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CONTENTS

FROM THE EDITOR'S DESK

This issue of newsletter carries a bouquet of exciting abstracts and articles. The abstracts covers a wide range of topics, which is perhaps expected as atomic and molecular physics has foot prints in several branches of physics. Two abstracts of letter papers report the use of relativistic coupled-cluster method in atomic calculations. It is an elegant method for precision atomic and molecular calculations but its use poses serious theoretical and computational challenges. The authors have used the method to calculate properties of alkaline earth ions to very high accuracy. The results are important in designing better atomic clocks and tests of fundamental symmetries.

We have several abstracts of experimental papers on electron collision with atoms, molecules and surfaces. The dynamics associated with core electron ionization of atoms and molecules are presented in a series of abstracts. Either by design or coincidence there are articles on the studies of carbon dioxide and nitrogen dioxide. Both of which are not on good terms with human life. However, the unfriendliest is perhaps antimatter, about which we also have abstracts. There are two abstracts on positronium, a bound of state of the extreme kind: matter-antimatter. To compensate for all the hazards of carbon dioxide, nitrogen dioxide and antimatter, there is an abstract on the study the of dissociation of ethanol!

We hope the readers shall find the article on "Recoil Ion Momentum Spectroscopy" interesting. The article has a gentle introduction on the technique and follows with examples which demonstrates the power of the technique.

We also hope that readers would find the article on "UK-Indian Collaboration: Opportunities" useful.

K.P. Subramanian   **Dilip Angom**
EDITOR, ISAMP Newsletter   Guest Editor

A B S T R A C T S

Abstract#1

Velocity selective optical pumping effects and electromagnetically induced transparency for D_2 transitions in rubidium

Shrabana Chakrabarti, Amitkiran Pradhan, Biswajit Ray and Pradip N Ghosh[1]

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It is shown that the pump-probe spectroscopy of Λ–type system for the D_2 transition of ^{87}Rb exhibits additional absorption enhancement peaks due to velocity selective optical pumping along with the electromagnetically induced transparency (EIT). The separation of these peaks is consistent with the hyperfine splitting of the upper levels. For ^{85}Rb the peaks are not clearly discernible since the hyperfine splitting is much smaller.

Abstract#2

Electric Quadrupole Moments of the D States of Alkaline-Earth-Metal Ions

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[2]Indian Association for the Cultivation of Science, Kolkata, India
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The electric quadrupole moment for the $4d^2D_{5/2}$ state of ^{88}Sr$^+$; one of the most important candidates for an optical clock, has been calculated using the relativistic coupled-cluster theory. This is the first application of this theory to determine atomic electric quadrupole moments. The result of the calculation is presented and the important many-body contributions are highlighted. The calculated electric quadrupole moment is 2.94 ± 0.07 ea_0^2, where a_0 is the Bohr radius and e the electronic charge while the measured value is 2.6 ± 0.3 ea_0^2. This is so far the most accurate determination of the electric quadrupole moment for the above mentioned state. We have also calculated the electric quadrupole moments for the metastable $4d^2D_{3/2}$ state of ^{88}Sr$^+$ and for the $3d^2D_{3/2,5/2}$ and $5d^2D_{3/2,5/2}$ states of ^{43}Ca$^+$ and ^{138}Ba$^+$ respectively.

Abstract#3

Photophysical processes involved within the anisole-thioindoxyl dyad system

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The photophysical properties and the nature of the photoinduced electron transfer (PET) reactions within a synthesized anisole (A)-thioindoxyl (T) dyad system (24MBTO) have been studied by electrochemical, steady state, and time-resolved spectroscopic techniques. Computations on the dyad were performed both in gas phase as well as solvent environment by TD-DFT method with B3LYP density function. The geometry optimization calculation of 24MBTO was done by 6-311G(d,p) basis function set implemented in the Gaussian package. The theoretical values of singlet vertical excitation energies were found to correlate well with the experimentally observed ones. The electrochemical measurements indicate the possibility of occurrence of PET reactions within 24MBTO between the linked redox centers A and T. Both steady-state and time-resolved spectroscopic measurements on the novel synthesized 24MBTO dyad demonstrate the formations of the two types of isomeric species: Z- and E- forms, resulted from the charge separation reactions. From the detailed studies it reveals that the present thioaurone may behave as a versatile photoswitchable system. It has been hinted that the loss process (charge recombination) within 24MBTO could possibly be prevented by incorporating it within the hydrophobic cavity of beta-cyclodextrin.

Determination of active sites for H atom rearrangement in dissociative ionisation of ethanol

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In an electron impact dissociative ionisation experiment on C_2H_5OH, the formation of molecular ions requiring rearrangement of H atoms has been studied using a momentum spectrometer. H_3^+, H_2^+ and HOH^+, H_2OH^+ observed in the experiment are molecular ions of this type. By comparing the mass spectrum of C_2H_5OH with that of its isotopomer C_2H_5OD, we determine the proportions of H-- bond rearrangements involving carbon and oxygen sites. We find that the formation of H_3^+ due to the breaking of the O--H bond and rearrangement of the H atoms on the CH_2 site is about 2.5 times as likely as its formation involving atoms from the CH_3 site alone. No such difference is seen in case of the H_2^+ ion. The role of the O--H bond in formation of all observed ions has been assessed. Kinetic energy distributions of the molecular ions suggest that two or three electronically excited states contribute to their formation.

Submitted to: *J. Chem. Physics* (2006)

Triply-charged carbon-di-oxide molecular ion: its formation and fragmentation

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In an experiment involving detection of a photoelectron and up to three photoions from CO_2 in coincidence, we observe the triple ion coincidence $[C^+:O^+:O^+]$. Moreover, we observe double coincidences between doubly charged cations and singly charged cation pairs $[C^{2+}:O^+]$, $[O^{2+}:C^+]$, $[O^{2+}:O^+]$. These ion triplets and pairs arise from fragmentation of the triply charged molecular ion CO^{3+}. Other ion pairs, viz. $[C^+:O^+]$, $[O^+:O^+]$, $[O^+:CO^+]$, arising from the doubly charged molecular ion CO^{2+}, and reported previously in the literature, are also observed. From an analysis of the coincidence pattern we postulate four decay modes of the CO^{3+} ion. Kinetic energy release in the channel leading to $[C^+:O^+:O^+]$ is measured and its distribution is postulated to have four contributing precursor states.

Submitted to Phys. Rev. A (2006)

Oscillator strenghts and lifetimes in Kr XXV

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Energy splitting of 53 fine-structure levels as well as oscillator strengths and radiative decay rates for all electric-dipole-allowed and intercombination transitions among the $(1s^2 2s^2 2p^6)3s^2(^1S)$, $3s3p(^{1,3}P^o)$, $3s3d(^{1,3}D)$, $3s4s(^{1,3}S)$, $3s4p(^{1,3}P^o)$, $3s4d(^{1,3}D)$, $3s4f(^{1,3}F^o)$, $3p^2(^1S, ^3P, ^1D)$, $3p3d(^{1,3}P^o, ^{1,3}D^o, ^{1,3}F^o)$, $3p4s(^{1,3}P^o)$, and $3d^2(^1S, ^3P, ^1D, ^3F, ^1G)$ states of Kr XXV are calculated using very extensive configuration-interaction (CI) wave functions. These wave functions are obtained using the CIV3 computer code of Hibbert. The important relativistic effects in intermediate coupling are incorporated by means of the Breit-Pauli Hamiltonian. In order to keep our calculated energy splitting as close as possible to the experimental values, we have made small adjustments to the diagonal elements of the Hamiltonian matrices. Our excitation energies, including their ordering, are in excellent agreement with the available experimental results. The enormous mixing among several fine-structure levels makes it very difficult to identify them correctly with the result that their positions in other calculations are interchanged compared to our results and the experimental values. From our transition probabilities, we have also calculated radiative lifetimes of some fine-structure levels. Our calculated oscillator strengths, radiative decay rates and the lifetimes are found to be in good agreement with the experimental and other theoretical results (wherever available). In this calculation we also predict new data for several fine-structure levels where no other theoretical and/or experimental results are available. We believe that the

new oscillator strengths reported in this paper will be useful in many astrophysical applications and in technical plasma modeling.

Abstract#7

Doppler effect in fluorine K-Auger line produced in electron-induced core ionization of SF_6

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An experimental evidence is reported on the observation of the Doppler effect in fluorine K-Auger line emitted from a core-ionized SF_6 molecule under an impact of 16 keV electrons. The emitting source of the Auger line is found to acquire a kinetic energy of 4.7±0.3 keV. We propose that such large energy is released from the Coulomb repulsion taking place between F^+ and SF_5 fragment ions under influence of an intense focusing field of the incident electrons. In the presence of the Coulomb field of these ions, the Auger line obtains a polarization P=76%±7%.

Abstract#8

Total ionization cross-sections of CH_4 and C_3H_8 molecules for impact of 10-28 keV electrons

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The total ionization cross-sections of methane and propane molecules are measured for impact of 10-28 keV electrons. The cross-sections are found to follow the variation shown by Bethe formula as a function of electron impact energy. Also, the present results compare well with the available data in the literature. Further, the measured cross-sections of the above hydrocarbon molecules are found to correlate strongly to the total number of molecular electrons and to molecular dipole polarizability.

Abstract#9

Backscattering of 8-28 keV electrons from a thick Al, Ti, Ag and Pt targets

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Measurements of electron backscattering co-efficient η for thick Al, Ti, Ag and Pt targets have been made for incident electrons with energy 8-28 keV. The variations of η with angle of incidence a, impact energy E_0 and with target atomic number Z have been studied. The data are compared with available theories. The mean fractional energy absorbed in the backscattering process has been determined and compared with an analytical expression and with Monte-Carlo simulations based on the Kanaya and Okayama electron-electron and electron-nucleus interactions and on the Quinn electron-plasma interactions. The comparison between our experimental data and the model calculations using Monte-Carlo simulations and analytical expression shows a reasonably good agreement among themselves within experimental errors of measurements.

Abstract#10

Differential cross-section measurements of multiply charged xenon ions produced in 10-28-keV e--Xe collisions

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Partial single-differential ionization cross sections PSDICSs of a multiply ionized xenon atom Xe^{n+}, n =1-7 are measured for impact of 10-28 keg electrons with xenon by performing coincidences between the produced recoil ions and the electrons of indiscriminate energies detected at 90° with respect to the incident electron beam direction. Values of relative PSDICSs for doubly charged ions are found to be about 25% larger

than those for singly charged ions in the considered impact energy range. The examination of charge-state fractions and relative cross-section fractions of multiply charged ions as a function of incident electron energy suggests that the multiply charged ions are produced via creation of an inner-shell vacancy followed by Auger and shake-off processes. The mean charge state of the ions produced in the collisions is found to be independent of the impact energy and reaches a constant value close to 2.6. The Fano-Bethe plots of the PSDICSs suggest that higher charge states of the ions are weakly produced via optical transitions; moreover, the latter process becomes a dominant channel for producing the doubly charged ions that are correlated with the electrons detected at 90°.

Physical Review **A 72**, 052705 (2005)

Abstract#11

Coincidence electron spectroscopy of electron-impact multiple ionization of argon

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Measurements of the partial double differential ionization cross sections of argon atoms have been made by performing coincidences between recoil ions and energy- and angle-selected slow electrons produced in 12-24 keV e--Ar collisions. Results show that the Ar^{3+} ions are formed mainly by a two-step-one process via electron shake-off. These measurements have enabled determination of the shake-off probability S $=0.14\pm0.01$ for L2,3 subshell, which is in good agreement with a theoretical predication. Additionally, Ar^{2+} and Ar^+ ions are found to arise respectively from the filling of L-shell vacancy by an auger transition and from the direct ionization of M-shell of the argon atom.

Physical Review **A72**, 062721 (2005)

Abstract#12

Findings in Ps-H scattering

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The best 3-channel projectile-inelastic close-coupling approximation (CCA) is used to study the resonances in positronium (Ps) and hydrogen (H) scattering at the energy region below inelastic threshold. The s-wave elastic phase shifts and s-wave elastic cross sections are studied using the static exchange, 2-channel and 3-channel projectile-inelastic CCA for both the singlet (+) and triplet (-) channels. The singlet resonances which were detected for the first time using different CCA schemes confirms previous predictions [1,2]. We report a new resonance in triplet channel too using the present 3-channel CCA scheme.

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Phys. Rev. A (in press, 2006)

Abstract#13

Low energy scattering of positronium by atoms

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The survey reports theoretical studies involving positronium (Ps)-atom scattering. Investigations carried out in last few decades have been briefly reviewed in this article. A brief description of close coupling approximation (CCA), the first Born approximation (FBA) and Born-Oppenhiemer approximation (BOA) for Ps-atom systems are made. The CCA codes of Ray et. al [1-6] are investigated using very fine mesh-points to search for resonances. The article advocates the need of an extended basis-set and a systematic study using CCA.

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Review Article in Conference Proceedings published by GSFC, NASA, May 2006 (in Press).

Determination of cross sections and rate coefficients for the electron impact dissociation of NO_2

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Energy dependent and angle dependent differential cross sections for the production of the NO_2^+, NO^+, O_2^+, N^+ and O^+ ions resulting from dissociative ionization of NO_2 by electron collision have been evaluated at a fixed incident electron energy. The semi-empirical formulation based on the well-known Jain-Khare formulation which requires the oscillator strength data as input has been employed. As no previous data seem to exist for differential cross sections, we have derived the partial and total ionization cross sections from these differential cross sections from ionization threshold up to 1000 eV and compared with available experimental and theoretical data. We also evaluated the ionization rate coefficients on the basis of calculated partial ionization cross sections and Maxwell-Boltzmann energy distributions.

Relativistic Coupled-Cluster Theory of Atomic Parity Nonconservation: Application to $^{137}Ba^+$

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We report the result of our *ab initio* calculation of the $6s^2 S_{1/2} \rightarrow 5d^2 D_{3/2}$ parity nonconserving electric dipole transition amplitude in $^{137}Ba^+$ based on relativistic coupled-cluster theory. Considering single, double, and partial tripl

excitations, we have achieved an accuracy of less than 1%. If the accuracy of our calculation can be matched by the proposed parity nonconservation experiment in Ba^+ for the above transition, then the combination of the two results would provide an independent nonaccelerator test of the standard model of particle physics.

Anomalous oxygen isotope enrichment in CO_2 produced from O+CO: estimates based on experimental results and model predictions

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The oxygen isotope fractionation associated with $O+CO \rightarrow CO_2$ reaction was investigated experimentally where the oxygen atom was derived from ozone or oxygen photolysis. The isotopic composition of the product CO_2 was analyzed by mass spectrometry. A kinetic model was used to calculate the expected CO_2 composition based on available reaction rates and their modifications for isotopic variants of the participating molecules. A comparison of the two (experimental data and model predictions) shows that the product CO_2 is endowed with an anomalous enrichment of heavy oxygen isotopes. The enrichment is similar to that observed earlier in case of O_3 produced by $O+O_2$ reaction and varies from 70 to 136 ‰ for ^{18}O and 41 to 83 ‰ for ^{17}O. Cross-plot of $\delta^{17}O$ and $\delta^{18}O$ of CO_2 shows a linear relation with slope of ~0.90 for different experimental configurations. The enrichment observed in CO_2 does not depend on the isotopic composition of the O atom or the sources from which it is produced. A plot of $\Delta(\delta^{17}O)$ versus $\Delta(\delta^{18}O)$ (two enrichments) shows linear correlation with the best fit line having a slope of ~0.8. As in case of ozone, this anomalous enrichment can be explained by invoking the concept of differential randomization/stabilization time scale for two types of intermediate transition complex which forms symmetric ($^{16}O^{12}C^{16}O$) molecule in one case and asymmetric ($^{16}O^{12}C^{18}O$ and $^{16}O^{12}C^{17}O$) molecules in the other. The $\delta^{13}C$ value of CO_2 is

also found to be different from that of the initial CO due to the mass dependent fractionation processes that occur in the O+CO→CO_2 reaction. Negative values of $\Delta(\delta^{13}C)$ (~12.1 ‰) occur due to the preference of ^{12}C in CO_2^* formation and stabilization. In contrast, at lower pressures (~100 torr) surface induced deactivation makes $\Delta(\delta^{13}C)$ zero or slightly positive.

Submitted to: J. Chem. Phys. (2006)

NEWS

Limit to 'extreme' magnetic field

Every physical quantities must have a limit. So also the maximum magnetic field allowed in our universe. According to two theoretical physicists in Russia and Israel, it is 10^{42} Gauss -- a value that is a billion times smaller than the previous estimate for the upper limit. This has got some fundamental interest too. If the new estimate of maximum magnetic field is correct, it may rule out theories on *"superconductive cosmic strings"* and also some accepted mechanisms of producing other hypothetical objects such as magnetic monopoles (Phys. Rev. Lett. **96** 180401).

Earth's magnetic field is less than 1 G. In contrast, the magnetic field associated with compact astronomical objects such as white dwarfs, neutron stars and black holes are ~ 10^{17} G. However, theorists have also predicted that hypothetical objects called superconductive cosmic strings could have even higher magnetic fields near them of 10^{47} to 10^{48} G.

Extremely thin one-dimensional topological defects in the space-time fabric are believed to be the cosmic strings. They are invoked in grand unified particle physics models and are thought to have been produced just after the Big Bang. However, the new maximum value for magnetic fields of 10^{42} G, which has been calculated by Anatoly Shabad of the Lebedev Physics Institute in Moscow and Vladimir Usov at the Weizmann Institute of Science in Rehovot, is lower than that associated with cosmic strings. If the revised estimate of maximum magnetic field turns out to be correct, it would rule out the existence of extremely strong magnetic fields in the vicinity of these objects.

The new estimate is 10^9 times lower than the previous upper limit of 10^{51} G, which assumes that *"Dirac monopoles"* exist in nature. These particles, predicted by some theories that seek to unify the electroweak and strong interactions, have never yet been observed experimentally.

Shabad and Usov employed *"Bethe-Salpeter"* equation, which is good for studying relativistically bound states formed from charged particles interacting with each other. They obtained their result by considering what the maximum possible value of the magnetic field could be in pure quantum electrodynamics (QED), which describes the fundamental forces between particles as being due to the exchange of *"field quanta"*. Until now, scientists believed that a magnetic field could take on arbitrarily high values in QED. They solved the equation in the case of a positronium atom, which contains an electron and a positron.

They observed that the attraction between electron and positron in a positronium atom becomes stronger and stronger until the electron and positron "fall" onto one another at a maximum field of 10^{42} G. This is termed as the "collapse" of the positronium. For magnetic fields larger than 10^{42} G, the energy gap separating the electron and positron shrinks so that the positronium becomes indistinguishable from the vacuum. This means that fields higher than 10^{42} are not possible. The argument they put forward is that, if field strengths higher than 10^{42} G was permissible, then the vacuum would explode resulting in the formation of "collapsed positronia."

Source: Article by **Belle Dumé** in **PhysicsWeb**
(abridged by Editor, ISAMP Newsletter)
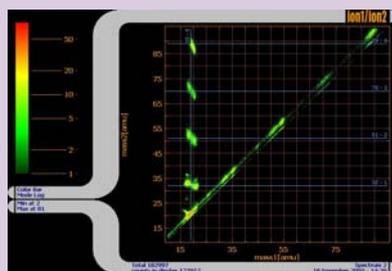
Momentum-Spectroscopy of Molecular Fragmentation

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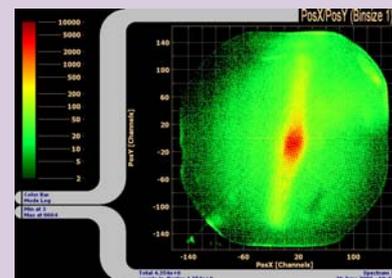
Introduction

A collision between a charged particle or a photon with atoms or molecules may create ions and electrons. Atomic ions have low kinetic energy, since most of the KE is carried by electrons. Molecular ions, if stable, also have low kinetic energies, but the situation changes drastically, if the molecular ion is unstable and dissociates. A reaction like

$$q, \gamma + AB \rightarrow AB^{+*} + e^{-}$$

$$AB^{+*} \rightarrow A^{+} + B$$
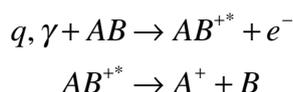
leads to energetic fragments. Energy and angular distributions [*alternatively, momentum distributions*] of product ions give valuable information about the dynamics of unimolecular reactions. The dynamics are largely governed by the potential energy surface of the intermediate unstable molecular ion. One approach towards understanding the dynamics is to calculate the PE surfaces to the last detail. The other is to determine the complete kinematics of all fragments in an experiment and from there work the evolution backwards to the unstable state. In reality neither approach is entirely successful, and one uses a combination of the two. In this article we shall view the dynamics through an experimentalist's microscope.

Several methods have been devised to measure angular and energy distributions, and these can be broadly grouped into two categories, namely translational energy spectrometry and time-of-flight spectrometry. The latter is the more popular and versatile of the two. Thanks to the advances in electronics and detector technology, TOF based techniques have seen a big boom in the last decade. The developments can be generically described as momentum imaging methods. Many variants of the basic method go under various names, and can be sampled across the world. For details, the reader is referred to several excellent monographs and review articles in the bibliography. Our focus shall be on demonstrating the power of the recoil-ion momentum spectroscopy (RIMS) in studying molecular fragmentation.

The momentum spectroscopy technique

The primary idea behind RIMS is the dispersion in *space and time* of ions formed in a reaction. Suppose there is a tiny region in space (on a few mm scale), within which the collision is brought about by the intersection of a molecular beam and a photon or charged particle beam. Place this source in an electric field ($\vec{\mathbf{E}} = E\hat{z}$) which is uniform over a large volume. Ions will be accelerated in this field and cover the (fixed) distance to a detector (z_D) in a time given by the second equation of motion.

$$z_D = \frac{p_z^{0}}{m}t + \frac{qE}{2m}t^2$$

The time-of-flight (TOF) is experimentally measured. Nature provides us with a clock. The electron ejected in the reaction is accelerated by the same electric field in the opposite direction of the ion flight. Since the electron is much lighter, and the drift distance can be made short, the electron can be detected almost at the instant of formation. Electron detection starts the clock for the ion flight-time measurement. This is called an *electron–ion coincidence.* As the ion traverses the electric field, its x, y-components of momentum remain unaffected (See Figure 1). The effect of these component is to cause deviation of the trajectory of the ion from the
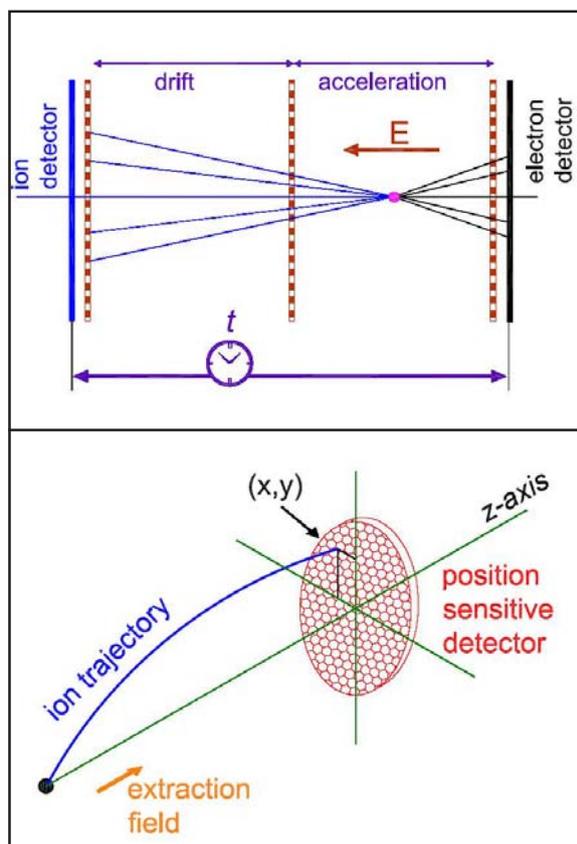
Fig 1: *Schematic of time-of-flight measurement and of measurement of spatial dispersion in the direction perpendicular to the extraction field.*

z-axis by amounts given by

$$x = \frac{p_x^{\,0}}{m} t \qquad\qquad y = \frac{p_y^{\,0}}{m} t$$

If – in addition to the TOF – we can also measure the (x, y) deviations, we can obtain $\left(p_x^{\,0}, p_y^{\,0}, p_z^{\,0}\right)$, *i.e.* the complete momentum vector of the ion when it is was born. Lest it should seem like a simple technique, let me point out the (t, x, y) need to be measured *simultaneously* for each ion reaching the detector for the method to succeed. It is not enough to measure the arrival times and positions and histogram their distributions, since *correlated* (t, x, y) information is a must!

Without going into the history of the development of such detectors and their associated electronics, let us look at what is currently the state-of-art. We need a large-area position-resolving detector with a fast response. Like in many charged particle detection set-ups, the primary detector is a channelplate, but the simple metal plate anode is replaced by a

"delay-line" anode. A delay line enables measurement of position based on the time taken for an image charge to propagate. The detector provides pulses corresponding to the time of arrival of the ion and the time of propagation of the delay line pulses with reference to the time of arrival of the ion. The clock is started by the pulse provided by the electron detector. The clock is a computer-based time-to-digital convertor. The next crucial step is to store all time entries for each ion hit. With fast computers and communication protocols, this task has become feasible. Data values are buffered to computer memory and periodically written to the disk. The output of the experiment is an event list; each item in the list is the triplet (t, x, y). The data list can be analysed *post-facto*, and various conditions can be applied to sort the data.

Very often in a molecular reaction, a single molecule may give rise to two or more ionic fragments. In such a case, we can contemplate an ion–ion coincidence, that is detection of two or more ions in rapid succession using the *same detector*. The ion arrivals would be separated in time, depending on their masses. This is perfectly possible with our detector, as long as the flight times are separated by 20 ns or more. Let us pause for a moment, to examine the information generated by the spectrometer in this situation. First we have the electron starting the time measurement. The first ion reaches the detector, its (t_1, x_1, y_1) are recorded. The next ion reaches the detector, its (t_2, x_2, y_2) are also recorded. In effect, we have the momentum vector for each ion formed by dissociation. By recording thousands or even more of such events, we generate a momentum map of the dissociation. The (t_1, t_2) pair also tells us which ions they are, since the mean of the t_i distribution is proportional to $(m/q)_i^{1/2}$. Position sensitive detection, time-of-flight measurement and list mode data acquisition and electron–ion–ion coincidence form the building blocks of the momentum spectroscopy method. Using these building blocks, we have built a momentum spectrometer for studying molecular fragmentation by electron impact. It is sketched in Figure 2. You would have noticed that it has an
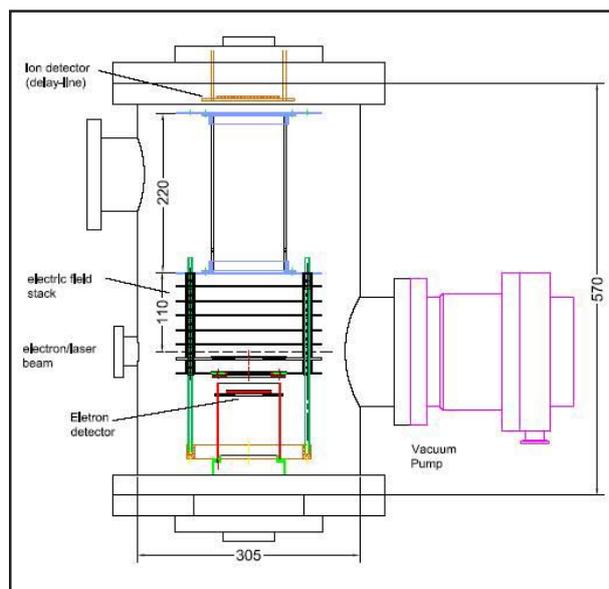
Fig 2: *Sketch of the momentum spectrometer built at PRL.*

acceleration region for ions, followed by a drift region. This is done to improve the resolution. The resolution achieved is $\Delta p_x, \Delta p_y = 11$ and $\Delta p_z = 4$ in atomic units.

Experiments in our Lab

We now present some of our results which indicate the power of this technique. This is done by four examples. The first example demonstrates the usefulness of the electron–ion–ion coincidence technique in determining ion-pair formation cross-sections, the second example is of determination of the lifetime of metastable molecular ions. The third one demonstrates how kinetic energy release in a fragmentation can be obtained, while fourth example shows how bond angles of the intermediate molecular ion can be estimated.

Multiple Ion-coincidences

Consider a large molecule like ethanol (CH_3CH_2OH). When subject to dissociative ionisation, many ions and neutrals may emerge. In an ordinary time-of-flight spectrometer, one would get a simple mass spectrum (line graph in Figure 3), but by augmenting this with a multi-hit coincidence capability, the information content increases dramatically. The colourful plot in the same figure is a *coincidence map*. This a two-dimensional histogram of events which had

two ions. The two variables in this plot are the flight-times of the two ions which were born in a single fragmentation. Intensity of each 'island' gives the relative cross-section for each ion pair.
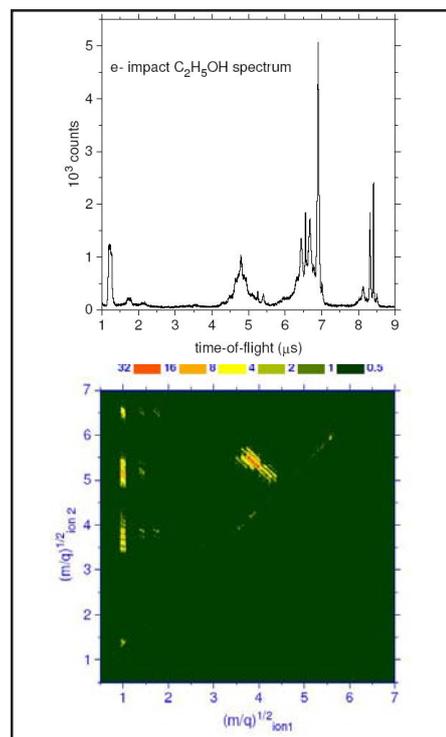
Fig 3: *Upper plot shows the mass spectrum of positive ions from ethanol under electron impact. The bottom plot shows the intensity distribution of ion-pairs detected in coincidence when multiply charged ethanol ions fragment.*

Of course, the partial cross-section for each ion species can also be separately had in the usual fashion. One can imagine extending this pair coincidence to triple and quadruple coincidences. The observation of multiple coincidence of ions is a direct evidence of formation of molecular ions with very high charge, which are inherently unstable. Such ions would not be detectable in an ordinary mass spectrometer!

Lifetimes of metastable ions

As noted above, most highly charged molecular ions are unstable, but some could be metastable, and may survive part of the journey from formation to detection. Take the example of CO_2^{2+}. It has several electronic states, some of which are metastable and may lead to dissociation into CO^+ and O^+. If a metastable CO_2^{2+} ion is formed, it will start moving towards the detector, while one of the electrons ejected
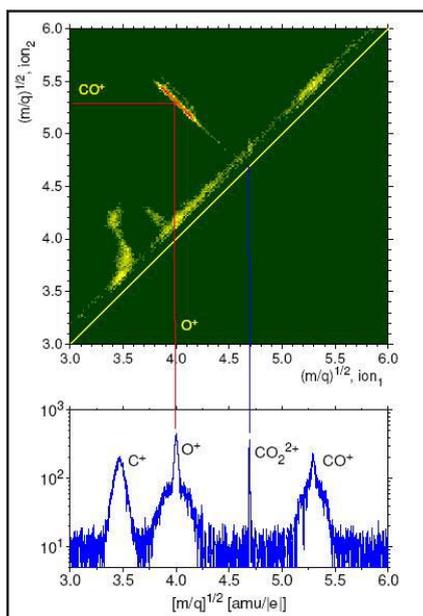
Fig 4: *The upper panel is a ion-ion coincidence map of CO$_2$ under electron impact. The main portion of the CO$^+$:O$^+$ coincidence island is due to spontaneous dissociation of CO$_2^{2+}$. Its tail is due to delayed dissociation of CO$_2^{2+}$, whose time-of-flight (provided it reaches the detector undissociated) can be read off the bottom panel.*

during its formation will starts our time-of-flight clock. It will dissociate on the way, resulting in O$^+$ and CO$^+$ ions. These will arrive at the detector at times which do not correspond to that of the ions which were born right at the ion source. A coincidence between the ion pair in a delayed dissociation will nonetheless be observed, but its 'island' will not match the standard [O$^+$:CO$^+$] coincidence island. Experimental data for this is shown in Figure 4. We see a long tail due to the delayed dissociation of CO$_2^{2+}$. The lifetime of this metastable CO$_2^{2+}$ state is determined from the intensity distribution in the island – it turns out to be 2.3 μs in this case.

Kinetic Energy Release

During the break-up of a molecular ion, the internal energy is converted to kinetic energy of the fragments. If the kinetic energy (or equivalently, the momentum) of each fragment arising from the break-up is determined *in coincidence, for each event*, then the kinetic energy release (KER) in the break-up can be determined. When a multitude of excited states participates in the dissociative ionisation process, the kinetic en-

ergy of fragments has a multi-modal distribution. The KER distribution is one-to-one map of excited state energy levels of the precursor molecular ion. Combined with the knowledge of
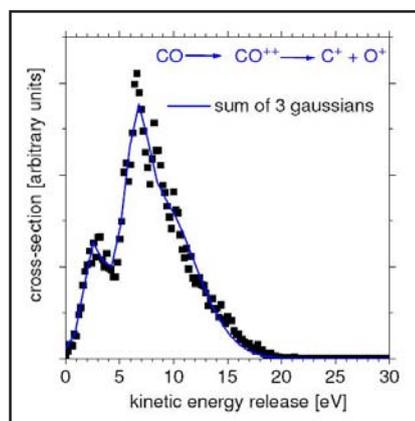
Fig 5: *Kinetic energy release in dissociation of CO^{2+}. The fit to the KER is a sum of three Gaussians, suggesting contribution from three excited states to the disscoication cross-section.*

the potential energy surfaces of the precursor, KER distributions give us a full picture of the dissociation energetics. Figure 5 shows the KER distribution for the dissociation of the CO^{2+} molecular ion. It has three components, suggesting the participation of three excited states. They can be identified, if the PE curves of CO^{2+} are known.

Geometry of Intermediate Excited States

In the RIMS method observing fragments of a dissociation, combined with ion-ion coincidence measurement, we determine the
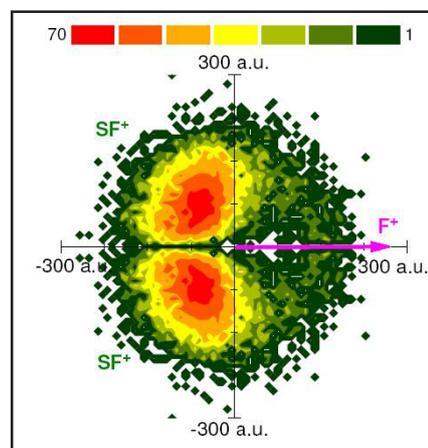
Fig 6: *Distribution of the momentum vector of SF$^+$ ions relative to the momentum vector of F$^+$ ions resulting from fragmentation of SF$_6^{2+}$.*

momentum vector of all fragments. The momentum vectors are signatures of the relative orientations of the ions *at the instant of the break-up*. In other words, the free angle between the momentum vectors of an ion pair is nothing but the bond angle between the departing ions. Let us look at the dissociative double ionisation of SF_6. The neutral molecule has an octahedral geometry (all S–F bond angles are 90^0). When it is doubly ionised, this geometry changes. The molecular ion is unstable, and leads to the formation of the $[F^+:SF^+]$ ion pair. In an experiment on this molecule undergoing dissociative ionisation by 1300 eV electrons, we determine the distribution of the momentum vectors of the two ions. This is shown as an intensity plot of the SF+ momentum vector relative to the direction of the momentum of F+ (Figure 6). One notes, that the angle between the two momentum vectors peaks at 120^0. This tells us that the SF_6 molecule has undergone substantial distortion during dissociative ionisation.

Summary

I hope you enjoyed this short tour of the RIMS method, and could appreciate its usefulness in studying dissociation dynamics of molecules. Just to recapitulate:

- ion-ion coincidence technique permits determination of fragmentation patterns

- lifetimes of metastable molecular ion states can be determined

- when combined with momentum analysis, great details of the fragmentation can be had, viz: excited state energy levels and bond angles can be estimated

- complete understanding requires calculation of PE surfaces of molecules

This technique has taken roots in many laboratories throughout the world. A few laboratories in India are also using variants of this technique. I hope many exciting results will come out of all our efforts.

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2. D. Mathur, *"Structure and dynamics of molecules in high charge states"* Physics Reports, Vol. 391, No. 1. (February 2004), pp. 1-118.

TOF and Momentum imaging techniques

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2. O. Jagutzki et al *Imaging Spectroscopy IV, Proceedings of International Symposium on Optical Science Engineering and Instrumentation*, Eds. M. R. Descour & S.S. Shen, Proc. SPIE **3438** 322 (1998). See also {http://www.roentdek.com}

3. R. Moshammer et al. Nucl. Instru. Meth. B **108** 425 (1996)

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A few recent papers using momentum spectroscopy for studying molecular dynamics

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2. Y. Muramatsu et al. Phys. Rev. Lett. **88**, 133002 (2002)

3. M. Tarisien et al. J. Phys. B **33** L11 (2000)

"The world little knows how many of the thoughts and theories which have passed through the mind of the scientific investigator have been crushed in silence and secrecy by his own severe criticism and adverse examination; that in the most successful instances not a tenth of the suggestions, the hopes, the wishes, the preliminary conclusions have been realized."

Michael Faraday (1791-1867)

[Faraday was an enthusiastic collector of engravings, lithographs, and photographs, particularly portraits. He developed lasting friendships with many of the leading artists of London and served as an advisor to the British Museum, National Gallery, and Westminster Abbey on the preservation of sculpture and architecture.]

Opportunities for Collaboration and Exchange between UK and Indian Scientists

Nigel John Mason

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> *The previous issue of the ISAMP News Letter* carried the **UK Delegation Report on AMO Activity in India**. *The article below is a supplimentary document to the above report detailing various collaborative opportunities between the two countries.*
>
> *We hope, readers would find the information below useful. The active links embedded in the article may be used to reach to the specific informetion centers.*
>
> *Editor, ISAMP N.L.*

Following the recent visit by the UK delegation to discuss opportunities for collaboration between UK and Indian Scientists in Atomic, Molecular, Optical and Chemical Physics (AMOCP) it is timely to review the opportunities for collaboration and exchange between UK and Indian scientists. There are a myriad of schemes that allow such collaborations to take place so only a brief summary will be given here of those most relevant to AMOCP, there are many others linked to medical/biological research and environmental research which will not be reviewed here. It should, however, be noted that many UK Universities/Institutes have (or are initiating) their own individual schemes for academic exchange, e.g. through their research centres; and many have private funds for university (PhD) studentships (e.g, funded by entrepreneurial activity or university funds supporting specialised research centres). Hence any Indian researcher contemplating a collaboration with a UK Institution should seek to develop initial links with a specific academic colleague in that institution who may have knowledge of local funding opportunities. Below we list a few of the more general schemes that may be used.

The UK-India Education and Research Initiative (UKIERI)

The UK Government has recently targeted India as a country with which it seeks to develop educational and research links (see the India-UK Government declaration of 2004). This programme is entitled '*The UK-India Education and Research Initiative (UKIERI)*'. The initiative was announced by the UK Prime Minister, Tony Blair, during his visit to India in September 2005 and was formally launched in the UK on April 18th 2006 by Prime Minister Tony Blair (see http://stories.indobase.com/article_4148.shtml) and will be organized by the UK's Foreign and Commonwealth Office (FCO), the Department for Education and Skills (DfES), the Office of Science and Technology (OST) and the British Council. *Over the next 5 years UKIERI aims to create a step change in the educational relations between India and the UK so that in the longer term the UK and India becomes each other's partner of choice in education. , and has a commitment of £10 million from the UK Government, which will be augmented by contributions from the business sector and the educational institutions involved.*

A conference on Research Cooperation between the two countries was held in Delhi (13th & 14th March 2006). Held in partnership with the University Grants Commission, India, the event discussed cooperation between university departments, research centres and individuals of excellence and involved mainly public institutions from India, central universities and research institutions. The conference 'addressed areas covering: existing collaborations, their successes and lessons learned; making a 'step change' in the India-UK relationship; sustainability; identifying 'blue skies' research of mutual interest and processes to identify and evaluate potential projects.'

This meeting was followed by a conference on 'Collaborative Programme Delivery also held in Delhi (16th & 17th March 2006). This conference involved prominent public and private sector organisations from across India: UGC, AICTE, universities, independent providers, and employers' representatives. It discussed all aspects associated with the collaborative

delivery of higher education programmes in India including current activities and reviewed the needs of the Indian sector and increasing demand for provision, and examine the regulatory environment in India.

The two principal activities of UKIERI will be promoting research partnerships between centres of excellence in science and social sciences, and developing joint and dual course delivery.

The UKIERI initiative has an emphasis on creating institution to institution links - establishing durable channels and vehicles for collaboration in the years ahead. Excellence will be the hallmark of the project and of the research collaborations funded. Project proposals will be evaluated rigorously according to research merit, potential for innovation and overall economic benefit, with subject areas drawn from science and technology, the social sciences and other areas of economic importance in the India-UK relationship.

The UKIERI initiative, particularly in its pilot phase, will support exchanges and visits, facilitating matchmaking between HE and research centres of excellence. Matched institutions, through a bidding process, will request support for research projects, staff and researcher exchanges, and the development of jointly delivered programmes, mostly at postgraduate level. Research cooperation projects will include staff secondments, exchanges of postdoctoral research fellows for periods up to 12 or 24 months, and support for postgraduate research students leading to split PhD awards. Collaborative delivery projects will include taught Master's courses (e.g. Business Studies, Engineering), and shorter postgraduate professional courses which may carry an award or CATS credit rating. Collaborative delivery projects will normally receive support for a three year project start-up period.

By 2011, the following minimum targets should have been met:

- 70 new collaborative research projects linking centres of excellence
- 40 new UK award programmes delivered collboratively in India with 2,000 Indian students enrolled
- 300 additional Indian research students, postdoctoral researchers and staff will have worked in the UK
- 200 UK researchers worked in India and 200 UK undergraduate students supported for studies in India
- 2,000 Indian research students completed research degrees in the UK through collaborative delivery

Further links:

http://www.hcilondon.net/india-uk-relations/india-uk-education.html

Full details will be on the British Council website in India shortly. www.britcoun.org/india

Other Funding opportunities:

1. Engineering and Physical Sciences Research Council (EPSRC) www.epsrc.ac.uk;

This is the main UK research council funding research in the physical sciences and covers the whole AMOCP remit . EPSRC has an international research portfolio and funds collaborative visits for example;
Visiting Fellowships – typically lasting from 1 month up to one year with full UK salary and travel costs. Short visits by UK academics to overseas countries – including India (http://www.epsrc.ac.uk/researchfunding/fundingopportunities/visitingresearchers.htm)

Workshops held both in UK and aboard. Currently plans for a series of AMOCP workshops between Uk and Indian research communities are being planned. .

EPSRC co-ordinated the INTERACT Scheme under which several UK teams have visited India in the past two years to review opportunities for collaboration and establish inter group links.

Applications to the EPSRC must be made by the UK host /organising team.

2. The Royal Society

http://www.royalsoc.ac.uk

Traditionally the Royal Society has with its Indian partners organised many visits by Indian Scientists through its Short visits programme and its Joint Projects scheme. The latter typically runs for two years and allows multiple visits lasting a 1-3 months. This scheme has often been used by more senior researchers but the Royal Society is seeking to encourage younger academics (recently appointed) to apply. The application is submitted by the UK host and requires a reference from the heads of both collaborating institutes as well as often one other

referee. It is very competitive scheme and often those applications that are unsuccessful are due to there not being a clear advantage to BOTH partners of such a collaboration. Indian researchers often do not demonstrate the lasting benefits to their own group of such a visit while UK team often seems to only be using Indian staff 'additional labour'. A younger Indian researcher/postdoc might be seen as benefiting more than the lead Professor from such 'knowledge transfer'.

Details Visiting Fellowships

http://www.royalsoc.ac.uk/funding.asp?id=2349

and
http://www.royalsoc.ac.uk/funding.asp?id=2118

3. Royal Society of Edinburgh;
http://www.royalsoced.org.uk/

With the establishment of the Scottish Parliament and hence some devolution from the London parliament Scotland is rapidly developing its own science and research programme. The main Scottish universities have formed consortia in both Physics and Chemistry funded by local parliament, therefore there are new opportunities for collaboration. The Royal Society of Edinburgh has funding to support collaborations (including overseas) with Scottish universities. Therefore should your UK partner be in Scotland you might explore these extra funding sources.

4. Leverhulme Trust.

One of the UK's largest charities funding scientific research. The Leverhulme trust has a wide variety of schemes with its Visiting Professors scheme being of particular note. In this case senior faculty are likely to be more successful than junior staff since one provision is often that the visiting academic give a series of lectures at the host institute (and other UK Universities with related research). There are also study abroad schemes which UK academics may use to spend extended time in India.

http://www.leverhulme.org.uk/grants_awards/grants/visiting_professorships/

5. Commonwealth www.acu.ac.uk

a. There are still many advantages of the old Imperial links (not just cricket!). There are a large range of scholarships and fellowships available fro a range of students and staff.

- Commonwealth Scholarships
- Commonwealth Academic Staff Scholarships
- Commonwealth Split-site doctoral Scholarships
- Commonwealth Academic scholarships
- Commonwealth Academic fellowships

b. Commonwealth Professional fellowships

Commonwealth Scholarship Commission provides support for Indian students to study at masters and postgraduate level in a UK university for one (exceptionally two) years. This is an excellent scheme if you wish to develop a joint PhD programme between your on group and your UK partner with your students being able to conduct pat of his/her studies using UK facilities applications are often made through the Indian office.

5. UNESCO

At a more general level there are academic exchange and training schemes offered by international agencies such as UNESCO. For UNESCO's basic sciences programme see http://portal.unesco.org/sc_nat/ev.php?URL_ID=1489&URL_DO=DO_TOPIC&URL_SECTION=201&reload=1049188728

Often it is possible to use more than more scheme and combine visiting times to lengthen a visit.

"Things are distinct not in their essence but in their appearance; in other words, in their relation to one to whom they appear. This is art, the truth of which is not in substance or logic, but in expression. Abstract truth may belong to science and metaphysics, but the world of reality belongs to art. "
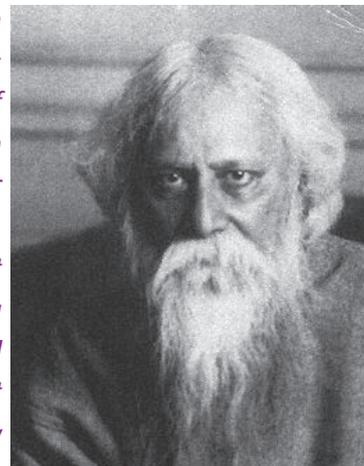
Rabindranath Tagore
(1861-1941)

IPA AWARDS - INVITATION FOR NOMINATIONS

Indian Physics Association invites nominations for the following prestegious awards for the year 2004-2006. Last date for receiving nominations is **July 15, 2006.**

More information is available on http://www.tifr.res.in/~ipa

SHRI MURLI M. CHUGANI MEMORIAL AWARD - 2004 FOR EXCELLENCE IN APPLIED PHYSICS

Instituted in the year 1998, the award is given to a scientist who has made outstanding contributions in the area of Applied Physics e.g. Engineering Physics, Aeronautics, Physics in Ballistic Missiles, Physics of satellites, Bio-Physics, Reactor Physics, Computers and associated technologies etc.

R.D. BIRLA AWARD - 2006

Instituted in the year 1980, the award is given to a scientist who has made outstanding contributions in Physics. Previous recipients of this prestigious award are Prof. A. Salam, Prof. B.V. Sreekantan, Prof. Subrahmanyan Chandrasekhar, Prof. R. Ramanna, Prof. Govind Swarup, Prof. Sivaramakrishna Chandrasekhar, Dr. P.K. Iyengar, Dr. R. Chidambaram, Prof. G.S. Agarwal, Prof. J.V. Narlikar, Prof. Ashoke Sen, Prof. Bikash Sinha and Prof. P.K. Kaw.

BUTI FOUNDATION AWARD - 2006 FOR EXCELLENCE IN THEORETICAL PHYSICS, ASTROPHYSICS AND BIOPHYSICS

Instituted this year, the award is given to a scientist who has made outstanding contributions in the area of Theoretical Physics, Astrophysics and Biophysics.

S. N. SESHADRI MEMORIAL INSTRUMENTATION AWARD IN PHYSICAL SCIENCES – 2006

The award would be for innovation and / or excellence in indigenous Instrumentation Development in Physical Sciences. The instrumentation shall involve a substantial amount of hardware. It can also include the add-on Instrumentation developed to increase the versatility and usefulness of sophisticated / complex systems. The Award carries a citation and a cash prize of Rs. 20,000/-.

Obituary

Professor Arvind Bhatnagar
1936-2006

Internationally renowned Solar physicist, Prof. Arvind Bhatnagar passed away on May 18, 2006 at Udaipur following severe cardiac and respiratory complications. He was the Founder-Director of the Udaipur Solar Observatory.

Born in Beawar, Rajasthan on 19th November 1936, he had his early education in Agra, Almora and Nainital. He obtained his Ph.D. degree in Solar Physics in 1964 from Agra University while working at the Kodaikanal Observatory under the guidance of Prof. M K. Vainu Bappu. He then worked as a Meteorologist in the India Meteorological Department during 1965-67. He was awarded the Carnegie Fellowship to work at Mount Wilson and Palomar Observatories, USA, during 1968-70.

In 1972, Prof. Bhatnagar returned to India to establish a unique island solar observatory in the middle of Lake Fatehsagar in Udaipur. Due to his efforts, the solar observatory was taken over by the Department of Space in December 1981 for speedy growth, and was affiliated to the Physical Research Laboratory, Ahmedabad. It is also one of the six observatories located around the world participating in the Global Oscillations Network Group (GONG) for the study of solar interior.

Prof. Bhatnagar was elected a Fellow of the prestigious National Academy of Sciences, India (Allahabad). He was a founder member of the Astronomical Society of India and a member of the International Astronomical Union. Prof. Bhatnagar was the founder Director of the Nehru Planetarium, Mumbai from 1976 to 1978, and advisor to many planetaria in the country, namely Jawahar Planetarium, Allahabad, Nehru Planetarium, Delhi, and Sardar Patel Planetarium, Baroda. He encouraged a number of young students to take up active interest in pursuing scientific activities and also guided several students during their research career.

(Editor, ISAMP Newsletter)

XVI National Conference on Atomic and Molecular Physics

Tata Institute of Fundamental Research, Mumbai
January 08 – 11, 2007

isamp

TIFR

Areas to be covered

High Resolution and Precision Spectroscopy
Laser Cooling and Trapping
Intense Laser – Matter Interactions
Quantum Optics
Ultrafast Dynamics
Photoionization
Electron – Atom / Molecule Collisions
Ion – Atom / Molecule Collisions
Collisions with Surfaces and Clusters
Molecular Dynamics
Exotic Atoms
Applications
Novel Techniques

Plenary Talks
Short Presenations
Thesis Presentations
Poster Sessions
Prof. S. N. Ghosh Award Talks

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R. Palit
R. G. Pillay

G. Ravindrakumar
L. C. Tribedi

C. S. Unnikrishnan
A. Venugopal (BARC)
S. Wategaonkar

Important dates: Registration: 1/09/06, Abstract Submission: 1/09/06., Request for support: 1/09/06
Contact website for relevant web-interfaces
Contact Address: Prof. E. Krishnakumar, Convener (XVI-NCAMP). TIFR, Homi Bhabha Road, Mumbai - 400 005

E-mail: xvincamp@tifr.res.in   Website: www.tifr.res.in/~xvincamp
Conference Secretary: Vinay Bhonsle, E-mail: vinay@tifr.res.in

Professor SN Ghosh Award for Young Scientists
To download the nomination form click on the link: SNG_Award.pdf

International Conference on Lasers and Nanomaterials (ICLAN)

(150 years Celebration of University of Calcutta)
Department of Physics, University of Calcutta

November 30 - December 2, 2006

RajaBazar Science College, C.U.
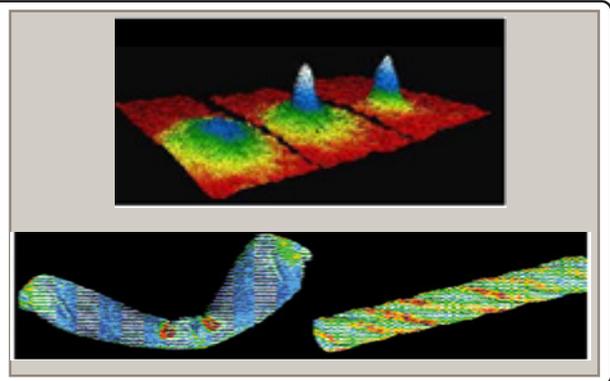
About the Conference

The department of physics started its journey with renowned scientists like S. N. Bose, M. N. Saha and C. V. Raman. The present activities of the department are described in the homepage of the University. The new statistics formulated by Bose led to the concept of Bose Einstein Condensation (BEC). Since its experimental realization in 1995, the subject has been an important field of research. The conference based on the emerging topics of laser physics, nanomaterials and on their interfaces will be the first of its kind in our country and will be part of the hundred fifty years celebration of the University of Calcutta.

Topics to be covered

A. LASERS

i.   Quantum Optics
ii   Laser Cooling and Atomic Physics
iii. Bose-Einstein Condensation (BEC)
iv. Nano-optics
v.   Laser Spectroscopy
vi. Laser Instrumentation

B. NANOMATERIALS

i.   Novel Nanomaterials
ii.   Synthesis and Characterization
iii. Photonics and Plasmonics
iv.   Low dimensional properties
v.   Nano-device and its application

The conference will comprise of invited talks and contributed papers (mainly as posters).

Important Deadlines

1. For abstract submission   **31.08.2006**

2. For registration   **31.08.2006**

Note: *Acceptance of the abstract for the poster will be notified by*   **28.09.2006**

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http://www.caluniv.ac.in/news/seminar_frame1.htm
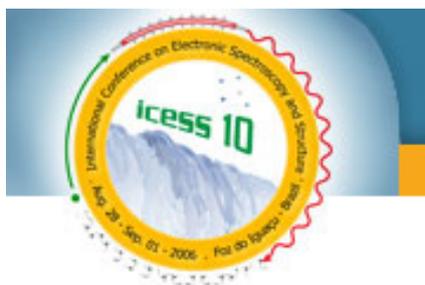
International Conference on Electronic Spectroscopy and Structure

ICESS-10 in Foz do Iguaçu, Brazil

28th August to 1st September 2006

http://www.lnls.br/icess10

The program involves applied and fundamental experimental research, theory development, as well as industrial research. Here are some of the scientific topics covered:

- Photoelectron and Auger spectroscopies in all forms, including resonant excitation/deexcitation processes.

- Electron spectroscopies involving atom or ion deexcitation.

- Related soft x-ray emission and near-edge x-ray absorption spectroscopies , as well as resonant elastic and inelastic x-ray scattering, and x-ray optical measurements.

- Electron-energy-loss spectroscopies at low and high energies, including electronic and vibrational excitations.

- Photon- and electron-based spectro-microscopies and microspectroscopies , including those using laboratory x-ray and synchrotron radiation sources, electron beams, and energy loss in electron microscopes.

- Excitation cross-sections, relaxation effects, and many-electron phenomena.

- Measurements with variable light polarization, spin detection, and time resolution; "complete" experiments of various types.

- Coincidence spectroscopies using electrons.

- Photoelectron, Auger electron, and other electron-based diffraction and holography; x-ray fluorescence holography.

- Scanning tunneling spectroscopy and related electronic spectroscopies.

- New developments in both laboratory and synchrotron radiation instrumentation.

- New theoretical approaches for describing electronic structure and dynamics, as well as for interpreting experiments.

- Femtosecond and attosecond spectroscopies.

- Harmonic generation and Free electron laser research applied to diluted samples.

- Applications of the above to atoms, molecules, liquids, surfaces/interfaces, nanostructures, clusters, catalysts, environmentally relevant problems, novel and complex materials, strongly correlated and magnetic materials, biological systems, and industrial analytical problems.

Deadlines

New date for submission of abstracts	**May 15th, 2006**
Early Registration	**July 7th, 2006**
Hotel Registration	**July 14th, 2006**

Conference Co-chairs directions:

Arnaldo Naves de Brito (Brazil)
arnaldo.naves@uol.com.br, arnaldo@lnls.br

George G. Kleiman (Brazil)
kleiman@ifi.unicamp.br

Jonder Morais (Brazil)
jonder@if.ufrgs.br

Satellite meeting
International Symposium
Scattering, Coincidence and Absorption Studies of Molecules (SCASM)
Rio de Janeiro, Brazil, September 4-6, 2006
a sattelite symposium of ICESS 10

http://server2.iq.ufrj.br/~scasm2006/

Miscellaneous

JOB OPENING:

Solar Postdoctoral Scholar at California State University Northridge

The Department of Physics and Astronomy at California State University Northridge (CSUN), invites applications for a post doctoral position. The appointment will begin in the Fall 2006 semester. To be considered, candidates must be in possession of a doctorate in Physics, Astronomy, or other closely related field. Candidates are expected to participate in a vigorous research program in experimental solar astrophysics conducted at San Fernando Observatory and the Department of Physics and Astronomy of California State University Northridge.

RESPONSIBILITIES:

The specific duties for this post will include the observation and data analysis of magnetic field of solar active regions using various instruments at San Fernando Observatory, National Solar Observatory and Solar-B telescope. Preference will be given to the candidates with prior experience with observations planning and campaign coordination. Familiarity with the IDL and / or LabView programming environment is desired.

Applicants should submit

(1)   a curriculum vitae,

(2)   a statement of current research interests and pursuits,

(3)   arrange to have three letters of recommendation sent to:

Dr. Debi Prasad Choudhary
Department of Physics and Astronomy,
California State University Northridge,
Northridge, CA 91330-8268.
     (Phone: 818 6777113)
debiprasad.choudhary@csun.edu.

Evaluation of applications will begin in early August 2006. California State University Northridge is an Equal Opportunity/Affirmative Action, Title IX, Section 504 Employer.