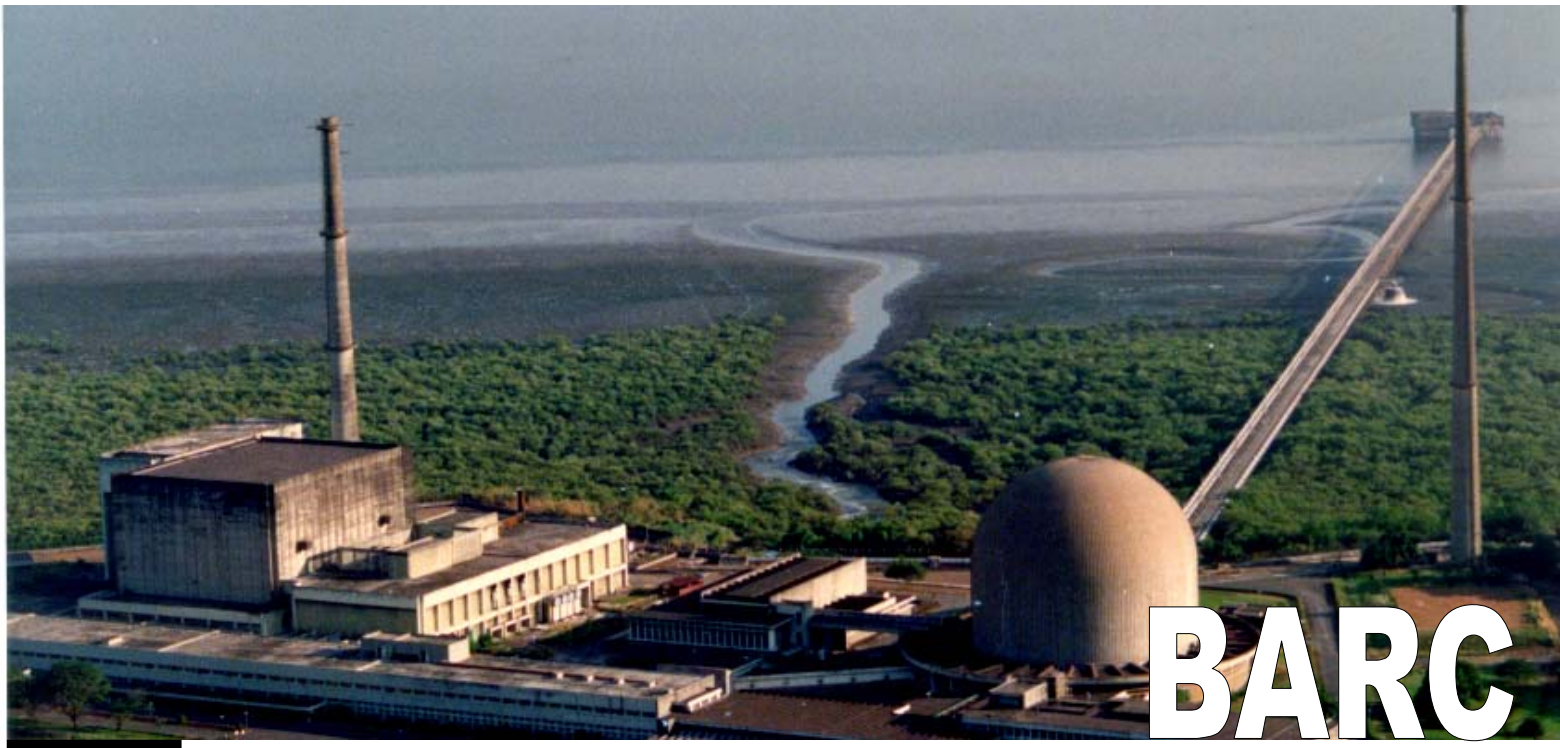

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TIME OF FLIGHT MASS SPECTROMETRY FOR THE STUDY OF LASER INDUCED PHOTOCHEMICAL PROCESSES IN MOLECULAR BEAMS

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Introduction

The field of gas phase photochemistry has progressed explosively in the past few decades due to the development of ultra fast high power lasers. Unique properties of lasers such as monochromaticity, coherence, tunability over a wide wavelength range and high intensity makes them a powerful pump and probe tool for a number of spectroscopic as well as photochemical studies like laser induced fluorescence, photoacoustic spectroscopy, laser ionization spectroscopy, etc.

Lasers coupled with mass spectrometer (also called laser mass spectrometry) find wide application in photochemical studies for identification of different ions formed due to photoexcitation/ionisation of gaseous molecules by laser. Here, laser is used as an ionization probe, while mass spectrometers, due to their high mass and ion sensitivity, are used for detection of different ionic species formed during laser-molecule interaction. Though different types of mass spectrometers are used for photochemical studies, Time of Flight Mass Spectrometer (TOFMS) is the instrument of choice for laser spectroscopy due to its versatile features. In this article, we present principle of TOFMS followed by a brief description of the laser Ionization-

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TOFMS setup which has been designed, fabricated and installed in Chemistry Division, BARC. Finally, we give an overview of studies carried out on different class of molecules, introduced in the form of a molecular beam, using this apparatus.

Principle of Time of Flight Mass Spectrometer

Mass selection in TOFMS is achieved by accelerating the ions with different *m/z* values, formed upon ionization, to identical kinetic energies and allowing them to separate due to their mass-dependent velocities. Thus, ions with different *m/z* value reach the detector at different times. Ions with lower mass reach the detector faster than the higher mass ions [1]. This principle of *separation-in-time* is unlike the *separation-in-space* principle which is used in magnetic sector and quadrupole spectrometers.

For an ion with mass to charge ratio *(m/z),* the time *(t)* spent in the flight tube (drift region) of length *D* upon acceleration is given by the expression-

$$t_{\text{flight}} = \frac{D}{\text{v}_{\text{ion velocity}}} = D\,(m/2zeV)^{1/2}$$

Here, *V* represents the accelerating voltage applied in the ion source region and is same for all the ions and ze is the charge of the ions. Thus, depending on the *m/z* values, the flight time for different ions is different, thereby, facilitating the mass separation. After the flight tube, ions are detected by a charged particle detector, like micro-channel plate detector and the mass spectrum is recorded as a function of flight time. The resolution of TOFMS is given by the relation :

$$\text{R} = \frac{t_{\text{flight}}}{2\Delta t_{\text{FWHM}}}$$

Here t_{flight} is the flight time of the ion while Δt_{FWHM} is the full-width at half-maximum of the ion peak. From the above expression, it is clear that the mass resolving power is restricted by the small difference in the measured flight-times for the ions of the same mass. This difference arises due to initial spread in molecular velocity along with spatial and temporal distribution of ions prior to acceleration. Thus, the resolution of TOFMS can be improved by minimising the spread in molecular velocity with the help of molecular beam, whereby the velocity spread in TOF direction is minimal. Temporal distribution can be reduced by using ultrashort laser pulses. Additional improvement in resolution can be achieved by space focusing of the ions produced in the finite ionization volume using Wiley-Mclaren technique [2]. For linear time of flight mass spectrometer, a maximum resolution of few thousand (1000-5000) can be obtained by careful design. But, the kinetic energy distribution of the ions, which is inherent in the ionization process, is difficult to eliminate.

To increase the resolution of the instrument further, Mamyrin and Shmikk [3] formulated reflectron principle for the energy focusing of the ions. This led to the birth of reflectron time of flight mass spectrometer (R-TOFMS). The reflectron compensates for the kinetic energy distribution by ensuring that ions with different kinetic energy (but with same mass) reach the detector at the same time. This is achieved by placing a reflectron (an assembly of grids with parabolically increasing retarding potential) at the end of drift region. The faster ions in a given ion packet penetrate deeper into the grid before getting reflected back, thus taking longer time to travel in the reflectron assembly, while the slower ions on the other hand penetrate less and thus have a shorter trajectory in the grids. This leads to energy focusing as well as an increase in the overall flight length as the ion packet reaches the detector after getting reflected by the retarding field. Both these factors significantly improve the resolution. Thus, for a R-TOFMS, a resolution of 5000-10,000 can be easily obtained. With small and well defined ionization volumes, high resolution detector and faster data processing electronics, mass resolution of 20,000-50,000 are achievable.

Molecular Beam

When molecules of interest, seeded in inert carrier gas (pressure =1-10 bar), are expanded through a small nozzle into a vacuum chamber (~ 10^{-5} bar or below), a jet is formed. During expansion, the random motion of the gaseous mixture is converted into directed flow, thereby reducing the translation, rotational and vibrational temperature of the molecule to few Kelvin. Also, the mean free path of expanding gases downstream from the nozzle quickly becomes sufficiently large for intermolecular collisions. Under these conditions, collimating slits (or a skimmer) are placed in the expansion region to create a well defined beam of molecules. Such molecular beams have a small angular divergence. By interacting the molecular beam with laser pulse beam from orthogonal direction, better spectral resolution is possible. Due to adiabatic expansion, Doppler width of spectral lines is greatly reduced and the possible effects of collision- (or pressure-) broadening are almost eliminated [4]. Such molecular beams are widely used to carry out high resolution spectroscopic studies on isolated molecules in collision free environment.

Instrumentation

A schematic diagram of the molecular beam assembly coupled with linear time of flight mass spectrometer setup, designed, fabricated and installed at our lab for carrying out photochemical studies on gas phase molecules, is shown below in Fig. 1. This system consists of three interconnected vacuum chambers, i.e sample introduction chamber, ionization chamber and flight tube, which are differentially pumped. During experiments, this entire system is maintained under vacuum of ~10^{-6} torr or better.

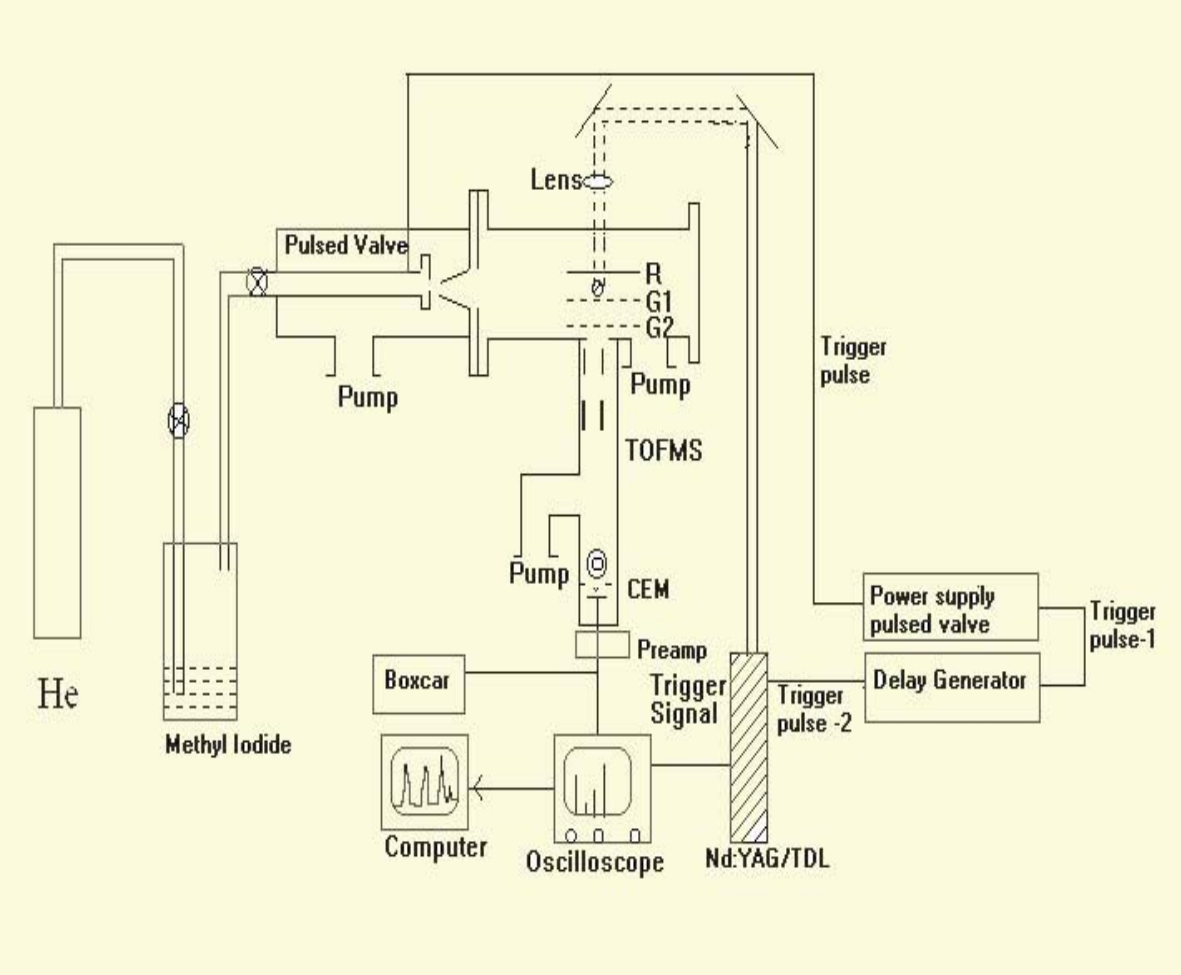


Fig. 1 : Schematic diagram of Time of Flight Mass Spectrometer

The ion optics of this instrument comprises of Repeller and Extraction grids and is based on Wiley-McLaren double focusing principle. In addition, deflection plates (horizontal and vertical), Einzel lens are also used for guiding the ions through drift tube and focussing them on the detector. Drift region is a simple SS tube of 1 meter length and 78 mm diameter. Detection system comprises of charged particle detector like Micro Channel Plate (MCP) or Channel Electron Multiplier (CEM). The resolution of this instrument is ~500 [5,6]. A digital delay generator is used to synchronize the temporal overlap of laser pulse with molecular beam. A typical experiment is carried out in following way.

A trigger pulse T1 from delay generator activates the pulse valve to inject the gas pulse in the expansion chamber. After 600 μs (typical time taken by the gas pulse to reach ionization chamber), the delay generator provides another trigger T2 to the laser system which fires the pulse. By varying the delay between trigger signal TI and T2, different portions of the molecular beam can be scanned. The ions formed by laser ionization are repelled towards detector using a combination of extraction field (~ 500 volts/cm) and acceleration field (~1700 volts/cm). After traveling through the ion optics and flight tube, the ions hit the detector and generate a signal in the form of pulsed electrical output. This signal is then fed to a fast preamplifier (rise time ~ 1 ns, gain ~100) whose output is given to digital storage oscilloscope for averaging and further data processing. Fig. 2 shows a close up view of Time of Flight Mass Spectrometer.

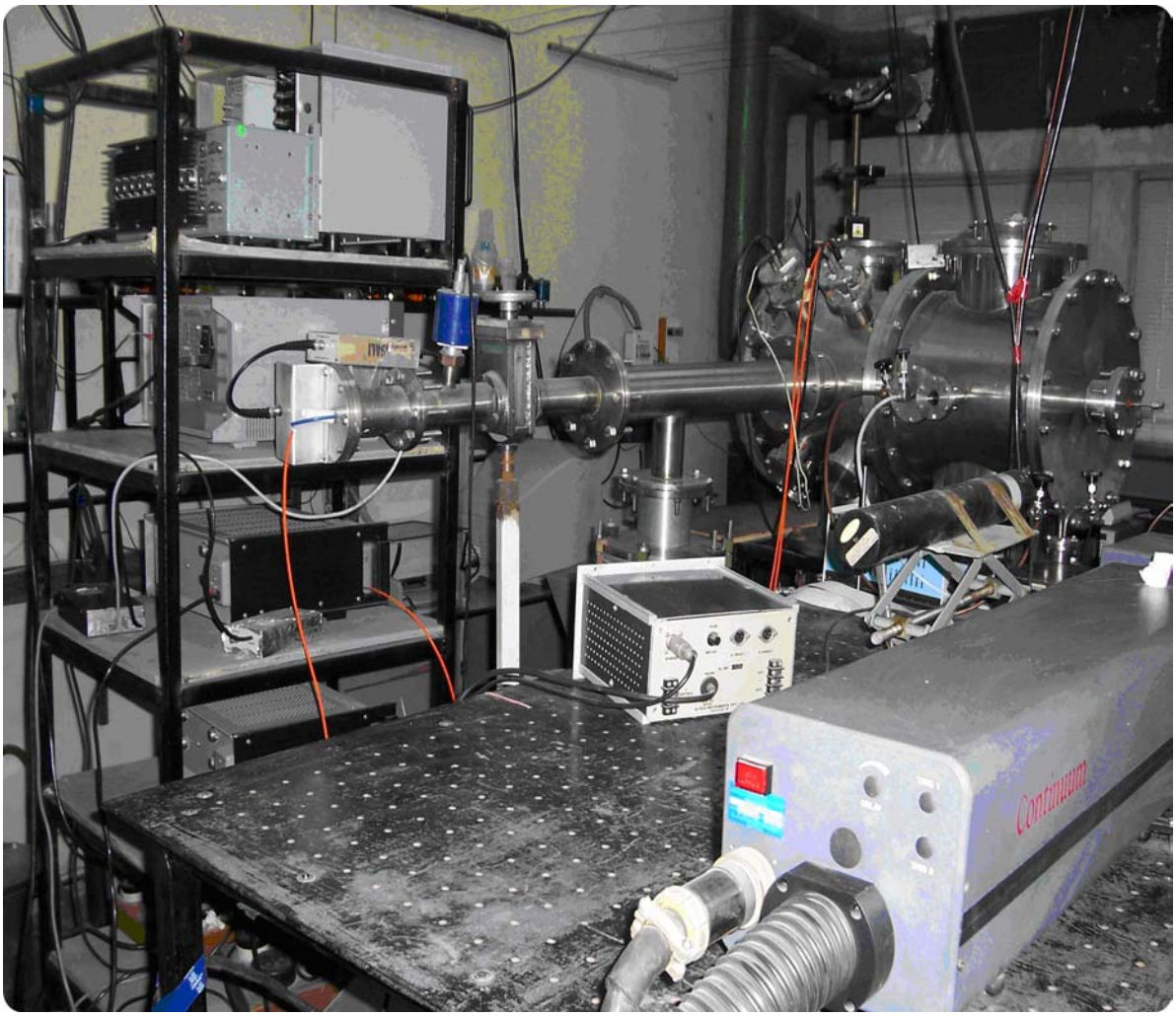


Fig.2 : Lab view of time of Flight Mass Spectrometer designed and fabricated at Chemistry Division

Single-photon ionization of molecules requires short-wavelength photons (UV or VUV), but multiphoton ionization (MPI) of molecules by visible light has been made possible due to the advent of lasers. Here, the photodissociation/ photoionization is the result of a single molecule absorbing many photons from the UV/visible laser pulse, and as a result of this, the yield of ionic product has a strong nonlinear dependence on light intensity; that is why it is called "nonlinear photochemistry" [7]. In the present set-up, multiphoton ionization of gas phase molecules is carried out using pulsed Nd:YAG pumped dye laser system so as to produce the photons of variable energy. Due to their pulsed nature, lasers mate well with TOF instruments. Also, deposition of large amount of well defined energy in a very short period makes lasers ideal for efficiently producing ion bursts compatible with TOFMS.

Gas Phase Photochemistry

Some of the basic questions which need to be understood for gas phase photochemistry using such a equipment are listed below :

i. Which neutral species are produced by laser induced photodissociation?
ii. Which are the different ionic species produced during the interaction of laser pulse with the isolated gas molecules?
iii. Which energy level of the species is excited and how many photons are used for this purpose?
iv. How does multiphoton and single-photon photochemistry differ for the same mean excitation energy?

These studies are vital to understand the energetics, reaction dynamics, kinetics and energy transfer processes that occur in the excited molecules. Using the above set-up, nonlinear photochemistry of various atmospherically important molecules like- $CFCl_3$, $CHCl_3$, CH_3COCH_3, CH_2Br_2, CH_2Cl_2, CH_3SCH_3 and CH_3SSCH_3 has been investigated. Due to the presence of several different spectroscopically accessible excited electronic states of CH_3I and their different dissociation/ ionization dynamics, CH_3I is an interesting molecule for photochemical studies. We have carried out photochemical studies of CH_3I and its clusters in the UV and visible region using tunable pulsed laser. Some of the important results obtained from our studies are briefly presented below.

Photodissociation of halocarbons

Chlorine and bromine radicals are regarded as the major catalysts for stratospheric ozone destruction that has occurred over the past few decades. The synthetic chemicals, which are major source of halogens, are the chlorofluorocarbons (CFCs) and halons. CFCs are highly stable compounds containing carbon, chlorine and fluorine. They are nonflammable, low in toxicity, and inexpensive to produce. Over the time, CFCs have found wide use as refrigerants, solvents, foam blowing agents, and a number of other applications. All of these compounds have atmospheric lifetimes long enough to allow them to be transported by winds into the stratosphere. CFCs release chlorine or fluorine radicals on exposure to strong UV radiations in the upper atmosphere which react with ozone molecule causing major damage to the protective ozone layer. In addition to CFCs, approximately 20% of stratospheric chlorine and 50% of stratospheric bromine originate from halomethanes. The atmospheric behaviour, sources and sinks of these halomethanes are not well understood. With a view to understand the photodissociation behaviour of these compounds, nonresonant laser-induced multiphoton dissociation/ ionization studies have been carried out for $CFCl_3$ (CFC-11), $CHCl_3$, CH_2Cl_2 and CH_2Br_2 at 355 nm using Time of Flight Mass Spectrometer.

The fragment ions observed in case of $CFCl_3$ were C^+, CF^+, Cl^+, CCl^+ and $CFCl_2^+$. For $CHCl_3$ peaks due to C^+, CH^+, Cl^+, CCl^+, $CHCl^+$ and

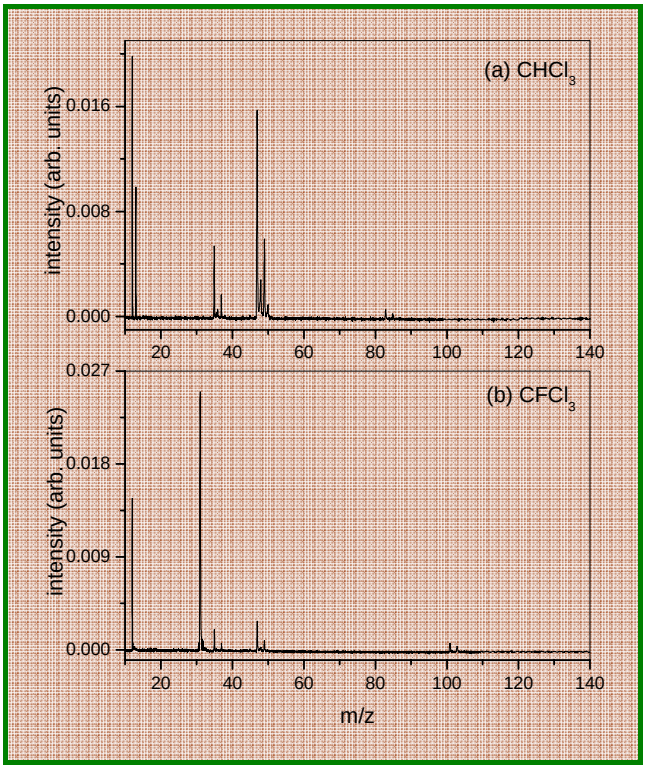


Fig.3 : Time of flight mass spectra of $CHCl_3$ and $CFCl_3$

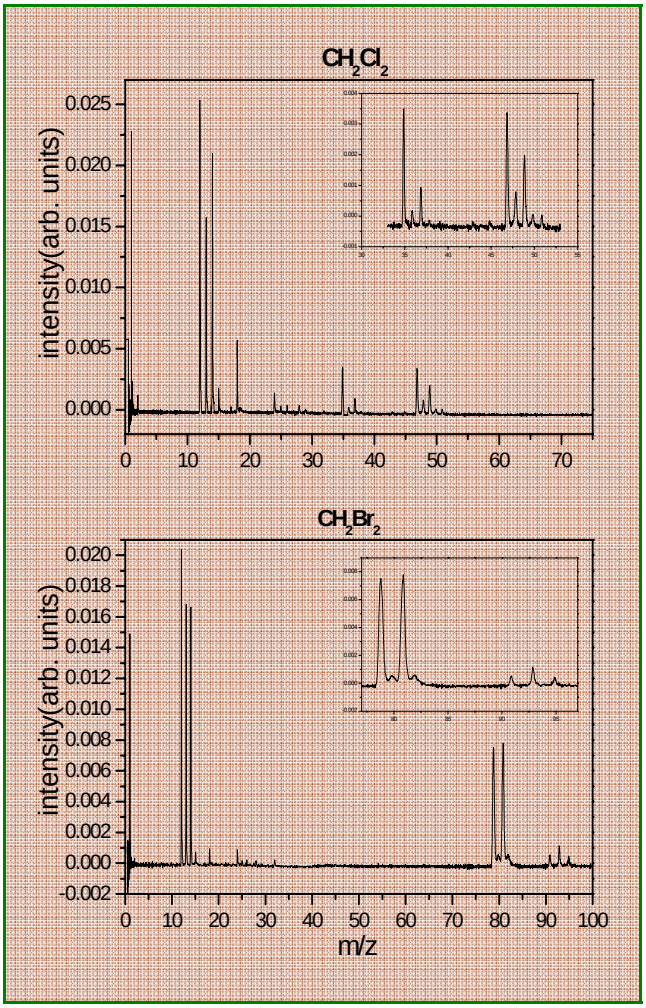


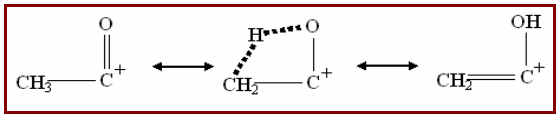
Fig.4:. Time of flight mass spectra of CH_2Cl_2 and CH_2Br_2

$CHCl_2^+$ were observed (Fig.3). Both the molecules have quite similar ionization pattern except for the fact that $CFCl^+$ was not observed for $CFCl_3$, whereas $CHCl^+$ was observed for $CHCl_3$ [8]. For CH_2Cl_2 and CH_2Br_2, the major fragment ions observed in the mass spectra were H^+, C^+, CH_2^+, X^+, CX^+ and CH_2X^+ (X=Cl or Br) (Fig.4). Parent ion signal was found to be missing for all these compounds and almost similar fragmentation behaviour was observed for analogous compounds. Based on the relative abundance of different fragments ion, absence of parent ion signal and the reaction energies calculated using ab initio methods, it was inferred that on multiphoton excitation at 355nm these molecules undergo fast dissociation into radicals via sequential multistep halogen atom elimination followed by ionization of the resultant fragments [9].

Isomerisation study of acetyl ion

Ketones such as acetone, ethyl methyl ketone, diethyl ketone are widely used as industrial solvents. Though these molecules are easily decomposed in the troposphere, it is of interest to know the various reactive transient species and intermediates which are generated by these molecules. We have investigated the multiphoton ionization/ dissociation of these molecules at 355 and 532 nm using TOFMS [6].

Time of flight mass spectrum of acetone molecule photoirradiated at 355 nm is shown in Fig.5. Peaks at *m/z*=12-15 & 24-27 could be assigned to $C_nH_m^+$ type (n=1-2, m=0-3) of species. While peaks at *m/z*=28, 29 and 43 were assigned to CO^+, CHO^+ and CH_3CO^+ ions. Under high laser fluence the *m/z* =43 peak showed a bimodal distribution which has been assigned to two different isomeric product channels, one having a keto and the other an enol form as shown below.



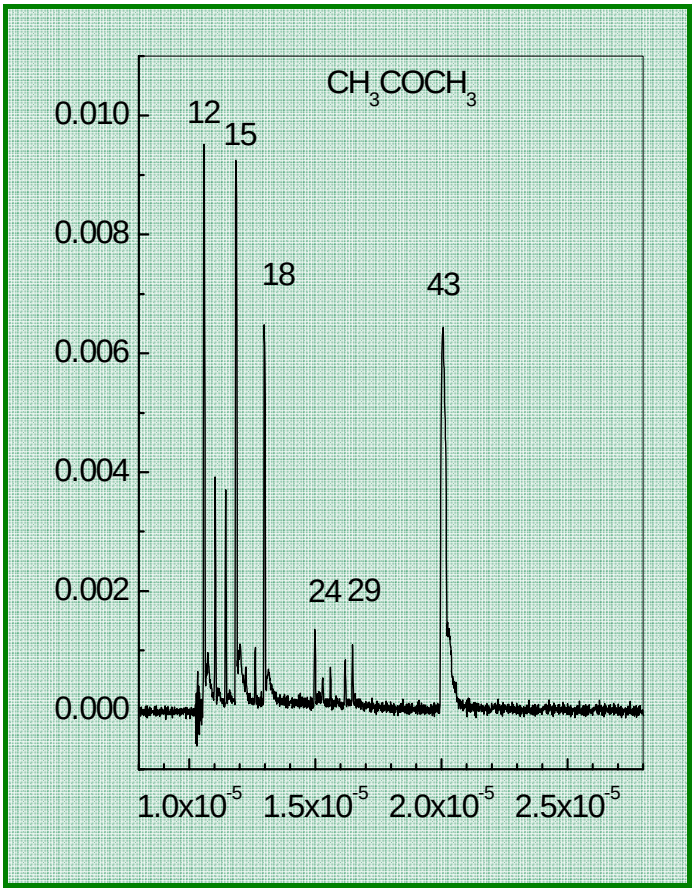
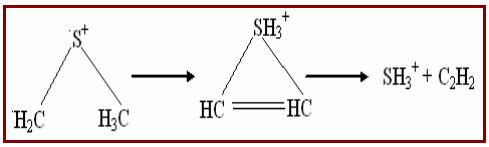


Fig.5 : Time of flight mass spectra of acetone recorded at 355 nm. Broad peak at m/z=43 is due to contribution from keto and enol form of CH_3CO^+

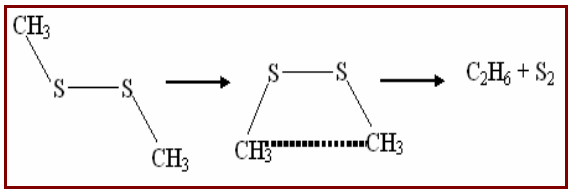
The keto form of CH_3CO^+ leads to generation of CO^+ while the enol form leads to generation of CHO^+ upon photodissociation, which was further confirmed using deuterated samples. Based on laser power dependent studies and absence of ion signal at *m/z* =58 due to molecular ion, it was concluded that molecular ions produced upon photoionization at 355nm undergo photodissociation by absorption of additional photons from laser pulse.

Study of transient species SH_3^+ and CHS^+ formed during multiphoton dissociation/ ionization of sulphur containing organic compounds

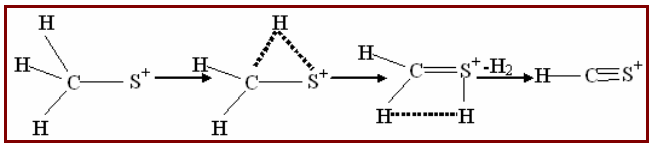
Dimethyl sulphide (CH_3SCH_3, DMS) and dimethyl disulphide (CH_3SSCH_3, DMDS) are important precursors in the atmospheric sulphur chemistry cycle that contribute to the formation of acid rain. Hence, it is of fundamental importance to identify their wavelength dependent dissociation channels and characterize the intermediates which take part in sulphur chemistry cycle. With this view, photodissociation/ionization studies were carried out for dimethyl sulphide and dimethyl disulphide. The major fragment ions observed for CH_3SCH_3 at 355 nm are C^+, CH_3^+, HCS^+, CH_2S^+, CH_3S^+ and $CH_3SCH_3^+$ (Fig.6b) [10]. However, during 532nm photoionization process, no parent ion signal could be observed. The signal at *m/z*=35 was assigned to SH_3^+ which originates from $CH_3SCH_2^+$ via a cyclic transition state as shown below :



For dimethyl disulphide, the prominent peaks in TOFMS have been assigned to CH_3^+, S^+, CHS^+ and S_2^+ with CHS^+ being the most intense signal (Fig. 6a) [11]. No evidence for the formation of molecular ion signal was observed under our experimental conditions. An additional ion signal observed at *m/z*= 30 suggested concerted elimination of ethane from the excited state of neutral CH_3SSCH_3 via a cyclic transition state generating C_2H_6+ S_2 as shown below :



The fragmentation results suggest that multi-photon dissociation of DMS and DMDS at 355 proceeds via cleavage of C—S and S—S bonds. Based on the similar results obtained for the formation of HCS^+ ion for both DMDS and DMS, it has been inferred that the CH_3S^+ isomerises to form CH_2SH^+, which undergoes H_2 elimination by unimolecular decay to produce HCS^+.



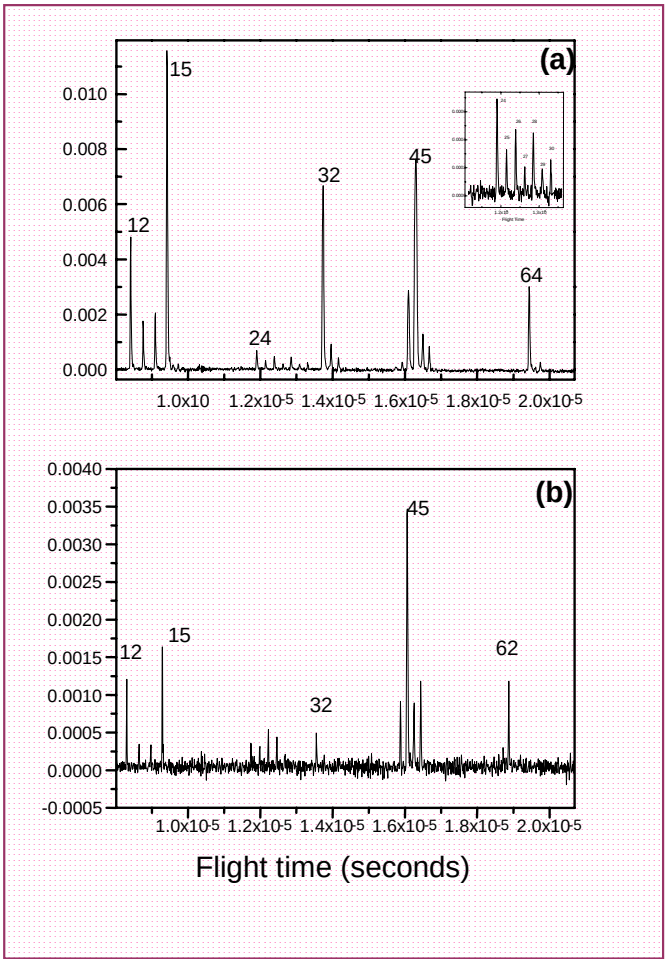


Fig. 6: Time of flight mass spectra of (a) DMDS and (b) DMS recorded at 355 nm

Ã and C State mediated photodissociation/ photoionization of CH_3I in visible and UV region

Photodissociation dynamics of CH_3I varies with the excited electronic state, i.e., valence Ã state or the higher energy Rydberg B, C and D states (Fig. 7). With a view to understand its dissociation dynamics, time of flight mass spectrometric studies on CH_3I were carried out at different wavelengths in the UV (355, 266 nm) and visible region (532 nm) (Fig. 8). At 532 and 355 nm CH_3I monomer undergoes three or two photon resonant-multiphoton ionization (MPI), respectively. Under low laser intensity, the mass spectra showed peaks at *m/z* = 15, 127 and 142 corresponding to CH_3^+, I^+ and CH_3I^+ species at both these wavelengths. The laser power dependence for CH_3I^+, I^+ and CH_3^+ ions showed a three-photon dependence at 532 nm. For the same three ions, photoionization studies at 355 nm gave a power dependence of 2. Both these results suggest that an electronic energy level at ~ 7 eV corresponding to the Rydberg C state of methyl iodide acts as the resonant intermediate state for the ionization of CH_3I. At these wavelength fragment ions observed in mass spectra mainly arise due to photodissociation of parent ion due to bound nature of Rydberg C state. Additional experiments at 266 and 282.1 nm, which access the Ã band directly via one photon transition, showed absence of parent ion. Here the mass spectra showed peaks corresponding to CH_3^+ and I^+ only. Due to dissociative nature of Ã band, at 266 and 282.1 nm CH_3I molecule first undergoes dissociation to CH_3 and I radicals which are then subsequently ionized by the laser pulse [12].

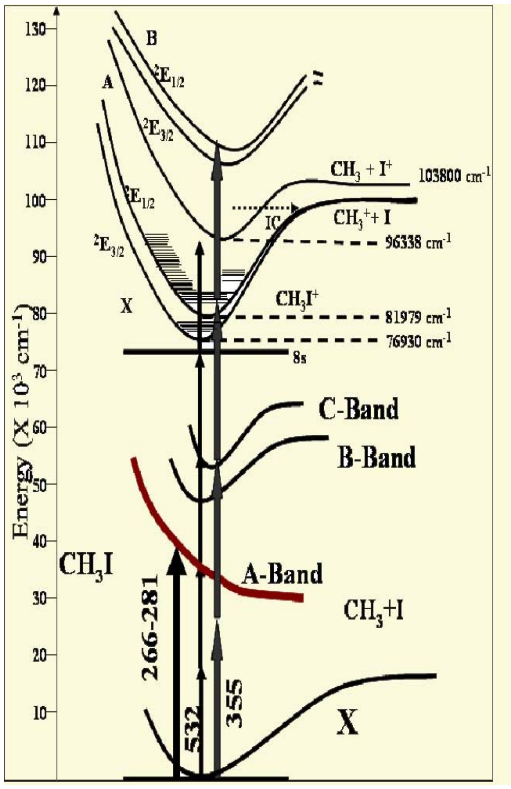


Fig. 7 : Energy level diagram of methyl iodide

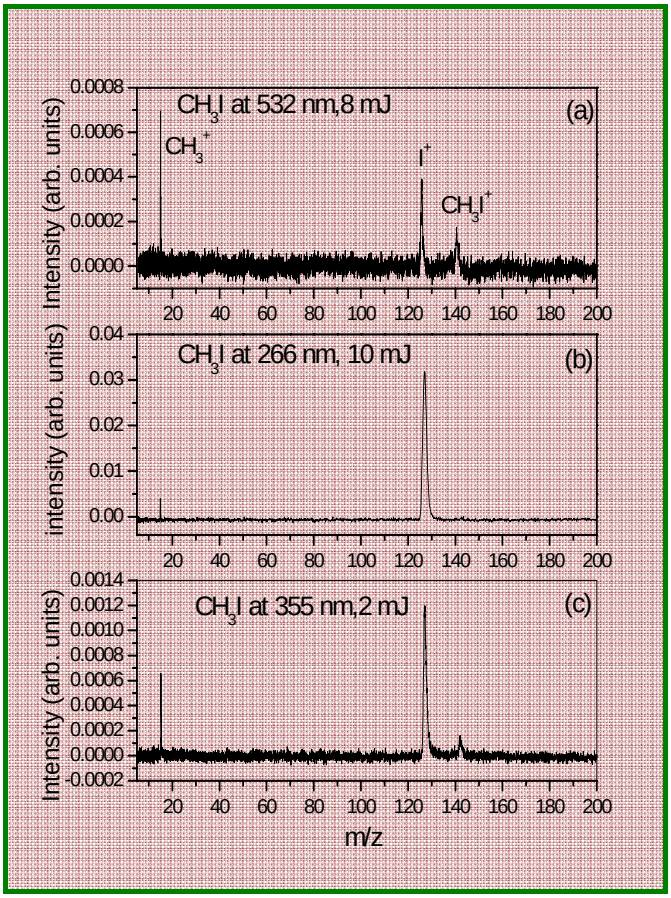


Fig.8 : Time of flight mass spectra of methyl iodide at 532, 266 and 355 nm

Photodissociation/photoionization studies on clusters

During the last decade, the interest in gas phase molecular spectroscopy has extended from molecules to molecular systems held together by weak Vander waals forces (i.e. molecular clusters). These weak interactions lead to solvation phenomena in the liquid phase and influence the chemical reactivity in solution. With a view to understand the photochemical behaviour of Vander waals clusters, we have carried out multiphoton ionization studies on clusters of CH_3I and acetone at different wavelengths.

For methyl iodide clusters, photoexcitation studies were carried out at different wavelengths in the UV and visible region. It was found that in the UV region, the clusters undergo fragmentation and only lower clusters are observed in the TOFMS. Using longer wavelength photons, we could detect larger clusters upto $CH_3(CH_3I)_8^+$ (Fig. 9).

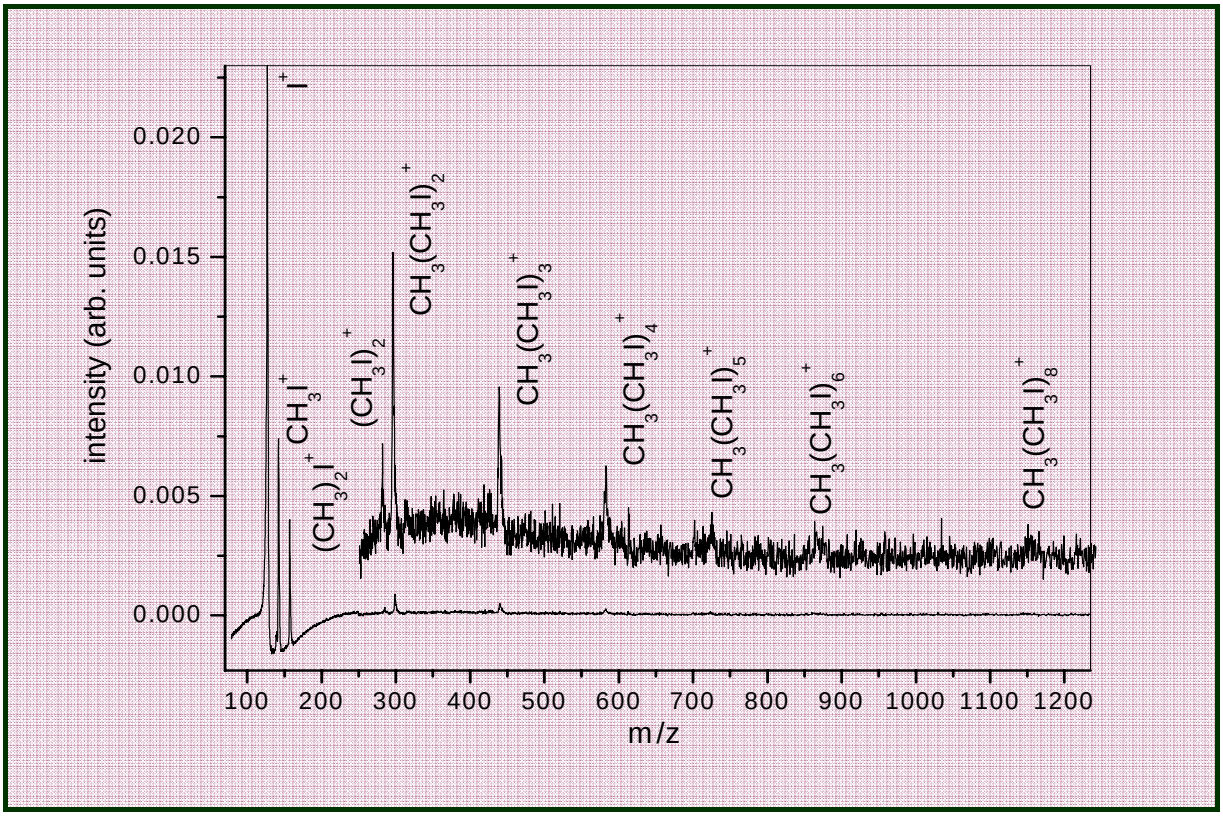


Fig.9 : Methyl iodide cluster fragments detected upon irradiation by 563 nm laser pulse

For 266 nm excitation of these clusters, peaks corresponding to CH_3I^+ and its dimer cation were observed. The higher mass peaks were absent. An additional peak at *m/z*=254 due to I_2^+ ion was observed. This peak has been found to originate due to intracluster reaction. These results show that photochemistry of clusters is highly dependent on wavelength. For studies carried out on mixed clusters of CH_3I-acetone, acetone was found to solvate the methyl iodide molecule resulting in the formation of clusters of type: $[(CH_3COCH_3)_n(CH_3I)CH_3]^+$ (n=1-4).

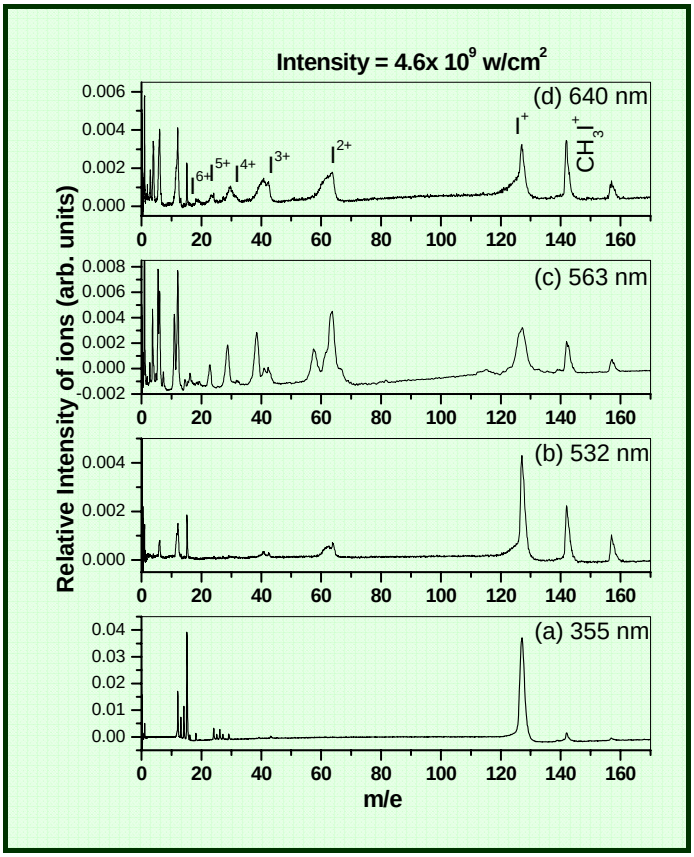


Fig.10 : Wavelength dependency of Coulomb explosion phenomena

Observation of Coulomb explosion phenomena in Methyl iodide Clusters

Interaction of intense laser pulses with molecular clusters has lead to several interesting phenomena including Coulomb explosion, leading to the generation of higher order harmonics, energetic electrons, multiply charged ions and even neutrons [13]. Coulomb explosion in clusters occurs due to the stripping of a large number of electrons by intense laser field and the high positive charge on the cluster leads to its disintegration and creation of positively charged ions with significantly large kinetic energy. In the past, laser induced Coulomb explosion of methyl iodide monomers and its clusters has been studied using pico and femto-second lasers, having intensity in the range of 10^{14}-10^{16} W/cm^2 and the formation of highly charged carbon and iodine ions with large kinetic energies was reported. For the first time, observation of Coulomb explosion in methyl iodide clusters induced by nanosecond dye laser pulses of 557-567 nm wavelength has been observed in our studies at an average intensity of 10^9 W/cm^2 using linear Time of Flight Mass Spectrometer.

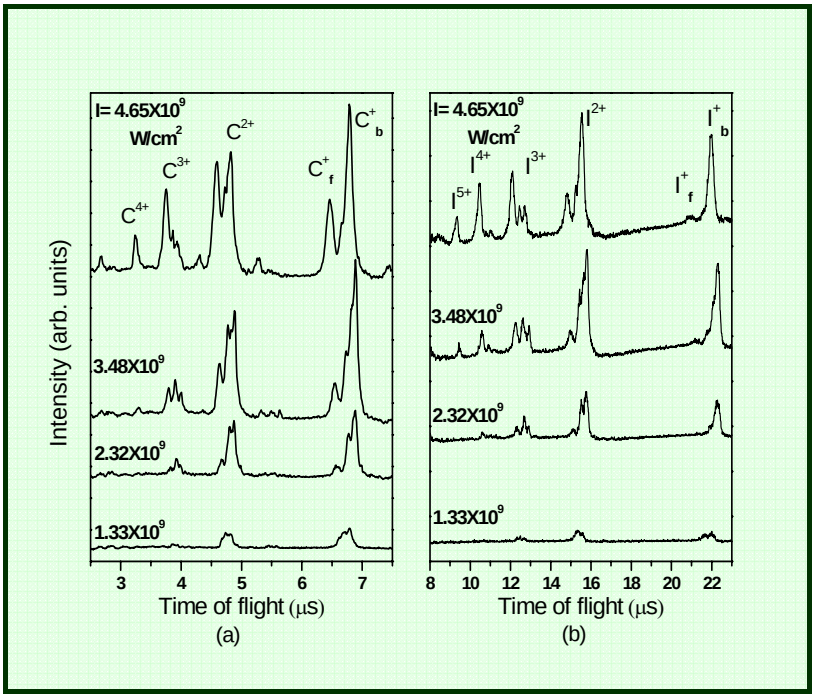


Fig.11 : Variation in signal of multiply charged atomic ions as a function of laser intensity

Signals due to multiple charged atomic ions up to C^{4+} and I^{5+} with kinetic energies in the range of 0.3-2 keV and a series of cluster fragments of the type $[(CH_3)(CH_3I)_n]^+$ with $1 \leq n \leq 6$ were observed. The charge states and kinetic energies associated with different ionic species in the present study using nanosecond laser are comparable to those of femtosecond lasers with intensities in the range of 10^{14}-10^{16} W/cm^2. With a view to understand the wavelength dependence of Coulomb explosion phenomena, additional experiments have been carried out over few selective wavelengths in the region of 355 to 643 nm and clear evidence for the enhancement of Coulomb explosion process with increasing wavelength is observed (Fig.10). Experiments were also carried out as a function of laser intensity. It was found that with increase in laser intensity, there was an increase in the yield of higher charged atomic ion. Fig.11 shows intensity dependent mass spectra of multiple charged carbon and iodine ions [14].

Conclusion

In conclusion, we have shown that TOFMS is a versatile tool to study a wide variety of laser induced photochemical processes. The greatest advantage of TOFMS comes from direct determination of mass as well as the kinetic energy distribution of the fragment ions. The prospects for future innovations in the study of chemical dynamics by TOFMS are excellent. The advantage of time-of-flight mass spectrometry (TOFMS) comes from the simplicity of construction, along with high transmission and resolution that has been achieved. The instrument lends itself naturally to a coupling with pulsed laser sources, though this is not a prerequisite. The entire spectrum can be recorded in few microseconds. It also affords a time resolution far beyond that traditionally achieved with mass spectrometric rapid scan techniques. Furthermore, the mass range appears to be extremely large: mass up to 500 kDa and beyond can be readily measured in the laboratory today. The present article attempts to give a brief account of some studies that have been carried out using this instrument.

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STATEMENT BY DR ANIL KAKODKAR, CHAIRMAN, ATOMIC ENERGY COMMISSION AND LEADER OF THE INDIAN DELEGATION, AT THE 49TH GENERAL CONFERENCE, IAEA, VIENNA

Dr Anil Kakodkar, Chairman, Atomic Energy Commission, addressing the 49th General Conference of International Atomic Energy Agency at Vienna

Mr. President,

Kindly accept congratulations on behalf of my Government and my own behalf on your election as President of the 49th General Conference. I am sure, under your able leadership and with the support of your team and the Secretariat of the Agency, this General Conference will be able to accomplish the tasks before it.

I take this opportunity to welcome the entry of Belize to the membership of the IAEA.

Let me also use this occasion to once again congratulate Dr. Mohamed ElBaradei on his re-appointment as Director-General, IAEA for another term. We wish him all success and as in the past, we will continue to work in close cooperation with him in achieving our collective objectives in accordance with the statute of the Agency.

Mr. President, the issues related to global climate change, sustainability of energy resources while meeting the ever increasing energy needs to support economic development and concerns regarding escalating trends in fuel prices, point to the inevitability of nuclear power. Global nuclear renaissance is now a reality.

India which constitutes one-sixth of the global population is on the rapid economic growth path. A recent study has revealed that we will need to augment our electricity generation nearly ten-fold in next four to five decades. This would be a significant fraction of global electricity generation. A large fraction of this energy coming from nuclear power would be of immense benefit, in the context of environment and sustainability concerns, for India as well as for the rest of the world. Nuclear energy is thus an important and inevitable option for India. As a part of realizing this objective, we have been pursuing a self-reliant indigenous nuclear power programme.

This programme is tuned to realize our long-term energy requirements utilizing our vast thorium resources. This is of crucial importance to us as our uranium resources are modest. In this context, let me quote from the statement of our Prime Minister made in our Parliament on 29th July, 2005 "Our nuclear programme in many ways is unique. It encompasses the complete range of activities that characterise an advanced

nuclear power including generation of electricity, advanced research and development and our strategic programme. Our scientists have mastered the complete nuclear fuel cycle. The manner of the development of our programme which has been envisaged is predicated on our modest uranium resources and vast reserves of thorium. While the energy potential available in these resources is immense, we remain committed to the three-stage nuclear power programme, consisting of Pressurised Heavy Water Reactors (PHWRs) in the first stage, fast breeder reactors in the second stage and thorium reactors in the third stage. These would need sequential implementation in an integrated manner. Our scientists have done excellent work and we are progressing well on this programme as per the original vision outlined by Pandit Jawaharlal Nehru and Dr. Homi Bhabha. We will build on this precious heritage.

“Energy is a crucial input to propel our economic growth. We have assessed our long-term energy resources and it is clear that nuclear power has to play an increasing role in our electricity generation plans. While our indigenous nuclear power programme based on domestic resources and national technological capabilities would continue to grow, there is clearly an urgent necessity for us to enhance nuclear power production rapidly. Our desire is to attain energy security to enable us to leapfrog stages of economic development obtained at the least possible cost. For this purpose, it would be very useful if we can access nuclear fuel as well as nuclear reactors from the international market. Presently, this is not possible because of the nuclear technology restrictive regimes that operate around us."

While addressing at the Golden Jubilee Function of the Department of Atomic Energy (DAE) and the launch of construction of the Prototype Fast Breeder Reactor (PFBR) at Kalpakkam on 23rd October, 2004, our Prime Minister had said: "India is a responsible nuclear power. We are fully conscious of the immense responsibilities that come with the possession of advanced technologies, both civilian and strategic. While we are determined to utilize our indigenous resources and capabilities to fulfill our national interests, we are doing so in a manner that is not contrary to the larger goals of nuclear nonproliferation.

“India will not be the source of proliferation of sensitive technologies. We will also ensure the safeguarding of those technologies that we already possess. We will remain faithful to this approach, as we have been for the last several decades. We have done so despite the well-known glaring examples of proliferation, which have directly affected our security interests.

“The limitations of the present non-proliferation regime should not be further accentuated by artificial restrictions on genuine peaceful nuclear applications. Technology denial and closing avenues for international cooperation in such an important field is tantamount to the denial of developmental benefits to millions of people, whose lives can be transformed by the utilization of nuclear energy and relevant technologies.

“We call upon other advanced nuclear powers, and all those who have a stake in the future of nuclear energy, to come together for a constructive dialogue to evolve more effective measures that would stem the tide of proliferation without unduly constraining the peaceful uses of nuclear energy. Constraining those who are responsible, amounts, in effect, to rewarding those who are irresponsible. The international community must face up to the implications of this choice. We in India are willing to shoulder our share of international obligations provided our legitimate interests are met. India has actively embraced globalisation. There is no reason why nuclear energy production should be an exception."

We are happy that we are now feeling the winds of change. We welcome the statements of USA and France on this podium and the positive and cooperative approach of several key countries in this regard. We look forward to a rapid growth in nuclear power generation capacity in India based on full international civilian nuclear cooperation as we continue our efforts to develop appropriate indigenous technologies towards realization of the ultimate goal of large-scale utilization of thorium for energy production not only in the form of electricity but also as hydrogen. We expect that the unique case of India as a responsible country with advanced nuclear technologies developed in a self-reliant manner, its large-scale energy requirements which have ramifications in terms of protecting the global climate, ensuring sustainability of energy resources and restraining escalating spiral of fuel prices, its impeccable record in terms of non-proliferation of WMD & related technologies and adherence to all its international commitments would soon result in lifting of all restrictions on India. Predicated on our obtaining the same benefits and advantages as other nuclear powers, consistent with our national policy of maintaining the integrity of our three stage nuclear energy programme, and ensuring full autonomy of our nuclear programme of strategic and R&D significance, India would be prepared to take reciprocal steps in a phased manner in keeping with the responsibilities and obligations of an advanced nuclear power with the objective of full civilian nuclear energy cooperation with international partners. Since some of these steps will also include safeguards on facilities of a civilian nature, selected by India on a voluntary basis, we will, at the appropriate stage, approach the IAEA in this regard.

Mr. President, we would like to see a rapid increase in nuclear power generation capacity in India well above the planned programme of achieving 20,000 MWe by the year 2020. This capacity could consist of imported Light Water Reactors (LWRs) which run on imported fuel, domestic Pressurised Heavy Water Reactors (PHWRs) which run on imported fuel, domestic PHWRs which run on domestic fuel and Fast Breeder Reactors. Progressively power reactors running on thorium would get added to this list.

Let me now report some of the recent developments in India. With the PHWR programme well on its growth path and having established comprehensive expertise in Fast Breeder Reactor (FBR) Technology, we have now embarked on the development of FBR - based second stage of our programme with the start of construction of the 500 MWe Prototype Fast Breeder Reactor launched in October last year. Our studies indicate that we should be in a position to support around 500 GWe power generation capacity based on FBRs with plutonium bred from indigenously available uranium. We are certain that Fast Breeder Reactors by virtue of their crucial place in sustainable development of nuclear energy would come centrestage worldwide in a couple of decades. The first 540 MWe PHWR unit at Tarapur has commenced commercial operations about 7 months ahead of schedule. Unit - 1 of Kakrapar Atomic Power Station has been operating continuously for more than a year. This is an Indian record. The indigenously developed unique Pu-rich mixed carbide fuel used in the Fast Breeder Test Reactor (FBTR) has performed extremely well crossing a burn-up of 148,000 MWd/t, without a single fuel pin failure. One of the important achievements during the year was closing of the fuel cycle of FBTR. The FBTR fuel discharged at 100,000 MWd/t has been successfully reprocessed. This is the first time that the Plutonium-rich carbide fuel has been reprocessed anywhere in the world. As a part of development of higher burn-up fuel for PHWRs, 25 MOX bundles were successfully irradiated to a target burn-up of about 11,000 MWd/T. This year we have introduced additional 25 MOX fuel bundles in one of our PHWRs.

Construction of five PHWRs is progressing on schedule. These along with the two 1000 MWe VVERs presently under construction at Kudankulam in collaboration with Russian Federation would contribute 3420 MWe additional carbon-free electricity to the Indian grids in about 3 years' time.

We have taken up development of sites for new nuclear power units and have commenced work to identify additional sites for further expansion of the programme.

The design of Advanced Heavy Water Reactor, an innovative Indian design aimed at moving further on thorium utilization route, is under regulatory review. We intend to proceed further to take up its construction after the review process is completed. Work on development of a Compact High Temperature Reactor with the aim of producing hydrogen, which could be the most important energy carrier in the future as well as development of Accelerator Driven Systems that could sustain growth with thorium systems and enable incineration of long lived radioactive wastes is progressing well. The development of laser-based Uranium-233 clean up system, a crucial element in thorium utilization programme, has made significant progress. The Steady State Superconducting Tokamak, SST-1, would soon see the first plasma shot. We are looking forward to joining the ITER project as a full partner.

The safety record of our nuclear and radiation facilities continues to be excellent. During 2004, we had only 1 event at level-2 and 4 events at level-1 of the International Nuclear Event Scale (INES).

En masse coolant channel replacement and other safety upgradation jobs in the Madras Atomic Power Station Unit-1 are nearing completion and the Unit is expected to be back in operation before the end of this year. A comprehensive safety review of the Tarapur Atomic Power Station which is in operation since 1969 has been completed by our regulatory body and implementation of the identified ageing management and safety upgradation jobs will be taken up shortly.

On 26 December 2004, the Eastern and Southern coasts of India were hit by a tsunami. Unit-2 of the Madras Atomic Power Station which was in operation at this time experienced minor flooding in its sea water pump house due to tsunami - induced surges and was shut-down. Apart from this, there was no other impact on the plant and the Unit could be brought back to operation within one week after review of the incident and clearance by the regulatory body. The excavated pit at the Prototype Fast Breeder Reactor construction site got flooded due to sea water ingress on account of the tsunami. The pit was dewatered and cleaned and, after incorporating necessary corrective measures, construction work has been resumed. The tsunami did not have any impact on the construction site of the two VVER-1000 NPPs.

In the area of accelerators and lasers, the second Indian Storage Ring, the 2.5 GeV Synchrotron Radiation Source - Indus-2, has been fully assembled and integrated. All sub-systems have been made operational and initial experiments to store 600 MeV electron beam in the ring have been commenced. Laser - based coolant channel cutting technology has been developed and successfully tested on one of the channels in a PHWR. This development will greatly bring down the man-rem consumption during the planned en masse coolant channel replacement work in the Narora Atomic Power Station reactors.

There has been a steady progress in expanding the benefits of atomic energy for the society. Several radiation processing plants based on Cobalt-60 are under construction in private and cooperative sectors. Demonstration facilities for radiation processing of food and materials using electron beam accelerators are also in advanced

stage of construction. An Advanced Centre for Treatment, Research and Education in Cancer (ACTREC) has been set up with the specific mandate to undertake on mission-oriented basis applied and translational research on cancer prevalent in Indian subcontinent. It will also apply cutting edge technologies in the treatment of cancer in partnership with industry and leading institutions in India and abroad and conduct educational programmes and undertake human resource development in different disciplines of oncology. To meet the growing demand of Teletherapy machines to combat cancer, an indigenously designed and developed state of art Co-60 Teletherapy machine - BHABHATRON has been commissioned. We feel this product would be very useful for fighting cancer in the developing world. Indian experts are actively involved in the Agency's "Programme of Action for Cancer Therapy" (PACT).

The International Atomic Energy Agency is playing a vital role in the peaceful uses of nuclear science and technology in a safe and secure manner. As in the past, we have been working in close partnership with the Agency. Our experts are involved actively in the Agency's international project on Innovative Nuclear Reactors and Fuel Cycles (INPRO). India has committed itself to carry out an INPRO Joint Study for an assessment of an innovative nuclear energy system based on high temperature reactors for the production of hydrogen using the INPRO methodology. As a part of the INPRO programme, India is also participating in the joint study on Innovative Nuclear Fuel Cycles based on Fast Reactors with closed fuel cycles. We look forward to the initiation of phase - 2 of INPRO.

In the area of knowledge management, our experts take active part in the Agency's programme such as Asian Network for Higher Education in Nuclear Technology (ANENT) and in the recently conducted WNU's first Summer Institute of Fellows having an intense 6-week educational experience featuring some of the international community's foremost leaders in science, engineering and environment.

Nuclear technology is knowledge intensive. Development of individuals is central to knowledge management. Nuclear industry needs well-trained human resources and strong industrial infrastructure for its exploitation. High importance has been given to Human Resource Development, right from the beginning of our programme. Recently, our Prime Minister has announced the setting up of Homi Bhabha National Institute as a Deemed University to provide a platform for accelerating the pace of basic research as well as translation of basic research into development of advanced nuclear technologies.

We attach great importance to the Technical Cooperation Programme of the Agency. As in the past, we have pledged and paid our contribution to Technical Cooperation Fund in full and in time. In the year 2000, the Department of Atomic Energy had entered into a Memorandum of Understanding with the IAEA to further strengthen cooperation with the Agency covering Fellowship Training, Scientific Visits and Expert Services. An agreement was signed last month for streamlining the procedures for activities covered by this MoU. In the area of nuclear safety and security, India ratified the Convention on Nuclear Safety and participated in the third review meeting of the contracting parties held in April as an Observer. We also took active part in the amendment process to the Convention on Physical Protection of Nuclear Materials.

India, United States and IAEA have established a Regional Radiological Security Partnership programme (RRSP). Under this framework, India offered to provide infrastructure and expertise on a regular basis for conducting International Training Courses in India under the aegis of IAEA, on issues related to the Security of

Radioactive Sources and materials as also for locating Orphan Radioactive Sources in countries which are unable to effectively deal with them and which seek assistance from the IAEA. Like in the past few years, India will be conducting the Regional Training Course on Physical Protection of Nuclear Installations during November 7-18, 2005 in Mumbai.

Last month, a five-day international Workshop on external flooding hazards at Nuclear Power Plant Sites was organized at Kalpakkam. The Workshop provided the opportunity for experts to exchange experience and knowledge related to flooding hazards at NPP sites arising from various causes including tsunamis.

Mr. President, before I conclude, it is worthwhile for us to remind ourselves, on the eve of the Golden Jubilee year of the Agency, that the IAEA is the world's center of cooperation in the nuclear field and was set up as the world's "Atoms for Peace" organization within the United Nations family. The Agency has well established mechanisms to realise the full potential of atoms for sustainable development. With the huge development deficit that still exists, sustainable development is crucially dependent on the enormous power of atom. The challenge before us is to channelise this enormous potential to world peace and prosperity while preventing its destructive use by irresponsible state and non-state actors. Addressing this challenge successfully would change the perception of the Agency from just a 'nuclear watchdog' to a 'nuclear *Kamadhenu',* the Indian mythological cow,that symbolises an inexhaustible sustenance provider for the welfare of the humanity. Once we realise this, a good part of cause for conflict should vanish. We thus have a unique opportunity here at IAEA to make a lasting contribution to world peace. We owe this to this unique multi-disciplinary organisation and in fact the entire UN system.

Thank you, Mr. President.

RF CONTROL ELECTRONICS COMMISSIONED AT AUSTRALIAN NATIONAL UNIVERSITY, AUSTRALIA

RF control electronics developed at Electronics Division, BARC, has been installed and commissioned successfully at the Australian National University (ANU), Australia, in April 2005. The commissioning included initial test of RF electronics, high power conditioning, tuning, phase locking and operation of each cavity and the entire LINAC and finally developing 343 MeV Ni58 beam for the Nuclear Physics Experiments. Two engineers, Mr Gopal Joshi and Ms Sujo C.I. of Electronics Division, BARC, participated in the commissioning. As per the report presented by ANU at RF Superconductivity workshop at Cornell University in July 2005.'The RF system supplied by BARC demonstrated very high stability, simplicity of operation and high reliability allowing sustained operation of the linac facility'. Residual amplitude and phase errors were below 0.1% and 0.1 degree during the beam run.

After a careful evaluation of the various options available, ANU selected the RF control electronics developed at BARC for their linac upgrade. A total of 28 modules along with power supplies, bins and cabling was supplied to ANU in the month of January 2005, against their order worth USD 64,000. This work is in-line with the RF Control Electronics developed at Electronics Division, BARC, by the team led by Mr Gopal Joshi, for the super-conducting linear accelerators at BARC-TIFR (150 MHz, lead on copper) and Nuclear Science Center (97 MHz, bulk niobium).

Superconducting Linear Accelerator, ANU

The ANU Superconducting LINAC comprises 2 Quarter Wave Nb sputtered Resonators (QWRs) and 12 Split-ring Lead-tin plated Resonators (SLRs). The center-frequency of LINAC is 150 MHz. The LINAC receives beam from 14 UD accelerator at velocities of ~ 0.1β which have been bunched into pulses of ~ 1 ns by a room temperature buncher and chopper system. The beam is further superbunched by a Nb sputtered Quarter Wave Resonator (QWR) and time focused at the entrance to the LINAC. The beam is accelerated by twelve split ring resonators and can be later debunched or time focused by the second QWR.

Each resonator operates as a self-excited loop, which is formed by a feedback signal from the resonator, the RF control module and the power amplifier. Figure 1 shows the RF control modules developed at Electronics Division, BARC, for the ANU linac.

RF Control Electronics

The resonator controller modules and other control modules are assembled in a NIM style crate that contains modules to operate upto four resonators. The modules in one crate are:

a) 4 Resonator controllers
b) 1 Resonator controller support electronics
c) 1 Input module
d) 1 Reference splitter module

The main features of the RF Control System are :

Frequency range	: 105 to 175 MHz
Range of input gain	: 40 dB
Input range for amplitude and phase locking	: -10 dBm to +20 dBm
Phase and Reference Shifter range	: 0 – 360 degrees
Quiescent output	: + 10 dBm
Quiescent output Control range	: 20 dB

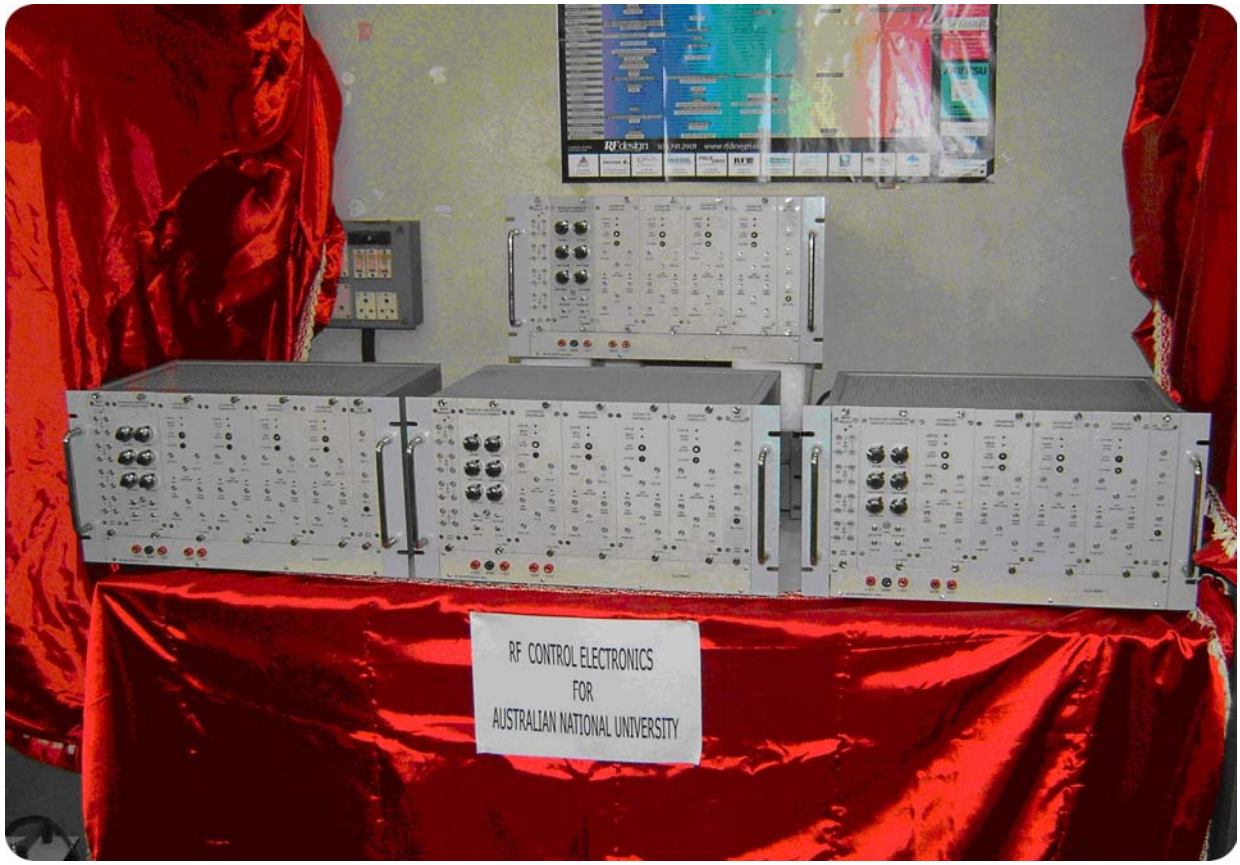

Fig.1 : RF control electronics developed in Electronics Division,BARC

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Quiescent output	: + 10 dBm
Quiescent output Control range	: 20 dB

The Reference Splitter module receives the reference clock signal as input and splits it into four outputs with the nominal level +10 dBm for an input signal range from –10 to +10 dBm. Each input module processes the pick-up signal from one of 4 resonators. It provides the option of inserting attenuation when the input field level goes above +10 dBm in order to increase the dynamic range of the controller. This module also makes available the RF pick-up signal on its front panel. This pick-up port is highly decoupled from the main loop RF signal.

The Resonator Controller includes the loop phase shifter and the limiter. For phase locking, a suitable phase reference is derived from the output of the Reference Splitter module. The amplitude reference is generated in the Resonator Controller module by setting the input gain attenuator. The resonator controller performs low-level signal processing and generates the drive signal for the amplifier to maintain phase and amplitude stability. Its operation is based on supplying quadrature power as the resonator center frequency varies. The product of the peak frequency excursion and energy content of the resonator determines the incident power required. This control strategy has been found adequate for the ANU QWRs and SLRs inspite of the fact that the SLRs have quite poor mechanical stability with a field derived frequency shift of $-100E_{acc}^2$. The sensitivity of the SLRs to gas helium pressure variations is also high ~0.24 Hz/mBar. Therefore, a high quality RF control system and greater circulating RF power are needed to stablilise the SLRs as compared to the stiff QWRs. The RF power requirement for an SLR is 100-120W at an operating field of 3 - 3.5 MV/m.

The required control signals can be generated either by a Computer Control System or by the Resonator Controller Support Electronics Module. During commissioning, the control signals were generated by computer control system. The computer control system was developed locally at ANU and integrated with the RF Control Electronics supplied by BARC.

A detailed description of the RF control electronics is given in the BARC *Newsletter* (March, 2003).

COMPLEX INTEGRATED CIRCUITS FOR NUCLEAR REACTOR APPLICATIONS DEVELOPED AT BARC : A STEP FORWARD IN IMPORT SUBSTITUTION

Shantanu Das , M.M Maity and B.B Biswas
Reactor Control Division BARC

Introduction

In past, we have successfully made reliable hardware for NPP and other high reliablity control applications. The standard hardware modules are now part of product series trade marked as ECBUS Boards™ and ECPS™. The philosophy of making reliable product for Nuclear applications is simplicity in design. Adequate margins in timings and power dissipation with consistency in control signal is provided as they propagate back & forth throughout the system.

Fig. 1: Imported Integrated Circuit Isolation Amplifiers, Clock Drivers and Isolated Current Transmitter

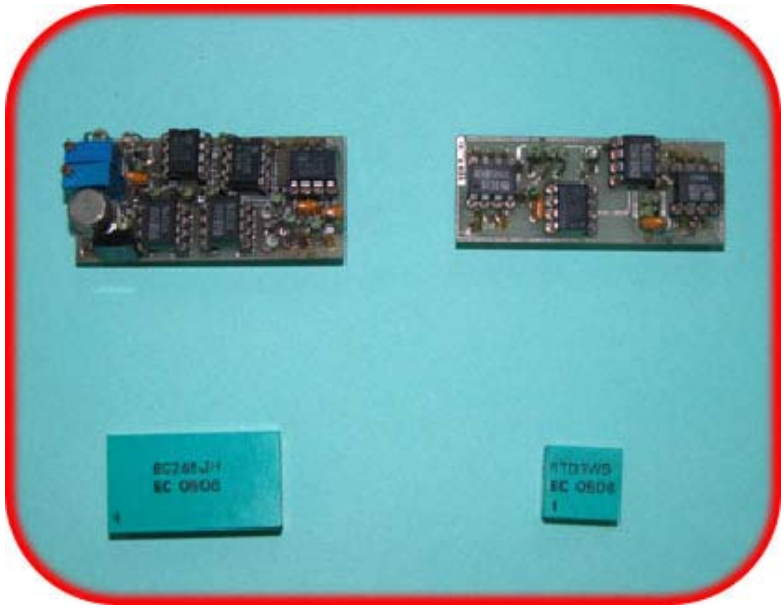

Fig. 2 : In-house developed and partly developed ICs, Clock Drivers, 3W-RTD IC, Isolation Amplifiers and Isolated Current Transmitter

Development Process

The isolation amplifier model used had many deficiencies which were accepted as a compromise on price ground. The circuit topology used in the imported module is a standard one. On the same lines, a hybrid module has been developed and fabricated with some design change and appropriate choice of component value and quality. Yet the production cost is seen to be less than the import cost. Extensive performance has been carried out to confirm the suitability for NPP application.

The signal conditioning of RTDs were performed by use of discrete op-amps, voltage reference and passive components. All these have been put in a 8-pin package.

The Clock Driver used for the isolation had very low supply voltage rating. This resulted in many failures due to voltage surge. The in-house developed Clock Driver module has a voltage withstanding capability of 20V against the normal supply of 15V.

Isolated 4-20mA Current Transmitter module also has been developed in line with the Isolation Amplifier described earlier.

The cost of I&C systems increases as we go for mandatory galvanic isolation for input and output for signal conditioning. Moreover, the modules which are used are from single source and are costly. After successful usage of these designs in the last twelve power reactors, RCnD initiated in-house effort to have these imported integrated circuits developed in the same footprints as to be used in existing cards utilized in these NPPs. Not only this effort will reduce the cost of the total I&C along with saving of foreign exchange but also enhance the performance quality.

Conclusion

Once ECIL takes up manufacturing of these modules in production volumes, the requirements of replacements in existing systems of NPPs and new NPP requirements will be met at a lower cost, saving a good amount of foreign exchange and with immunity from embargo.

REFURBISHMENT OF FOOD PACKAGE IRRADIATOR AT FOOD TECHNOLOGY DIVISION

The food package irradiator was installed and commissioned in FIPLY in the year 1967 in collaboration with Atomic Energy of Canada Ltd. Since then, the irradiator was being continuously used by the scientists of BARC for various R&D activities. However, owing to such extensive use, the irradiator has been lately giving operational problems very frequently. As FTD could not repair this equipment for want of imported spares, Centre for Design and Manufacture (CDM) was consulted for refurbishment of this equipment.

Fig.1 : Electrical Control Panel

CDM undertook the design and manufacture of the entire electrical and pneumatic control systems of the irradiator. The electrical control panel was thus manufactured using indigenous components of reputed make such as Siemens Ltd., OEN make relays having gold plated contacts, etc. The electrical control panel was installed at FTD after obtaining approval from the Safety Committee for Radiological Operations (SCRO), BARC.

The Electrical Control Panel (Fig.1) was installed at a new location to facilitate better operational convenience. Installing the control panel at the new location resulted in the length of all electrical cables falling short.

Therefore, the entire rewiring work of the food package irradiator also was carried out by CDM. Two Gamma Area Monitors (one for the maze area and the other for control area), designed and manufactured by the Radiation Protection Instrumentation Section of Reactor Safety Systems Division (RSSD), on the request of CDM, also were subsequently fitted on the electrical control panel. Thus, the entire work of the Electrical Control Panel was completed. The Sub-Committee of SCRO was fully satisfied with the functioning of the control system.

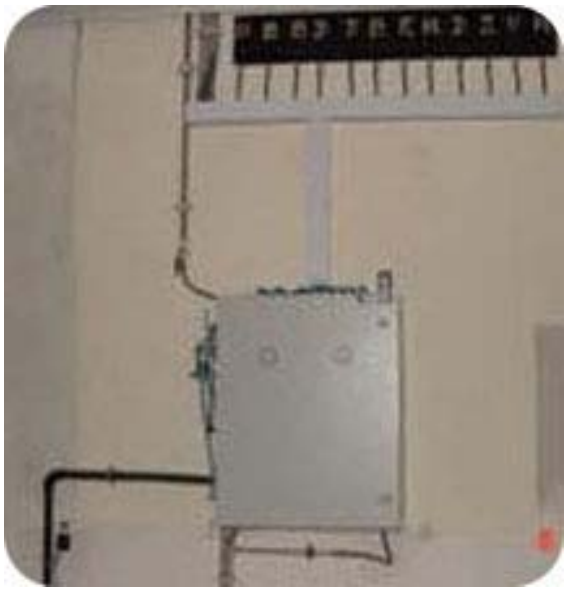

Fig.2 : Pneumatic Control System

In the original imported system, the radiation source used to get “raised/exposed” without any alarm/indication due to the malfunctioning of a solenoid valve. This unsafe and dangerous operating condition was taken care of by CDM. A new Pneumatic Control System (Fig.2) was

designed and got manufactured from M/s Festo Control, Bangalore, with more additional safety features and was installed at FTD.

As a result of this indigenous refurbishment work done by CDM, all the spares are now easily available. In-house expertise for the maintenance of the system is also available now. The entire refurbishment was done in a cost effective manner. The system is now in regular operation with hundred percent availability.

BARC TRANSFERS TECHNOLOGIES OF "NON-INVASIVE BLOOD PRESSURE (NIBP) MODULE" AND "PULSE OXIMETER (spO_2) MODULE"

The technologies of "Non-Invasive Blood Pressure (NIBP) Module" and "Pulse Oximeter (spO_2) Module" developed by Electronics Division, BARC, have been transferred to M/s. Larsen and Toubro Ltd., Mysore, on April 4, 2005.

NIBP module provides systolic, diastolic and mean blood pressures with an average period of 10 minutes (programmable). It uses oscillometric method for measurement of blood pressure. It comprises of a tourniquet, a pressure transducer, an inflation pump and deflation solenoid valve connected to electronic circuitry. The module can be coupled with the existing Patient Monitors or used as a stand-alone instrument by adding a microcontroller and a display unit.

The Oximeter Module provides saturation percentage of oxygen in blood. The measurement is based on the light (Red & Infrared) absorption property related to concentration of oxygenated and de-oxygenated

Photograph after signing of the technology transfer agreements. Sitting from left to right are Dr G. D. Jindal, ED, BARC, Mr Rohit Mehta, Joint General Manager, L&T Ltd, Mysore, Mr M.D. Ghodgaonkar, Head, ED, BARC, and Mr A. M. Patankar, Head, TT &CD, BARC. Standing from left to right are : Mr A. R. Kini, ED, BARC, Ms Soniya Murudkar, TT&CD, BARC, Ms Mausami Naik, ED, BARC, Ms Sadhana Mandlik, ED, BARC, Mr Vinit Sinha, ED, BARC, Mr Vishwanath Nayak, M/s L&T Ltd., Mysore, Mr U.P. Prakash, M/s L&T Ltd., Mysore and Mr B. K. Pathak, TT&CD, BARC

haemoglobin in blood. It has infrared and red light emitters with a common photo sensor mounted on a clip. The clip is attached to the finger for sensing the transmitted Red/ Infrared light. The photo current generated in the sensor is processed to obtain the oxygen saturation percentage of blood. The module can be coupled with the existing Patient Monitors or used as a stand-alone instrument by adding a microcontroller and a display unit.

Technology Transfer & Collaboration Division managed all activities related to this technology. It involved evaluation of the technology, documentation of the technology, fixing the TT fee to be charged, obtaining patent protection, announcement of the technology, evaluation and selection of a capable transferee, preparation and signing of the technology transfer agreement. Necessary inputs were provided by NA&BTD and FTD.

BARC TRANSFERS KNOW-HOW OF BANANA JUICE EXTRACTION

The know-how of Banana Juice Extraction was transferred to M/s. ITeMATRIX Co. Ltd., Bangkok, Thailand, on December 7, 2004.

The lab-scale process which was developed jointly by Nuclear Agriculture & Biotechnology Division (NA&BTD) and Food Technology Division (FTD), BARC, basically pertains to extraction of fruit juice from banana and production of banana powder as a by-product. Banana is the most abundant fruit crop grown in India and its in-country production accounts for over 20% of total banana production in the world. A comparatively short post-harvest shelf-life of banana coupled with a dearth of sufficient and good quality transportation/storage facilities leads to perishing of 35-40% of this nutritious fruit before it reaches the consumer. One effective

Photograph after signing of the agreement with M/s. ITeMATRIX Co. Ltd., Bangkok. Seen standing from left to right are : Mr A.M.Patankar, Head, TT&CD, BARC, Dr A.K.Sharma, Head, FTD, BARC, Dr V.H.Ron, Consultant, ITeMATRIX, Dr R. Chander, FTD, BARC, Dr R.B.Grover, Director, KMG, BARC, Mr B.K.Pathak, Head,TTS,TT&CD, BARC, Mr Viswam Ramesh, Director, M/s. ITeMATRIX Co. Ltd., Mr Atul Mishra, TT&CD, BARC, Mr S.F. D'Souza, Head, NA&BTD, BARC, and Dr N.K.Ramaswamy, NA&BTD, BARC

method of reducing this huge loss is to extract the juice out of the fruit before it perishes and preserve it. As of now, no commercially established process is available to achieve this. The moisture content of banana is in bound form as against many other fruits like apples and citrus fruits.

The BARC process achieves separation and extraction of banana juice through a series of operations like blending, churning, autoclaving and centrifuging. Clear juice with a yield of upto 550/o(w/w) is obtained without addition of any enzymes and can be stored upto months inside a cold storage at a temperature below 4^0C without adding any preservatives. The remaining pulp is converted into fine banana powder through freeze-drying followed by grinding.

Technology Transfer & Collaboration Division managed all activities related to this technology. It involved evaluation of the technology, documentation of the technology, fixing the TT fee to be charged, obtaining patent protection, announcement of the technology, evaluation and selection of a capable transferee, preparation and signing of the technology transfer agreement. Necessary inputs were provided by NA&BTD and FTD.

INTERNATIONAL WORKSHOP ON NEW GENERATION CHERENKOV TELESCOPES

An international workshop on New Generation Cherenkov Telescopes (NGCT-2005) was organised by the Astrophysical Sciences Division at the BARC Training School Hostel, during August 1-2, 2005. 15 invited talks and 5 contributed papers were presented at the workshop which was attended by 80 scientists including 30 foreign delegates. Inaugurating the workshop Dr V.C. Sahni, Director, Physics Group, BARC, and Director, CAT, Indore highlighted the need for international collaboration in the major new efforts being put up by the Indian scientists in setting up the world's highest altitude, low energy threshold gamma-ray telescope MACE at Hanle in the Ladakh region of North India. In his keynote address, Prof. T.Kifune, the well known Japanese gamma-ray astronomer conveyed the flavour of the excitement in the field generated by the recent new source detections by the new generation telescopes. He also emphasised the need for lowering the energy threshold and enhancing the sensitivity of the new systems and suggested a roadmap for the coming years. Many of the invited talks focused on the fine details of the mechanical systems, the imaging camera configurations, the data acquisition systems, simulation studies and the data analysis techniques adopted by the various groups to achieve the highest possible gamma-ray detection sensitivities with the new systems. The workshop provided an ideal opportunity to scientists working in the centre to interact and exchange ideas with experts in the field from both India and abroad.

SYMPOSIUM ON NUCLEAR AND RADIOCHEMISTRY (NUCAR 2005)

The seventh biennial DAE - BRNS Symposium on Nuclear and Radiochemistry (NUCAR 2005) was held at Guru Nanak Dev University, Amritsar, during March 15-18, 2005. The symposium was inaugurated by Mr S.K. Sharma, Chairman, Atomic Energy Regulatory Board (AERB), and was presided over by Prof S.P. Singh, Vice Chancellor, Guru Nanak Dev University (GNDU), Amritsar. Prof. R. K. Mahajan, Convener, Local Organising Committee (LOC), NUCAR 2005 and Head, Department of Chemistry, GNDU, welcomed the delegates. Dr Keshav Chander, Convener, NUCAR 2005, highlighted the theme

At the inaugural function seen on the dais from left to right are : Prof. K.S. Thind, Head, Department of Physics, Guru Nanak Dev University, Amritsar, Dr V. Venugopal, Director, Radiochemistry & Isotope Group, BARC, Prof. S.P. Singh, Vice Chancellor,Guru Nanak Dev University, Amritsar, and Mr S.K. Sharma, Chairman, Atomic Energy Regulatory Board who released the proceedings of NUCAR-2005

of the symposium. He informed that the objective of the symposium was to provide a forum for the effective interaction among active researchers working in different areas of Nuclear and Radiochemistry such as nuclear chemistry, chemistry of actinides and reactor materials, chemistry of fission and activation products, radioanalytical chemistry and applications of radioisotopes in physico-chemical sciences. Dr V. Venugopal, Director, RC&I Group, BARC and Chairman, NUCAR 2005, highlighted the role of Nuclear and Radiochemistry in the Indian nuclear energy programme. Mr S.K. Sharma, in his inaugural address, explained the importance of Nuclear and Radiochemistry in all the stages of nuclear fuel cycle, starting from mining to fuel fabrication and to back-end of the nuclear fuel cycle. Prof S. P. Singh, in his presidential remarks, spoke about scientific temperament of the GNDU for holding the prestigious symposium on Nuclear and Radiochemistry and welcomed the delegates to the holy city of Amritsar. Prof. K.S. Thind, Chairman, LOC, NUCAR 2005 and Head, Department of Physics, GNDU, presented the vote of thanks.

Mr S.K. Sharma formally released the bound volume of NUCAR 2005 proceedings, containing all the invited talks and contributed papers, which were distributed to all the delegates. NUCAR 2005 Souvenir (GNDU) and Experiments in Radiochemistry (IANCAS) were also released during the inaugural function.

A total of 255 delegates participated in the symposium. A record number of 301 contributed research papers were accepted for presentation. Out of these, 40 were oral and 261 were poster presentations. There were 16 invited talks, which were presented by eminent scientists from India and abroad. Six overseas speakers (Prof. G.R. Choppin, USA, Dr R.R. Greenberg, USA, Prof. A. Chatt, Canada, Prof. H.A. Das, Netherlands, Prof. Y.U. Teterin, Russia, and Prof. P. Warwick, UK) delivered invited talks on different aspects of Nuclear and Radiochemistry.

Seen on the dais from left to right are : Dr Keshav Chander, Convener, NUCAR-2005, FCD, BARC, Prof.K.S.Thind, Head, Department of Physics, Guru Nanak Dev University, Amritsar and Chairman, LOC, NUCAR-2005, Prof. R.K. Mahajan, Head, Department of Chemistry, GNDU, Prof. B.S.Tomar, Technical Committee, NUCAR-2005, RCD, BARC, Dr V.K. Manchanda, Head, RCD, BARC, Dr D.D. Sood, Ex-Director, RC&I Group, BARC, Prof. G.R. Choppin, Florida State University, USA, and Dr R. Acharya, Secretary, NUCAR-2005, RCD, BARC

The proceedings of the symposium were conducted in 12 technical sessions. Posters presented by the participants were summarised by experts in the Rapporteuring sessions. The highlight of the symposium was a half-day seminar on "Applications of Radioisotopes in Health care, Agriculture, Industry, and Chemical Research". In this seminar, Dr Aneesh Bhattacharyya, Dr S.F. D'Souza, Dr S. Sabharwal and Dr V. K. Manchanda delivered highly informative talks on the above topics, respectively.

The valedictory function was presided over by Dr D.D. Sood, Ex-Director, RC&I Group, BARC, and Prof. G.R. Choppin, who was the Chief Guest, distributed IANCAS awards to the young scientists from Academic institutes for best oral/ poster presentations. Dr B.S. Tomar, Chairman, Technical Committee, NUCAR 2005, summarised the deliberations of the symposium. It was observed that an effective collaboration between DAE and Educational Institutes/ Universities could be promoted through BRNS. Dr V.K. Manchanda, Head, Radiochemistry Division, BARC, identified a few areas where researchers from academic institutes can join in their scientific pursuits. These include Separation/ Analytical/ Environmental and Biochemical studies on Th, metal-colloid interaction and development of suitable solvent for use in back-end of nuclear fuel cycle. He also informed the delegates about the possibility of publication of a special volume of "Radiochimica Acta" based on the original contributions of NUCAR 2005. Dr Raghunath Acharya, Secretary, NUCAR 2005 proposed the vote of thanks.

IAEA/RCA EXPERT STEERING GROUP MEETING ON "STRENGTHENING OF MEDICAL PHYSICS THROUGH EDUCATION AND TRAINING"

IAEA/RCA Experts Steering Group Meeting on "Strengthening of Medical Physics through Education & Training", was held in Mumbai during May 4 - 6, 2005. Mr H. S. Kushwaha, Director, Health Safety and Environmental Group, BARC, inaugurated the meeting. Medical Physics experts of Australia, India, Japan, Malaysia, Thailand and a representative of IAEA participated in this meeting.

Terms of reference of the expert steering group (ESG) was to : (1) develop a definition and requirements for a qualified radiation oncology medical physicist (ROMP) suitable for the Asia-Pacific region; (2) review and develop guidelines for a clinical training program for radiation oncology medical physicists; (3) assist and advise the program co-ordinator in the management of the project and determine priorities; (4) oversee progress of project (Strengthening of Medical Physics); and (5) liaise with the IAEA and the country coordinators within RCA to facilitate progress of the project.

All the members of the ESG felt that there is a shortage of qualified and well-trained Medical Physicists (MPs) in the Asia-Pacific region. It is, therefore, necessary to initiate/ encourage educational and training programmes for MPs in all the countries of this region .It was also

Seated from left to right: Dr. John Drew, Lead Country Co-ordinator, Australia; Dr. K. Raghuraman, National RCA Representative, India; Dr. Frank Pernicka, Technical Officer, IAEA; Mr H. S. Kushwaha, Director, Health, Safety and Environmental Group, BARC; Dr. B. S. Rao, Head, RP&AD, BARC and National Project Co-ordinator, India; and Mr S. D. Sharma, Scientific Officer, RP&AD, BARC & Member, National Project Team, India.

Identified that the roles and responsibilities of the MPs should be defined and the education and training (academic & clinical) programmes should be tailored accordingly to enhance the professional standards as well. Medical Physicists in Asia Pacific region will be designated as Medical Physics Specialists (MPS) who will have sufficient knowledge, training and experience to accept full responsibility and are competent to practise independently in one of the medical physics specialties.

The particular specialty of Radiation Oncology Medical Physics (ROMP) pertains to:

1. The therapeutic applications of ionizing radiation
2. The equipment associated with their production, use, measurement and evaluation
3. The quality and handling of images resulting from their production and use, and
4. Radiation protection associated with this specialty

An MPS is required to be certified by an appropriate professional body. Suggested framework for certification of Radiation Oncology Medical Physics Specialists

- Degree majoring in physics or equivalent
- Postgraduate degree in medical physics OR postgraduate degree in science/engineering and participation in a medical physics course of at least 6 months duration
- Three years of clinical training as a medical physics resident (if this training does not exist a time frame shall be identified in which the training program can be established)
- Passing an appropriate assessment

Dr. B. S. Rao, Head, RP&AD, BARC, and Mr S. D. Sharma, SO(E), MPSS, RP&AD, BARC, participated in this meeting.

TRAINING COURSES AT CENTRE FOR DESIGN AND MANUFACTURE (CDM)

In order to have trained manpower in different fields, CDM organised in-house training courses during the last one year in various subjects such as Safety in Material Handling, Industrial House Keeping, Metrology and Dimensional Inspection, Non-destructive Testing, CNC Machining and Advanced Computer Aided Design & Analysis. Experts from various sections of CDM, other divisions of BARC and private industries were invited for delivering lectures. In all, a total of 202 staff members from various Divisions of BARC and CDM attended these courses.

The main objective of each course was to impart in-depth theoretical as well as practical knowledge of the subject. Few courses were supported by demonstration and practicals to give hands-on experience to the participants. As per the feedback received from the participants, these courses were very useful and have helped them to improve the work-quality. Following is the brief description of the various courses organised at CDM during the last one year:

Metrology and Dimensional Inspection

A one-week course was organised during March 14-18, 2005 in which twenty-seven employees participated.
Demonstration of the inspection and metrology equipments was found to be of great interest by the participants.

ISNT Certification Course on Magnetic Particle Testing – Level I

This one-week certification course was organised during February 21-25, 2005 as per the guidelines of IS 13805. Eleven employees working in the field of Non-destructive Testing attended theory as well as practical classes. At

the end of the course, theory and practical examinations were conducted by an external examiner recommended by Indian Society for Non-Destructive Testing (ISNT), Mumbai-Chapter. Certificates were awarded to successful candidates by ISNT.

Some time back a similar certification course was organised by CDM, on Liquid Penetrate Testing-Level I.

Non-destructive Testing (NDT)

Considering the overwhelming response during the last course, this one-week course was repeated again during April 25-29, 2005.

Expert faculty members were drawn from AFD and CDM. Demonstrations of various NDT methods such as Ultrasonic Testing, Magnetic Particle Testing, Radiographic Testing, Liquid Penetrant Testing, Eddy Current Testing and Leak Testing were arranged for twenty-one participants.

CNC Machining

Twenty-three participants attended this three day course at CDM during April 18-20, 2005. Various CNC machines and machining processes were demonstrated to the participants.

Advanced Computer Aided Design and Analysis

This one-week course was organised by CDM from March 28, 2005 to April 1, 2005. Fifteen participants had availed of the opportunity to interact with experts from M/s Addonix Technologies, Mumbai, M/s Design Tech Software, Pune, M/s Ranal Software, Pune and CDM.

Safety in Material Handling

One-day course each for riggers and helpers was conducted on December 10, 2004 and March 11, 2005 for 38 and 34 participants, respectively.

Industrial House Keeping

This course was jointly organized by CDM and Landscape and Cosmetic Maintenance Section, BARC. Thirty-four cosmetic helpers from various divisions of BARC attended this one-day course on February 17, 2005.

FORTHCOMING SYMPOSIA

(A) 50th ANNUAL SOLID STATE PHYSICS SYMPOSIUM

The 50th (Golden Jubilee) Annual DAE Solid State Physics Symposium is being held this year in Mumbai during December 5-9, 2005.

On all days except December 7, 2005, it will be organised at BARC. On December 7, 2005, all the deliberations will be conducted at Tata Institute of Fundamental Research (TIFR). The symposium will cover a wide range of topics in condensed matter physics, in the form of invited talks by international experts, selected presentations orally by Young achiever awardees and PhD thesis candidates, and poster presentations.

The topics to be covered are :

- Phase Transitions
- Soft Condensed Matter including Biological Systems & Liquid Crystals
- Nano-materials
- Experimental Techniques, Instrumentation & Solid State Devices
- Liquids, Glasses & Amorphous Systems
- Surfaces, Interfaces & Thin Films
- Electronic Structure & Phonons
- Superconductivity
- Transport Properties
- Semiconductor Physics
- Magnetism including Spintronics
- Novel Materials including Single Crystals

To celebrate the 'Golden Jubilee' of this symposium, a special 'Young Achiever Award' has been instituted. Recipients of these Awards will be selected from young contributors below 40 years by a Review Committee.

For further details, please contact :

Dr V K Aswal, Secretary,
Phone:(O):022-25594606 (R): 9322532545
Or
Dr K G Bhushan, Secretary,
Phone:(O) 022-25592909, (R):25481744
Email:ssps@magnum.barc.ernet.in

(B) EIGHTH BIENNIAL TROMBAY SYMPOSIUM ON RADIATION & PHOTOCHEMISTRY (TSRP-2006)

The eighth biennial "Trombay Symposium on Radiation and Photochemistry" is being organised at BARC, during January 5-9, 2006 under the auspices of the Board of Research in Nuclear Sciences/Department of Atomic Energy, in collaboration with Indian Society for Radiation & Photochemical Sciences (ISRAPS). The Organising Committee extends invitation to research scientists in universities and other institutions, engaged in basic research and development activity in the related areas to participate in the deliberations of the symposium. The scientific sessions include invited talks, in-depth discussions and poster presentations of contributed papers.

Scientific Programme

The scientific programme of the symposium will consist of several invited lectures of 30 minutes duration, delivered by international experts in the field of radiation and photochemistry, and poster presentations. Since its inception in 1992, TSRP has covered a broad range of topics in radiation and photochemistry and offered a unique opportunity for intense interaction among scientists working in the above areas. Many distinguished scientists from various countries are expected to attend and share their expertise in the forthcoming symposium, TSRP-2006.

The topics to be covered are :

- Fast & Ultra-fast processes
- Radiation & photochemistry of drugs and antioxidants
- Charge, electron & energy transfer processes
- Gas phase photochemistry & dynamics
- Radiation & photochemistry in biology and medicine
- Inorganic, organic & polymer radiation and photochemistry
- Radiation & photochemistry for environmental protection
- Industrial applications of radiation & photochemistry
- Radiation & photochemistry of advanced materials
- Role of radiation & photochemistry in nanoscience

Presentation

Facilities for multimedia presentation, overhead projection and 35 mm slides for invited presentation and approximately 1 m x 1 m space for poster presentation will be made available. All the contributed papers will be presented in poster sessions.

For further details please contact :
Dr. A. C. Bhasikuttan, Convener, TSRP-2006,
Radiation Chemistry & Chemical Dynamics Division,
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Email:tsrp2006@barc.ernet.in

भा.प.अ. केंद्र के वैज्ञानिकों को सम्मान /BARC SCIENTISTS HONOURED


Mr Ajay Kumar

● अजय कुमार, डॉ. आर. के. सिंघल, जे.प्रीता, एस. एन. जोशी एवं अे. जी. हेगडे, पर्यावरण अध्ययन अनुभाग, स्वास्थ्य भौतिकी प्रभाग. भा.प.अ.केंद्र द्वारा लिखित एक तकनीकी शोध पत्र ट्रॉम्बे के

Mr R.K. Singhal

Ms J. Preetha

Ms S.N.Joshi

Mr A.G. Hegde

आसपास भूमि पर पाये जाने वाले पेड़-पौधों की रेडियोधर्मीय मात्रा का आकलन को श्रेष्ठ शोधपत्र (पोस्टर) का पुरस्कार प्रदान किया गया । यह शोधपत्र जून 5-7, 2005 के दौरान ओस्मानिया विश्वविद्यालय, हैदराबाद में आयोजित पर्यावरण पर चौदहवें राष्ट्रीय, सम्मेलन में प्रस्तुत किया गया । इस शोधपत्र को "Journal of Geo-chemisry" भाग 8 (1-2) (2005) में विस्तारपूर्वक प्रकाशित किया गया है ।

A paper titled, "Evaluation of radiological doses to the terrestrial plants around Trombay", authored by Ajay Kumar, R.K. Singhal, J. Preetha, S.N. Joshi and A.G. Hegde of Health Physics Division was awarded Best Paper (Poster) award during National Symposium on Environment (NSE-14) held at Osmania University, Hyderabad, during June 5-7, 2005. The complete manuscript of the paper was published in *Journal of Geochemistry,* Vol. 8, Nos 1& 2 (2005).

• डॉ. अनिल कुमार पेबी, नाभिकीय पुनश्चक्रण वर्ग, तारापुर को मेंम्ब्रेन साइन्स एन्ड टेक्नॉलोजी में प्रमुख योगदान के लिए महाराष्ट्र अकादमी का अधिसदस्य निर्वाचित किया गया है। डॉ. पेबी के श्रेय में चार प्रकरण, एक पेटेन्ट ऑन नॉन डिसपर्सिव मेम्ब्रेन टेक्नालोजी को लेकर 135 से अधिक प्रकाशन हैं। हाल ही इन्हें नाभिकीय रसायनिकी के संपूर्ण पहलुओं के अनुप्रयोगों से संबंधित एक प्रतिष्ठापूर्ण अंतर्राष्ट्रीय पत्रिका "जरनल ऑफ रेडियोएनालिटिक्ल एन्ड न्युक्लियर केमिस्ट्री" के सहसंपादक के पद पर कार्य भार संभालने के लिए आमंत्रित किया गया है। यह पत्रिका स्प्रिंगर (अकॉडमिय कियाडो), बुडापेस्ट, हंगरी के द्वारा प्रकाशित की गई है। विश्व विशेषज्ञों की सहभागिता से रसायिनिकी, नाभिकीय, औषधीय तथा जैव तकनीकी अनुप्रयोगों की 50 प्रकरणों से निहित 2006 में प्रकाशित होने वाली मेंम्ब्रेन हेंडबुक के संपादक पद पर भी इन्हें नियुक्त किया गया है। इन्होंने "एप्लिकेशन ऑफ मेंम्ब्रेन टेक्नोलोजीज़ फॉर लिक्विड रेडियोएक्टिव वेस्ट प्रोसेसिंग नामक तकनीकी दस्तावेज़ के विकास के लिए आई ए ई ए में सलाहकार के पद पर कार्यभार संभाला है। डॉ. पेबी केमिकल इन्जीनियरिंग साइन्स, इन्डस्ट्रियल इन्जीनियरिंग केमिस्ट्री रिसर्च, जरनल ऑफ मेंम्ब्रेन साइन्स, हाइड्रोमेटलरजी, टलान्टा एनालिटिका एक्टा तथा अन्य अन्तराष्ट्रीय पत्रिकाओं के नियमित समीक्षक रहे हैं। नॉन-डिस्परसिव मेंम्ब्रेन टेक्नोलोजी एन्ड इट्स माडलिंग आसपेक्टस, प्रेशर ड्राइव मेंम्ब्रेन प्रोसेसिस, सोलवन्ट एक्सट्रेक्शन एन्ड मास ट्रान्सफर माडलिंग, मोक्रोसिलिक कम्पाउडंस् आदि भी इनकी शोध रुचि में शामिल हैं।

Dr Anil Kumar Pabby of PREFRE, Nuclear Recycle Group, Tarapur, has been elected as a Fellow of the Maharashtra Academy of Sciences for his outstanding contributions to membrane science and technology. Dr Pabby has more than 135 publications to his credit including four chapters and one patent on non-dispersive membrane technology. Recently, he was invited to join as Associate Editor of *Journal of Radioanalytical and Nuclear Chemistry,* a prestigious International Journal dealing with all aspects and applications of Nuclear Chemistry. It is published by Springer (Akademiai Kiado),

Budapest, Hungary. Dr Pabby has also been appointed as one of the Editors of the *Membrane Handbook* being published by Marcel Dekker, New York, USA in the year 2006 consisting 50 chapters with participation of membrane experts from all over the world covering chemical, nuclear, pharmaceutical and biotechnical applications. He has also served as consultant to IAEA for developing a technical document on "Application of membrane technologies for liquid radioactive waste processing". Dr Pabby has been a regular reviewer for papers for publication in international journals like *Chemical Engineering Science, Industrial Engineering Chemistry Research, Journal of Membrane Science, Hydrometallurgy, Talanta, Analytica Chimica Acta* and several others. His research interest includes non-dispersive membrane technology and its modeling aspects, pressure driven membrane processes, solvent extraction and mass transfer modeling, Mocrocyclic compounds, etc.

● टी. वी. दिनेश, फॉयर सर्विसेज् सैक्शन, भाभा परमाणु अनुसंधान केंद्र ने वर्ष 2004 का प्रतिष्ठित "गोडिवा पुरस्कार" प्राप्त किया। इन्सटिट्यूशन ऑफ फॉयर इन्जीनियरस् (यू.के.) द्वारा संचालित यह पुरस्कार उच्चतम-पद के नॉन-यूके परीक्षार्थी एम आइ फॉयर (ई) को दिया जाता है। यह पुरस्कार इनको 15 जुलाई 2004 को क्लोटार्ज़ कॉस्टेल होस्टल, डब्लिन, यू.के. में आयोजित एक समारोह में प्राप्त हुआ।

Mr T.V. Dinesh of Fire Services Section, BARC, bagged the prestigious "Godiva Award" for the year 2004. This award is given to the top non-UK candidate in the MI Fire (E) Exam conducted by Institution of Fire Engineers (UK). He received the award on July 15, 2004 at a function held at Clotarz Castel Hostel, Dublin, U.K.

● बी. एस. कुबाल एवं डॉ. एस.एफ. डिसूजा, नाभिकीय कृषि एवं जैव प्रौद्यौगिकी प्रभाग, भाभा परमाणु अनुसंधान केंद्र ने डिपार्टमेंट ऑफ बायोकेमिस्ट्री, मोलिक्यूलर बायोलोजी एन्ड जेनेटिक इन्जीनियरिंग, जी.पी.पंत यूनिवर्सिटी ऑफ एग्रिकल्चर एन्ड टेक्नॉलोजी पंतनगर (उत्तरांचल) में नवंबर 21-24, 2004 के दौरान "चेलेंजिज़ एन्ड अपोरचुनिटी टु हारनेस दि मोडर्न बयोलोजी फॉर सोशियो-इकोनोमिक डेवलोपमेंट इन जेनोमिक एरा" पर 73वीं सोसाइटी ऑफ बाइलोजिकल केमिस्ट्री (इन्डिया) में इमोबिलाइज़ेशन ऑफ केटेलेज़ बाई क्रॉस-लिन्किग ऑफ परमियब्लाज़ड यीस्ट सेल्ज़ इन ए प्रोटीन सपोर्ट "नामक शोध पत्र की प्रस्तुति के लिए उच्चत्तम पोस्टर पत्र पुरस्कार प्राप्त किया।

The paper entitled "Immobilization of Catalase by Cross-Linking of Permeabilized Yeast Cells in a Protein Support" authored by B.S. Kubal and S.F. D'Souza of Nuclear Agriculture & Biotechnology Division, BARC, has won the best poster award in the presentation at the 73rd Society of Biological Chemistry (INDIA) annual meeting and national conference on a "Challenges & Opportunity to harness the modern biology for socio-economic development in Genomic Era" held during November 21-24, 2004 at Department of Biochemistry, Molecular Biology & Genetic Engineering, G.P.Pant University of Agriculture & Technology Pantnagar (Uttaranchal).

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