explained.

(This article features online multimedia enhancements.)

J. Phys. B: At. Mol. Opt. Phys. **39** 1113-1123 (2006)

This research paper had the honour of being displayed on the cover of the journal (March 14, 2006). The result that came on the cover is reproduced here.

Editor, ISAMP N.L.

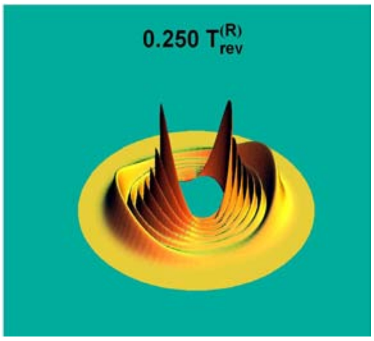

Fig: A rotational-vibrational fractional revival for a circular wave packet of H_2

N E W S

Cold Fermi gas in the news again!

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Cold, neutral Fermi atoms have recently created lot of excitement. Close on the heels of the discovery of vortices [1], which unequivocally established Cooper pairing in this system, has come the news of the discovery of another exotic form of ground state of Fermi matter, long speculated by the theorists.

Bardeen-Cooper-Schrieffer (BCS) superconductivity describes a ground state, where the number of up and down electrons, pairing up with opposite momenta near the Fermi surface, are equal in number. What is the nature of the ground state, when these two species are unequal, has been bothering the theorists for quite sometime. This asymmetric situation arises in a superconductor with magnetization, quantum chromo-dynamics (QCD) and neutron star.

Three possible ground states have emerged:

(i) The Fulde-Ferrel-Larkin-Ovchinnikov (FFLO) phase where pairs possess a non-zero center-of-mass momentum [2].

(ii) The breached pair or the Sarma phase, where Fermions pair up in certain momentum ranges, leaving others unpaired [3, 4, 5]; and

(iii) a phase where a spatial separation of paired and unpaired Fermions take place [6].

Recent experiments involving cold Li atoms [7] observed superfluidity with spatial phase separation near the strong coupling regime. It was observed above a critical value of population asymmetry. Feshbach resonance was used to explore both BCS and BEC regimes, involving the condensation of Cooper pairs and bound molecules respectively. The possibility of testing a variety of novel phases of matter in both strong and weak coupling regimes has emerged from these experiments.

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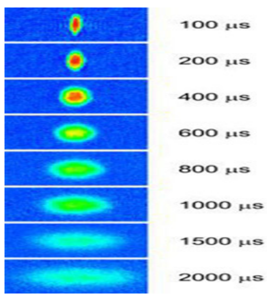
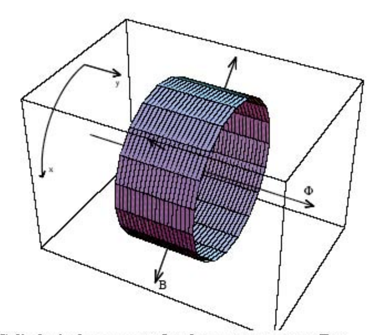
G.B. Patridge et al., ibid **311**, 503 (2006).

Curiosity Corner

The ultra-cold Fermi gas has the property of bursting outward in a preferred direction when released. The figure shows absorption images of the expanding, strongly-interacting gas as a function of time t for t=0.1 ms to t=2.0 ms. Very little motion occurs in the axial direction. Most of the energy is released in the transverse dimensions causing the gas to assume an elliptical shape. In the absence of interactions, the gas would expand with the same speed in all directions.





Cylinderical geometry for the anyon system. Two oppositely-moving edges along x-axis are separated by an incompressible anyon fluid. The cylinder is pierced by a solenoid which induces a magnectic flux Φ trough its cross-section.

Fractional Statistics and Quantum Computation

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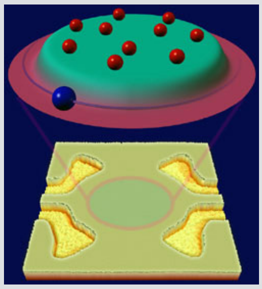

Fractional Quantum Hall Effects
Four voltage "gates" on this semiconductor surface created a central disk with "quasiparticles" having one-fifth of an electron's charge (red) surrounded by a ring of one-third charge quasiparticles (blue). There are (*somewhat controversial*) claims that anyons have already been seen in these experiments.

In last few years there is a revival of interest in the idea of "Fractional (or Anyonic) Statistics" because of the hope that "Anyons", i.e. the particles obeying such statistics may prove useful in providing high performance quantum computers. The purpose of this article is to provide a brief introduction to the concept of anyons and the fractional statistics obeyed by them. Those interested in more details, should look at my book on the subject [1].

In the last three decades it has been realized that whereas in three and higher space dimensions all particles must either be bosons or fermions (i.e. they must have spin of $n\hbar$ or $(2n+1)\hbar/2$ with $n = 0,1,2\ldots$ and must obey Bose-Einstein or Fermi-Dirac statistics respectively), in two space dimensions the particles can have any fractional spin and can satisfy *any* fractional statistics which is interpolating between the two. The particles obeying such statistics are generically called as *anyons*. In other words, if one takes one anyon slowly around the other then in general the phase acquired is $\exp(\pm\vartheta)$. If $\vartheta = 0$ or π (modulo 2π) then the particles are bosons or fermions respectively while if $0 < \vartheta < \pi$ then the particles are termed as anyons.

Why Fractional Spin and Statistics in two dimensions?

It is not very difficult to understand why angular momentum need not be quantized in two space dimensions. The point is that angular momentum in two dimensions differs fundamentally from that in three dimensions.

This is because whereas the angular momentum algebra is noncommutative in three and higher space dimensions

$$[J_i, J_z] = 2\, i\, \varepsilon_{ijk}\, J_k, \quad i,j,k = 1,2,3 \qquad (1)$$

it is a trivial commutative algebra in two space dimensions since only one generator (say J_z) is available. Thus, unlike in three and higher dimensions, in two dimensions, the angular momentum of particle states need not be $n\hbar$ or $(2n+1)\hbar/2$ but could take any arbitrary value. Now in relativistic quantum field theory, there is a deep and fundamental connection between spin and statistics. Particles with half-integral spin are fermions, those with integer spin are bosons. This suggests that in two dimensions particles may exhibit fractional statistics. In one of the most remarkable and clearly written paper, Leinaas and Myrheim [2] showed that this expectation is indeed realized. The two key points in their argument are (i) indistinguishability of identical particles in quantum mechanics (ii) Feynman's path integral approach to quantum mechanics.

The concept of the indistinguishability of the identical particles has a deep meaning in quantum mechanics. Actually, this concept was introduced by John Willard Gibbs in classical statistical mechanics, much before the advent of quantum mechanics in order to resolve the famous Gibbs paradox [3]. However, its ramifications are far deeper in quantum mechanics vis a vis the classical mechanics. The key point of the whole discussion is that if the coordinate space of a one particle system is X (typically X is the d-dimensional Euclidean space R^d) then the true configuration space of the

N-particle system is not X^N but X^N / S_N, which is obtained from X^N by dividing out by the action of the symmetric group S_N of *N* identical particles.

In particular, Leinaas and Myrheim [2] showed that there exists a continuously variable parameter, which one can choose to be the phase angle ϑ (*modulo* 2π) or $\alpha = \vartheta / \pi$ that characterizes different statistics: α equal to 0 or 1 corresponds to bosons or fermions respectively while $0 < \alpha < 1$ corresponds to more exotic possibilities and the particles obeying such exotic statistics are called anyons. It may be noted that in principle, α can be a rational or an irrational number.

Few years later, Goldin, Menikoff and Sharp [4] obtained the same results by an entirely different approach. Some of the key properties of anyons are:

- Anyons are sort of in between the bosons and the fermions i.e. the repulsion between two-anyons in the ground state monotonically increases as α goes from 0 to 1, with there being no repulsion between two bosons. Thus, in a sense, anyons are closer to the fermions than to the bosons since all of them will satisfy a generalized form of Pauli exclusion principle.

  Put another way, the trajectories of two anyons cannot cross and one can, in principle, distinguish crossing in front from crossing behind i.e. counter-clockwise from clockwise winding.

- The technical name for the group structure of the paths for anyons is B_N which is both apt and picturesque. The *braid* in braid group, refers to the interpretation of the disconnected piece of the trajectory space as topologically distinct methods of styling coils of hair. The one dimensional representations of the braid group B_N are labeled by the continuous parameter ϑ which is periodic modulo 2π. For comparison, let us note that there are two one dimensional representations of the permutation group S_N assigning 1 to each permutation or assigning ± 1 to each permutation depending on whether the permutation is even or odd and they correspond to bosons and fermions respectively.

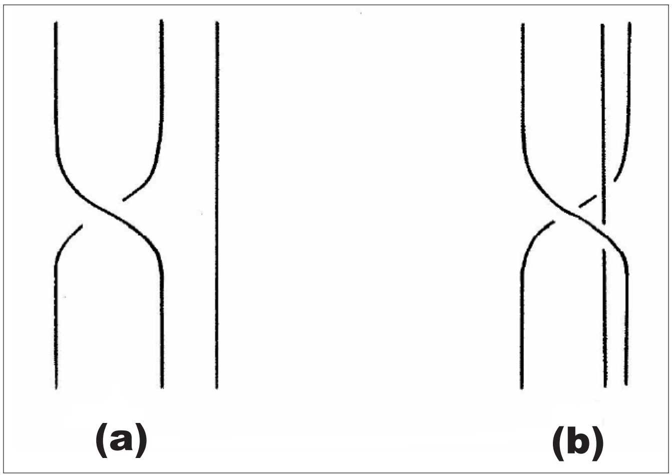

Fig.1: Two possible forms of three particle trajectories.

- A clarification is in order at this stage. It should be noted here that the anyonic statistics that we are talking about has nothing to do with para statistics. While para statistics can exist in any dimension and correspond to higher dimensional representation of the permutation group, anyons can exist in only two space dimensions and the underlying group is the Braid group.

- How does one braid a third particle trajectory into two? For example it can be done in two different ways as shown in Figs. 1a and 1b. In the first case, the third fellow is a sort of passive bystander while in the second case there is a nontrivial braiding which cannot be undone. As a result, we find that, whereas in the first case the phase factor is $e^{i\vartheta}$, in the second case the appropriate phase factor is $e^{3i\vartheta}$. *This is bad news because it means that the phase due to the exchange of two identical particles in two dimensions depends in principle on the position of all other particles.* It is this fact which makes even the simplest many-body problem of an ideal gas of anyons to be highly nontrivial. In fact till today complete solution is not known to any N-anyon problem ($N > 2$).

- One consequence of this is that only the second virial coefficient of an ideal anyon gas is known so far, while none of the higher virial coefficients are known till today and as a result the problem of an ideal anyon gas is still an unsolved problem. This is a kind of bench-mark study which is an absolute must before one can take into account the effect of interactions. Let us recall here that a similar study for an ideal Bose and Fermi gas was done right in the early days of quantum statistical mechanics.

Of course that was easily done since the wave function for N-bosons or N-fermions is merely the product of the single particle wave functions, but with appropriate symmetry or anti-symmetry factors. Unfortunately, till today we do not know how to write an N-anyon wave function in terms of single particle wavefunctions.

Models for Anyons

It is fair to say that the idea of the anyonic statistics did not receive enough attention in the physics community till the papers of Wilczek [5]. It is he who coined the name *anyons*. Apart from proposing the name, Wilczek's main contribution was the flux-tube model for anyons in which anyons turn out to be point particles having both the electric charge and the magnetic flux i.e. they are point charged vortices.

In 1986, Samir Paul and myself [6] showed that the abelian Higgs model with the Chern-Simons term [1] admit extended charged anyon solutions. In particular, we showed that the model admits charged vortex solutions of finite energy, finite quantized flux, charge and angular momentum, which is in general fractional.

Possible relevance to the real world

One might wonder if our discussion is merely of academic interest? The answer to the question is no. This is because, it is possible to strictly confine the electrons to surfaces, or even to lines or points. Thus it may happen that in a strongly confining potential, or at sufficiently low temperatures, the excitation energy in one or more directions may be much higher than the average thermal energy of the particles, so that those dimensions are effectively frozen out. Few examples where planar experimental physics is possible are electron gas, surface layer studies and copper-oxide materials. Of course, even there, at the most basic level, the fundamental particles are certainly fermions or bosons. However, the most direct and appropriate discussion of the low energy behavior of a material is usually in terms of the quasi-particles. The hope is that at least in some of these cases the quasi-particles could be anyons.

The best experimental candidates for anyons are in the case of the fractionally quantized Hall effect where the quasi-particles are believed to be charged vortices *i.e.* charged anyons. Several different experiments seem to confirm the existence of fractionally charged excitations, but similar irrefutable evidence for fractional statistics is still lacking. This is primarily because one does not know how to isolate the contribution of fractional statistics from that of Aharonov-Bohm phases that arise due to the quasiparticle charge encircling a region of magnetic flux. It has been suggested that isolating these pieces may prove easier in more exotic fractionally quantized Hall states with non-abelian statistics. The prime candidate for finding non-abelian statistics seems to be the state observed at filling fraction $\nu = 5/2$. In fact there are claims (although I feel they are little bit premature) that anyons have in fact already been seen in these experiments.

Quantum Computing and Anyons

This brings us to the most exciting possibility due to which this whole subject has become very popular in the last few months. I have in mind the possibility of anyon-based quantum computation [7].

In last few years the idea of quantum computation is attracting wide attention. The most formidable enemy of quantum computer is decoherence. The point is, a quantum system inevitably interacts with the environment. The information stored in the computer decays, resulting in errors and the failure of computation. In 1997, Kitaev [7] suggested a novel way of overcoming this problem, by anyon based computation. The central idea here to store and manipulate quantum information in a global form that is resistant to local disturbances. A fault tolerant gate should be designed to act on this global information so that the action it performs on the encoded data remains unchanged even if we deform the gate slightly, that is even if the implementation of the gate is not perfect. This is achieved by anyonic interactions which are topological in nature and which are immune to local disturbances. The idea here is to make use of braid group properties in order to do quantum computation.

The current idea of anyonic quantum computation is based on the following idea [8]. One considers a circuit consisting of a drop of fractional quantum Hall fluid with an island in the middle. An electric current can flow from one side of the drop to the other via two different paths. Now, if there are anyons on the island, they will affect the way one adds the contributions of these paths together. Latest proposals suggest several islands, allowing more intricate situations when paths can go over some islands and under some other. In this way, one hopes to open the vast potential of anyonics.

It must be pointed out at this stage that while all these schemes are theoretically possible, it is still not clear if we will be able to build an anyon based computer. This is because, I feel that the subject of "anyons" is still in its early developmental stage and it is not completely clear as to what direction this area will take in the future. This is because even the most basic problem of the statistical mechanics of a noninteracting anyon gas is still an unsolved problem. I strongly believe that unless one can solve this basic problem, no qualitative progress is possible in this field since in the absence of this bench-mark study, any calculation including interactions will always be unreliable.

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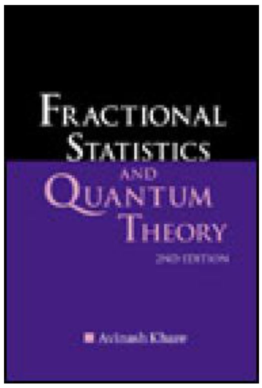

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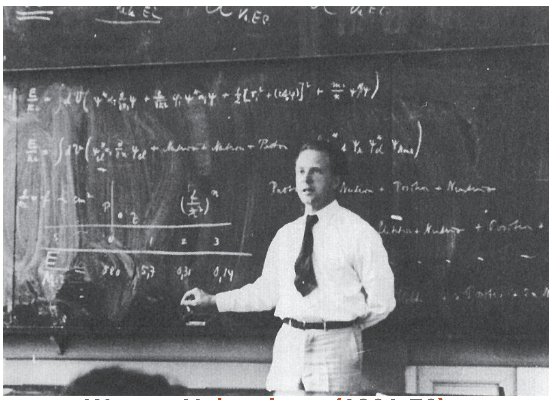

Werner Heisenberg (1901-76)

"Natural Science does not simply describe and explain nature; it is part of the interplay between nature and ourselves; it describes nature as exposed to our method of questioning."

UK delegation to India reports on Indian Atomic, Molecular, Optical and Chemical Physics and encourages future UK India collaborations

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During Dec 12-24, 2004 a delegation of British scientists visited various Universities and research centres in India for identifying mutual research interests in the field of atomic, molecular, optical and chemical physics and strengthen the collaboration between the scientists of these two nations. The report of the visit of the delegation for the UK audience has now been made available for the Indian colleagues as well.

The Editorial Board of ISAMP News Letter thank Professor N.J. Mason, Department of Physics and Astronomy, The Open University, UK for permitting ISAMP to publish this report.

Editor, ISAMP N.L.

Summary;

India has a long and distinguished history in Atomic, Molecular, Optical and Chemical Physics (AMOCP) research led by notable personages such as Sir C V Raman awarded the Nobel Prize for Physics for his discovery of the “Raman” effect and Satyendra Nath Bose who, with Einstein, formulated the idea of low temperature condensates. Throughout the 1960’s and early 1970’s links between the UK and Indian AMOCP research communities remained strong with many Indian students coming to the UK to study PhDs and conduct postdoctoral work before returning to India to establish their own research groups. Notable contacts included those with Professor Hasted’s electron and ion collisions group at University College London and (later) Birbeck college and long term collaborations in computational/theoretical physics at Queen’s University Belfast. Notable current senior Indian Research Professors to have benefited from this training include; Professor D. Mathur, now leading the internationally renowned laser physics group at the Tata Institute Mumbai and Professor K. L. Baluja, a leading theoretician at the University of Delhi who spent many years at Queen’s University of Belfast with Professor P. Burke, CBE, FRS.

However the introduction of costly overseas fees in the 1980s subsequently led to a marked decline in such activities and transfer of Indian students to the USA (where more financial support was forthcoming) and gradually contact between the two communities has reduced. Hence today there are relatively few contacts between the two communities and this has led to a gradual reduction in the presence of UK science in India at a time when the Indian Government has announced a major injection of resources into Science and Technology.

One area of science particularly suitable for collaboration is the area of Atomic, Molecular, Optical and Chemical Physics. This area of science underpins many of the areas of applied science that the Indian government wishes to see developed (*e.g.* plasmas for pollution control and manufacturing, laser physics, quantum optics) and is integral to studies in environment (*e.g.* spectroscopy for remote sensing) and the internationally recognised Indian Space and Astronomy programme. Hence AMOCP is an area in which significant investment has been made within India in recent years both in facilities and personnel. The UK has a strong and active research community in AMOCP accordingly there would appear to be many areas of mutual interest between the two communities such that it is timely to explore possible collaborative links between these UK and Indian Scientific communities and to develop a scheme within which such collaborations may be developed. The purpose of the UK INTERACT visit to India in December 2004 was to; (i) review the current status of Indian AMOCP and report this it the UK community, (ii) identify areas of potential collaboration and (iii) suggest mechanisms by which these collaborations may develop. An abbreviated version of the delegation’s report is printed below.

Report by UK delegation on atomic, molecular, optical and chemical Physics research in India and future collaborations between UK and Indian research communities.

1. Introduction

In December 2004 four senior UK Academics from the UK Atomic, Molecular, Optical and Chemical Physics (AMOCP) community visited India to review on-going Indian research in these areas and to explore the possibilities of furthering UK/India research collaborations. The visit was funded by the Engineering and Physical Sciences Research Council (EPSRC) under its INTERACT Scheme. The final report of this visit is now available and will shortly be circulated to all UK researchers in these research fields with the intention of providing information on the status of Indian research in these area and encouraging further/new UK-India research projects. New funding schemes to support such collaborations are being introduced and the report will include a listing of these schemes.

During their visit the UK team had the opportunity to visit many of India's leading research centres in atomic, molecular, optical and chemical physics and attended the XV National Conference on Atomic and Molecular Physics held at the Physical Research Laboratory Ahmedabad, the latter providing them with the opportunity to meet a larger cross section of the research Indian community. The delegation's final report reflected on the general status of Indian research - its strengths and some weaknesses – and recommended some methodologies for developing Indian AMOCP. In this article these findings and suggestions are summarized. It should, however, be noted that the UK team recognizes that it is almost impossible to review all aspects of Indian AMOCP in such a short visit and hence some of its conclusions must therefore necessarily be based on their personal perceptions. Nonetheless the UK team hopes that its report is useful to both its UK and Indian colleagues and provides a means for developing closer collaborations in the future. Should any reader wish to comment or require further information they should contact Professor Nigel Mason n.j.mason@open.ac.uk

2. The UK Delegation to India to review Atomic, Molecular, Optical and Chemical Physics

The delegation comprised;

- Professor Nigel J Mason, Centre of Atomic and Molecular Engineering, The Open University.
- Professor Jonathan Tennyson Head of Department of Physics and Astronomy, University College London.
- Professor Martin McCoustra, Department of Chemistry, University of Nottingham (from October 2006 Department of Chemistry, Heriot Watt University, Edinburgh, Scotland) and
- Professor Jeremy Hutson, Department of Chemistry, University of Durham

The itinerary for UK delegation was as follows:

December 11	*Depart UK arrive Delhi December 12*
December 13	*Visit to University of Delhi; Hosts Professor K Baluja (University of Delhi) and Prof Srivastava (IIT Rorkee)*
December 14	*Professors J Tennyson and J Hutson visit ITT Kanpur Professor N J Mason and Dr M McCoustra travel to Indore*
December 15	*Professor N J Mason and Dr M McCoustra visit Centre for Advanced Technology (CAT) Indore and the Indus Synchrotron facility*
	Professors J Tennyson and J Hutson Travel to Bangalore
December 16	*Professor N J Mason and Dr M McCoustra travel to Mumbai*
	Professors J Tennyson and J Hutson visit Bangalore
December 17	*Professor N J Mason and Dr M McCoustra visit Bhabha Atomic Research Centre*
	Professors J Tennyson and J Hutson travel to Mumbai
December 18	*UK Delegation visits Tata Institute for Fundamental research (TIFR) Mumbai*
December 19	*UK Delegation travel to **XV National Conference on Atomic and Molecular Physics** Physical Research Laboratory Ahmedabad, Gujarat.*

December 20 to 23	***XV National Conference on Atomic and Molecular Physics,*** *Physical Research Laboratory Ahmedabad.*
December 22	*Professor N J Mason visits Sardar Patel University and the Sophisticated Instrumentation Centre for Applied Research and Testing (SICART) in Vallabh Vidyanagar, Gujarat*
December 23	*Departure of Professor J Tennyson and Professor J Hutson*
December 24	*Departure professor N J Mason and Dr M McCoustra*

3. Current Status of Indian Atomic, Molecular, Optical and Chemical Physics

Indian research in Atomic, Molecular, Optical and Chemical Physics has undergone something of a renaissance in the last few (five) years with significant investment in experimental laboratories and central facilities. Furthermore there is evidence that further investment is planned and research funds are available to the Indian research community to pursue fundamental research projects. ***In comparison with research in the late 1980's and early 1990's modern Indian AMOCP research is topical and internationally competitive.*** New directions include;

- The construction and operation of cold atom traps; It is not perhaps surprising that India should chose to invest in cold atom research given the contribution of Satyendra Nath Bose. The first magneto-optical traps (MOTS) in India have been commissioned at Raman Research institute in Bangalore, to study formation and manipulation of interpenetrating lattices and the Indian Institute of sciences in Bangalore to act as a tool for metrology. The Bhabha Atomic Research Centre and the Tata Institute of Fundamental Research (Mumbai) also have groups working on ion traps and neutral atom traps. Theoretical work has developed rapidly *e.g.* in Centre for Nonlinear Dynamics, Department of Physics, Bharathidasan University, the Centre for Advanced Technology (Indore) and the National Physical Laboratory (New Delhi) and the Physical Research Laboratory, Ahmedabad.
- The assembly of a range ultra-fast laser systems for the study of molecular dynamics and design of new light sources; Within India considerable investment in such research has led to the emergence of international class groups *e.g.* those at the Tata Institute for Fundamental Research , Mumbai and facilities being developed at CAT Indore. Such experimental facilities are fully competitive with those in leading European and the US laboratories and results are being published in journals with the highest impact factor (e.g. Physics Review Letters).
- The development of a range of synchrotron based techniques. The commissioning of the first Indian synchrotron light source, INDUS 1 at the Centre for Advanced Instrumentation (CAT) Indore allows the Indian AMOCP research community to begin new range of experimental studies. Indus 2, currently under construction, is an impressive machine that will be fully compatible with light sources in Europe and the US, including Diamond and Soleil. That it has been (is being) largely constructed by scientists and technicians within India largely without contact with other synchrotron facilities is testimony to the growing skills of the Indian research community and the quality of its technical staff.

In addition to these new directions Indian AMOCP has strong research communities in collision physics e.g. through its use of accelerator facilities. The Tata Institute for Fundamental Research, Mumbai supports a well recognized experimental group in electron scattering and throughout India there are a number of theoretical groups whose work on atomic and molecular collisions and spectroscopy is recognized internationally. Several of the latter groups have, in recent years, developed international collaborations (e.g. the groups led by Professor Baluja at University of Delhi and Professor K.N. Joshipura at Sardar Patel University Vallabh Vidyanagar have on going collaborations with UK groups on use of the R- matrix code for electron scattering).

Thus the UK delegation was pleased to note that AMOCP in India had seen significant investment in recent years, investment that was leading to the Indian AMOCP community becoming more internationally competitive. The delegation also noted that such investment is not restricted to infrastructure. Academic salaries have significantly increased, particularly for younger researchers, making a scientific/academic career considerably more attractive and slowing/ reversing the large 'brain drain' of younger Indian researchers (largely to the USA) in the 1980's and 1990's. Hence the age profile is changing with the appointment of several younger academics in the new laboratories.

4. Perceived weaknesses of Indian Atomic, Molecular, Optical and Chemical Physics and recommendations

The delegation was greatly impressed with the advances being made by the Indian AMOCP community but noted some areas of weakness which it would draw to their attention with the expectation that such comments may be useful to that community and its funding agencies.

Project competitiveness. While the best laboratory facilities are now fully competitive with their international counterparts much of the research undertaken is often several years behind that conducted outside India. This may be ascribed to the insularity of the Indian AMOCP research community. It is very difficult for Indian researchers to travel outside India, their salaries though competitive in India are worth little in Europe or the US and therefore private travel is prohibitively expensive. Thus the Indian AMOCP community (and those in other research areas) relies on the support of conference hosts or special travel fellowships (*e.g.* those organized by the Royal Society in the UK). These are naturally limited, infrequent and often act against younger staff. Thus Indian researchers often rely on reading published material which by its nature reflects ideas and trends some three/four years earlier*. Indian research projects based on published material are therefore, by time of completion, somewhat outdated and appear to lack innovation.*

It appears that travel is not seen as an important part of most Indian research grants. Indeed funds are often so limited that it is impossible to fund collaborations within Indian since resources do not even meet internal travel costs. Hence there is evidence that several groups are developing techniques independent of one another (*e.g.* in the preparation of cold atom traps) leading to unnecessary delays and duplication of effort.

Accordingly the most important requirement for Indian Atomic, Molecular, Optical and Chemical Physics is to overcome its insularity and have the opportunity for regular and continued contact with external research groups. This requires exchange at senior level but also at postgraduate and postdoctoral level. Easier access to international conferences is also to be recommended. We also believe that the Indian research community would benefit from internal collaborations though a scheme similar to the UK's EPSRC Network programme.

Theoretical research. In contrast to experimental research, theoretical AMOCP in India does not yet seem to have had similar investment. Thus theoretical AMOCP in India has not been able to develop new fields of research as successfully as the experimental community, in part this is due to the chronic shortage of computational power in both the universities and research centres. It is also to be noted that the provision of network connections is very poor compared to European counterparts. Even the IIT's suffer from severe restrictions in their network connections and computer power with access to super computing facilities is limited. In addition, due to the buoyant employment market in the IT industry within India, it may have been difficult to attract and retain younger researchers in theoretical AMOCP compared to experimental research.

While Indian researchers have excellent analytical, mathematical and computational skills there is an urgent need for Indian researchers to be made familiar with new codes and methods in computational physics. Since much of the necessary infrastructure is not currently available in India such access should be through collaboration with UK, EU *etc.* research teams. Indian theoretical research would in addition be greatly assisted by the establishing their own internal network computational programmes such as the CCP series in the UK.

Finally it should be noted that (at least within the university Sector) the cost of access to published material was limiting Indian research with many library facilities faced with restricted budgets that precluded many journals from being accessed. Electronic access while cheaper was restricted to limitations in Network connections at many universities and some laboratories/research institutes. A bilateral deal with UK publishing coys (e.g. IOPP and RSC would be greatly advantageous to UK India collaborations and encourage Indian researchers to publish in UK Journals.

We recommend/encourage the Indian theoretical AMOCP community to review its current research and to identify areas in which it feels able to develop internationally competitive research programmes. These should be developed in collaboration with UK (And other international partners) with emphasis on acquiring knowledge and experience in the most modern computational codes. The formation of networks within India to develop and exchange knowledge of new codes. Practices and topical areas of research similar to the YUK CCP series is to be encouraged.

5. Research topics for future collaboration with the UK AMOCP Community:

With the recent investment in Indian scientific research it is timely to develop UK India research links. The strong traditional links between the UK and India have been greatly eroded since the 1970's when it was common for younger Indian researchers to come to the UK to conduct research and develop their research careers. In part this can be ascribed to the introduction of overseas fees which without corresponding sponsorship made the UK impossible for Indian students. Many of the Indian researchers have since been trained in the USA (or other EU countries e.g. France) where they have been able to obtain scholarships, indeed in 2002/3 ***some 70,000 Indian students*** went to the USA for graduate and postgraduate training! Since 9/11 the USA has set some visa restrictions for incoming students which has reduced the number of students/postdocs entering the USA providing an opportunity for UK and other EU countries to attract the brightest and most active younger researchers from the Indian AMCOP community.

There is a direct link between the country in which younger researchers are trained and the country with which they later collaborate and indeed purchase equipment from. In the 60's and 70's much of the laboratory equipment (*e.g.* vacuum, electronics, optics) was purchased form UK suppliers. During our recent tour of Indian laboratories we saw little evidence of UK equipment being used to furnish new research centres, most notably the Sophisticated Instrumentation Centre for Applied Research and Testing (SICART) in Vallabh Vidyanagar. SICART with over a dozen modern analytical research laboratories fully furnished in 2002-3 had no UK equipment and stated few tenders and no visiting agents from the UK had been received. In contrast visits from agents and bids from companies from Japan, the USA, Germany and the Netherlands had led to equipment deals. This example is but one example of how contact between the UK and India in Science and Technology has weakened to the detriment of both academic and industrial communities. Restoring such contacts will ultimately benefit academic, educational and commercial communities.

In Atomic, Molecular, Optical and Chemical Physics we have identified the following as possible areas that would benefit from UK/India collaboration;

Cold Atoms and BEC. It is not perhaps surprising that India should chose to invest in cold atom research given the contribution of Satyendra Nath Bose. The first MOTS in India have been commissioned at Raman Research institute in Bangalore, to study formation and manipulation of interpenetrating lattices the Indian Institute of sciences in Bangalore to act as a tool for metrology. The Bhabha Atomic Research Centre and the Tata Institute of Fundamental Research (Mumbai) have groups working on ion traps and neutral atom traps. Theoretical work has developed rapidly *e.g.* in Centre for Nonlinear Dynamics, Department of Physics, Bharathidasan University, Centre for Advanced Technology (Indore) and the National Physical Laboratory (New Delhi) and the Physical Research Laboratory, Ahmedabad. Nevertheless this concentration of effort in India has not yet been widely recognized in the wider International community. Given the UK strength in this area (experimental groups at Imperial College, University College London, Durham, Oxford, St Andrews, Strathclyde and the Open University) and the UK's world leading theoretical research in this area the opportunities to link these two communities are obvious and timely.

Synchrotron Radiation. The UK AMOCP Community pioneered the use of synchrotron radiation in the study of atomic and molecular photoionisation and photoelectron spectroscopy extending these from gas to surface phase studies. India has invested in two synchrotron radiation sources INDUS-1 and INDUS-2 at Indore, central India. INDUS-1 is a 450 MeV synchrotron radiation source with a critical wavelength of 61 angstroms. It has recently been commissioned with the first beam lines becoming active. INDUS-2 will be a synchrotron radiation source of nominal electron energy of 2 GeV and a critical wavelength of about 4 angstroms. Both INDUS-1 and INDUS-2 are national facilities accessible to all researchers from national laboratories, academic institutions and industries in India. With the commissioning of INDUS-2 Indian scientists will have powerful sources of photons with wavelengths in the visible, vacuum ultraviolet, soft x-rays and thus will embark upon an extensive programme of AMO based research. Links with the UK AMO/Synchrotron community are thus particularly timely and with the current development of 4GLS may provide the UK community with facilities when current Daresbury source is decommissioned prior to Diamond and 4GLS being made operational. Exchanges between INDUS and Daresbury/Diamond staff are to be recommended.

Molecular dynamics in laser fields: Photo-ion/photo-electron spectroscopy with intense laser fields is a new area of research that holds the promise of new insights into the non-perturbative dynamics of molecules in intense laser fields an the study of chemical (biological) reactions and processes on femto, pico and even atto-second scale. This is an area in which the UK physics and chemistry communities are recognized as being at the forefront with both laboratory based and central facility (RAL) experience. Experiments involving measurements of momentum distribution of the ejected electrons and ions are becoming feasible with technological developments in detector systems. Within India considerable investment in such research is now leading to the emergence of international class groups (*e.g.* those at the Tata Institute for Fundamental Research , Mumbai). This research is supported by theoretical work. Possible UK links are with the recent UK Basic Technology Programme on Attosecond technology – light sources, metrology and applications – Imperial College, UCL, Oxford, Reading, Birmingham, Newcastle and RAL.

Theoretical Studies The UK has a long and distinguished history of theoretical atomic, molecular, optical and chemical physics. India has likewise made several notable contributions to the development of theoretical studies in *e.g.* scattering theory (extended from nuclear physics to electron/ion collisions). In part Indian research is led by the need to conduct research that until recently has been low cost and low maintenance. However Indian students are recognized as being mathematically more advanced and experienced that many of their European counterparts. India currently lacks any high performance computation centres and therefore it is opportune to link their research base with the more extensive facilities available to researchers in the UK. Possible areas of interaction include electron/positron scattering (Queens University Belfast, UCL and Open University); non-linear optics and quantum processing (Oxford and Imperial College), chemical physics and reactive scattering (Oxford, Bristol and Durham).

AMOCP for Astrophysics India has invested heavily in its space programme and astronomy with large centres at the Indian Institute of Astrophysics, Bangalore and Physical Research Laboratory, Ahmedabad. However, unlike in the UK, in India there is apparently little interaction between the astronomical community and the AMOCP community. UK astrophysics and astrochemistry was recognized in the recent international reports on physics and chemistry to be one of the UK's research 'gems' as is its research programme in remote sensing for the environment. There are undoubted opportunities for linking these two research programmes with the Indian community. Indeed at the Indian National meeting in Ahmedabad the Indian astronomical community was particularly keen to develop links with the UK AMOCP community. Relevant UK groups include UCL, Manchester, Queens University Belfast, Nottingham, Durham, the Open University and Oxford.

6. Methodology for establishing research links

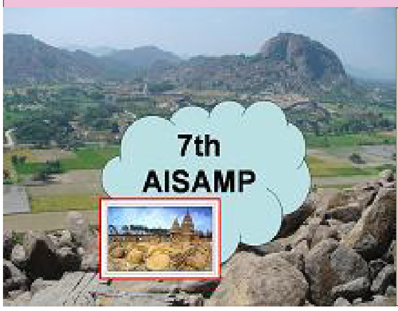
The UK delegation concluded

1. That it is timely and appropriate to (re)establish links between the UK And Indian AMOCOP communities.
2. That such collaborations would benefit from a greater exchange of knowledge as to the research undertaken by both communities.
3. That collaborations should be long term and that there should accordingly be continuity of funding for such collaborations to develop.
4. That training in the UK of Indian postgraduates and postdoctoral researchers is important to future integration of UK and Indian research.
5. That the methods by which collaborative schemes are arranged should be simplified and readily accessible by all UK and Indian researchers employed in both the University Sector or National/government laboratories.

In particular the delegation proposed that, as an initial step, a series of 'workshops' be held **IN INDIA** bringing together the Indian AMOCP community with key UK researchers. These workshops would target specific areas of research detailing state of the art research to the Indian Community and detailing appropriate research in the two countries. Four workshops are proposed; (1) Photon Physics (incorporating Synchrotron and intense laser research); (2) Cold Atom/Molecule Physics; (3) Chemical Physics (*e.g.* molecular dynamics and cluster physics) and (4) Applications of AMO Physics (*e.g.* to astrophysics, atmospheric sciences). Each workshop should last 3-4 days and allow sufficient time for discussion, reports of the meeting (with presentations) should be made available to the Indian research community.

An excellent example of a successful long term collaborative programme is that between France and India. Arranged by a single co-ordinating committee in Delhi comprised of academics from both countries the programme established ***three year projects*** providing opportunity for an Indian postdoc or postgraduate students to spend time in the French Group for 6 months to one year with shorter (2-4 week) visits by more senior staff in both directions. A small consumable budget for the Indian research group is allowable. Should this scheme be adopted we would further propose that (similar to the Humboldt scheme in the Germany) recipients of such awards maintain contact and be able to periodically renew their visits to their host (training) partner. A budget of some £60K for each programme (12 months postdoc = 20K and 12 months postgrad = 12K with 8K other travel and 5K consumables 15K overheads) would be appropriate with some 10 in year 1 rising to 15 projects funded per annum (in all areas of science). Note Full Economic costings would require overheads for the visitor to the UK to be provided to the UK host.

ANNOUNCEMENTS



7th Asian International Seminar on Atomic and Molecular Physics

December 4-7, 2006

Dept. of Physics, Indian Institute of Technology
Chennai-600036, India

Topics:

- Atoms and Molecules in Controlled Laser Fields
- Attosecond Physics
- Physics of Bio-molecules
- Atomic and Molecular Physics with Synchrotron Radiation
- Atomic and Molecular Collisions
- Laser Cooling, Cold Traps for Atoms and Molecules
- BEC Quantum Degenerate Gas
- Quantum Information Processing using Atoms and Molecules
- Atomic and Molecular Processes for Tests of Fundamental Laws

Deadlines:

Submitting Abstract: **15th May, 2006**
Registration : **30th September, 2006**

Registration Fees for Indian Delegates : **Rs. 1500**
Registration Fees for Foreign Delegates: **US$ 175**

[A 5% discount is available for early registration, before June 30, 2006. Registration at the rates mentioned is open till 30th September, 2006, a late fee of 2% will be charged on registration done after 30th September, 2006.]

The Registration Form is available in MS WORD and HTML format and must be sent through attachment on or before 30 June, 2006 to the following e-mail address :

aisamp7@physics.iitm.ac.in

For Hard Copy submission please send the form to:

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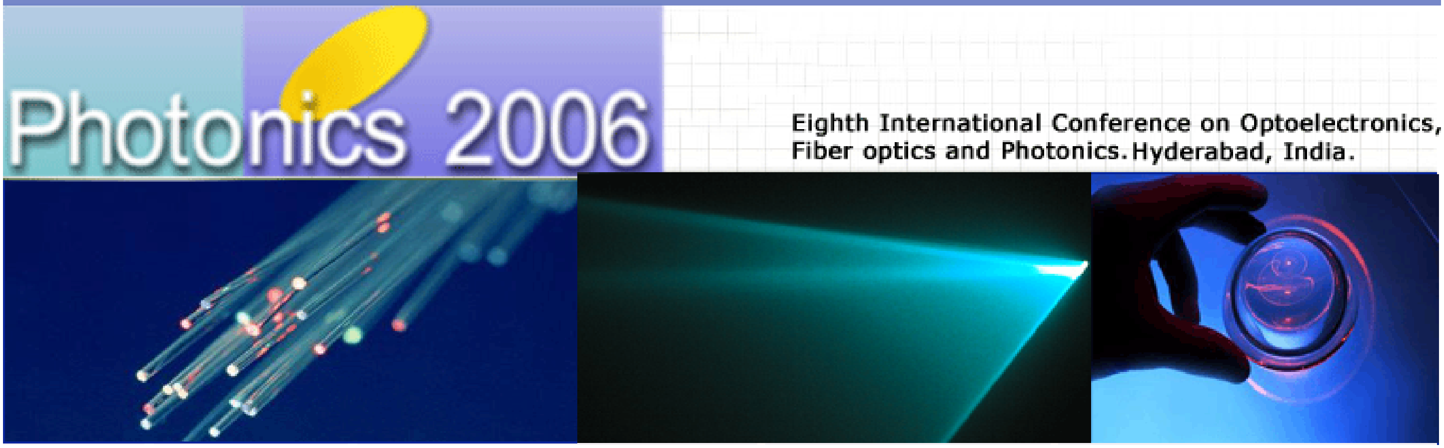

Photonics is an International Conference organized biennially in India. The seventh conference was held in Cochin during December 9 – 11, 2004. The eighth conference, Photonics 2006 organized jointly by University of Hyderabad, Optiwave Photonics and Defence Research Development Organization would be held during December 13 – 16, 2006 in University of Hyderabad, India.

Photonics 2006 will build on the strong traditions of previous conferences held in Bangalore, Chennai, New Delhi, Kolkata, Mumbai and Cochin and provide a forum for interaction and exchange of ideas among participants from Universities, Research institutions, Government organizations and Industry from various parts of the globe.

The theme of the conference is Optoelectronics

Fiber Optics and Photonics covering the areas of

- Optoelectronic materials and devices
- Integrated optics and devices
- Nonlinear optics
- Optical fibers, communications and networks
- Optical sensors, MEMS, Optical signal processing, optical computing, information storage
- Emerging areas of Biophotonics, Nanophotonics, Organic electronics and Quantum computing.

Photonics - 2006 will be a four-day conference and is planning to introduce two new sessions. One is aimed towards fresh Ph.D students presenting their work and facilitate an interaction with academia, research labs and industry. The second will introduce presentation of "Trend-setting" papers in any of the above-mentioned areas.

First announcement:

http://www.photonics2006.co.in/new.html

Technical Co-Sponsors

- Optics Society of America (OSA)
- International Commission for Optics (ICO)
- The International Commission for Optics has granted Photonics-2006 the status of "ICO endorsed conference."
- The International Society for Optical Engineering (SPIE)

Sponsors

- The International Materials Institute for New Functionality in Glass (IMI-NFG)
- Department of Science and Technology, India (DST)
- Defence Research and Development Organization of India (DRDO)
- Advanced Centre for Research in High Energy Materials, Hyderabad (ACRHEM)
- University of Hyderabad, Hyderabad, INDIA (UOH)

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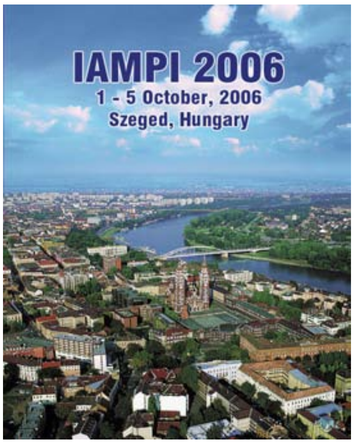
URL: http://www.photonics2006.co.in/



International Conference on the Interaction of Atoms, Molecules and Plasmas with Intense Ultrashort Laser Pulses

1 - 5 October, 2006

Szeged, Hungary

Scope of the Conference

Ultrashort laser pulses reaching extra high intensities open new windows to obtain information about molecular and atomic processes. These pulses are even able to penetrate into atomic scalelengths not only by generating particles of ultrahigh energy but also inside the spatial and temporal atomic scalelengths. New regimes of laser-matter interaction were opened in the last decade with an increasing number of laboratories and researchers in these fields.

The interactions with visible light in this parameter range also result in new radiation sources, such as soft and hard X-rays, gamma rays, moreover energetic particles (electrons, protons, heavy ions, and neutrons) are also generated. Even nuclear reactions such as fusion and fission can be effectively driven by strong laser pulses. Most of these intrinsically nonlinear interactions are occurring in plasmas, therefore it is no surprise that high-intensity physics have been strongly motivated since the beginning by the controlled thermonuclear fusion researches. On the other hand attosecond pulses even allow control and real-time observation of electron dynamics at sub-atomic dimensions.

This Conference which joins the ULTRA COST activity (“Laser-matter interactions with ultra-short pulses, high-frequency pulses and ultra-intense pulses. From attophysics to petawatt physics“) and the XTRA (“Ultrashort XUV Pulses for Time-Resolved and Non-Linear Applications”) Marie-Curie Research Training Network, intends to offer a possibility to the members of both of these activities to exchange ideas on recent theoretical and experimental results on the interaction of ultrashort laser pulses with matter giving a broad view from theoretical models to practical and technical applications.

List of Topics

1. Attosecond and/or XUV sources: generation and applications
2. Fast particles and intense x-ray radiation from the interactions with ultrashort, ultraintense laser pulses
3. Interaction of atoms with strong laser fields
4. Molecules in the field of ultrashort laser pulses
5. Plasmas on solid surfaces and in clusters
6. Lasers for ultrahigh intensities and for ultrashort pulses

Contributed Papers

In addition to the invited papers, oral and poster contributions will be selected on the basis of a one-page abstract. Authors are invited to submit the abstract of their contribution (oral presentation or poster) electronically, using the abstract submission form.

The deadline for abstract submission: 31 May, 2006

Publication

Selected presentations will be recommended for publication in the special issues of the journals Laser and Particle Beams and/or in Acta Physica Hungarica B (Quantum Electronics).

URL: http://www.prof-congress.hu/2006/iampi/