Intense laser fields and their interaction with matter*

Those of us who have played with a He–Ne laser would have noticed that focussing of the beam results in rarefication of air at the focal point. While lasers are special, intense lasers are even more special in their effects on atoms and molecules. Much of physics (and chemistry) that we learn in college concerns with matter and its interaction with weak electromagnetic radiation. When it comes to the interaction of matter with intense laser fields, the physics becomes somewhat different.

How intense is intense? The maximum intensity of a laser attainable in the laboratory has been increasing with years. While a megawatt (10^6 W/cm^2) laser was the order of the day in the late sixties, gigawatt (10^9 W/cm^2) lasers were available in the seventies and by the eighties getting a terawatt (10^{12} W/cm^2) laser was no problem. Lasers of 10^{18} W/cm^2 intensity (I) are around now. To give an idea of what these intensities mean, it should be pointed out that at $I \simeq 10^{13}$ W/cm^2, atoms and molecules ionize readily. At $I \simeq 10^{14}$ W/cm^2, multiple ionization occurs and when $I \simeq 3.5 \times 10^{16}$ W/cm^2, nonlinear atomic processes become important. Above 10^{19} W/cm^2, relativistic effects would become important and such an intensity is referred to as superintense.

Intense lasers have brought about interesting new chemistry and physics in the last thirty years. For one thing, the sheer number of photons arriving per unit time at the target atom or molecule makes multiphoton processes inevitable. Multiphoton dissociation and ionization were already being studied in the seventies. The high intensities that are attainable today lead to multiple ionization, above threshold ionization (ATI) and other nonlinear processes. One of the questions that arises is the mechanism of such processes. Are multiply charged species formed in a sequential process (for example, $Ar \rightarrow Ar^+ \rightarrow Ar^{2+} \rightarrow ...$) or in an instantaneous process ($Ar \rightarrow Ar^{3+} + 3e^-$)? What are the competing channels? Is there a way to control them, one over the other? When a multiply-charged diatomic species falls apart (dissociates) into two positively charged ions, for example, the Coulomb repulsion (referred to as Coulomb explosion) drives them apart. Is there a way to identify the distance at which theis happens? Is there a way to image them as they are in the process of falling apart? How do we understand these processes theoretically?

For intensities above 10^9 W/cm^2, the weak field interaction theories and perturbation theoretic approaches become simply inadequate. Are the other approaches based on numerical solution of the Schrödinger equation adequate and practicable?

These are some of the questions raised and partly answered at the discussion meeting in which a healthy mixture of experimentalists and theoreticians, some from abroad and some from within the country, including a number of young research scholars participated. The meeting started with an overview talk, with his own contributions put in perspective, by F. Faisal of University of Bielefeld, Germany. While S. L. Chin (Univ. of Laval, Quebec, Canada) spoke on experimental investigations on nonsequential ionization and electron trapping in atoms and molecules, E. Constant (Univ. of Bordeaux, France) discussed the results of his investigations on time-resolved Coulomb explosion imaging and enhanced ionization and L. J. Frasinski (J. J. Thompson Physics Lab., Reading, UK) on multielectron dissociative ionization (MEDI) of diatomic molecules in intense laser fields. D. Mathur (TIFR, Mumbai) discussed the alignment of molecules in the presence of intense laser fields and its effect on the spatial distribution of fragment ions, with a large number of examples from his laboratory, pointing out the surprises Nature has in store for anybody who cares to investigate her secrets. His coworker G. Ravindra Kumar discussed their findings on the interaction of intense laser fields with metal surfaces and the short wavelength generation from the resultant plasma. P. A. Naik of CAT, Indore gave a guided tour of the processes and products developed indigenously at Indore, with special emphasis on soft X-ray generation from laser-produced plasmas.

A. Bandrauk (Univ. of Sherbrooke, Quebec, Canada) discussed the need to go beyond the Born–Oppenheimer approximation and presented results of extensive numerical calculations on H_2^+ in intense laser fields. He pointed out recent developments on charge resonance enhanced ionization and laser induced electron diffraction. That India has a number of theoreticians of world class became evident from the talks of S. S. Bhattacharyya on the above threshold and below threshold multiphoton dissociation of HD^+, K. Rai Dastidar on above threshold ionization/ autoionization in H_2 and S. Saha on polarization and nonadiabatic effects on population transfer in H_2. All these three speakers, incidentally, were from a single Institute – the Indian Association for the Cultivation of Science, Calcutta. That having limited computational resources is no real limitation if one is willing to think hard and come up with alternative ways of doing theory was evident from the talk of B. M. Deb (Panjab Univ., Chandigarh) on density-based quantum fluid dynamical approach to time-dependent processes. M. Mishra (IIT, Mumbai) presented an elegant route to photodynamic control. Instead of relying on shaped pulses, to learn from the Fourier transform of a successful pulse and to choose the initial state of the molecule accordingly was his proposed strategy.

That following the time evolution of carefully chosen wave packets by numerically solving the time-dependent Schrödinger equation is an intuitively convenient and viable approach in monitoring the behaviour of molecules in general and in ultra-fast laser fields in particular, was the message conveyed by the overview talk by A. Suzor-Weiner (Univ. of Paris-Sud, France). This was amply supported by the examples presented by her student E. Charron and also by the talk by N. Sathyamurthy (IIT, Kanpur) on photo-

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induced desorption and resonance Raman aspects. A. R. P. Rau (Louisiana State Univ., Baton Rouge, USA) expounded the intricacies involved in solving time-dependent operator equations.

K. Miyazaki (Kyoto Univ., Japan) presented the results of his experimental investigations on high harmonic generation from atoms and molecules in intense laser fields and pointed out the discrepancies between experiment and theory that remain to be explained. T. Seideman (NRC, Canada) discussed the theory of shaping, steering and squeezing molecular beams with light. H. Shiromaru (Tokyo Metropolitan Univ., Japan) drew similarities in his talk between interaction of intense laser fields with molecules and collisions involving molecules and fast beams of highly-charged ions. J. H. Sanderson (Univ. College London, UK) gave an account of a new set of experiments being carried out on molecular ionization in femtosecond laser fields.

The grand finale of the extensive talks and intensive discussions on intense laser fields and their interaction with matter was in the form of yet another talk by S. L. Chin, but this time, on investigating the propagation and filamentation of Ti–sapphire laser pulses in the atmosphere with the aid of colourful slides. That all these investigations are not confined to the realm of ivory towers but are very much down to earth (and linking earth to the heavens) was emphasized by Chin by pointing out to their potential utilization in detection of chemical and biological molecules in the atmosphere and in controlling lightning.

It used to be said that India was lagging behind the West by 10 years in Science and Technology. This gap has been reduced considerably in recent times, thanks to improvements in telecommunication through phone, fax and more importantly, email. Still, if we want to be equal partners in the global playing field, there is need for instant exchange of ideas. This is where meetings and conferences play an important role. Because that is where we learn what *is* happening and not what happened some time back (as reported in the refereed Journals) and also some of the nitty-grittys which will probably never be spelt out in written form. With the dollar–rupee conversion rate being so high, it is becoming more and more difficult for Indians to travel abroad for meetings. Even when they do, they do so in small numbers. One way out of the situation is to organize international meetings in India and bring together young Indian researchers to interact with the active workers from all over the world.

Deepak Mathur and his colleagues must be congratulated for their organizing this timely discussion meeting and choosing the right ambience for academic discussions. All the participants, regardless of their status (from the juniormost research scholar to the most eminent practitioner in the field) stayed in the same hotel, dined and debated together, thus getting the most out of the Discussion Meeting. As the participants were checking out of the hotel, it was clear from their faces that it was time (and money and effort) well spent. They were richer with ideas and now could go back to their labs to pursue them further.

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Another brick in the Tower of Babel: The search for an universal language

Anindya Sinha

'And the whole earth was of one language, and of one speech. And it came to pass, as they journeyed from the east, that they found a plain in the land of Shinar, and they dwelt there. And they said to one another, Go to, let us make brick, and burn them thoroughly. And they had brick for stone, and slime had they for morter. And they said, Go to, let us build us a city and a tower, whose top may reach unto heaven; and let us make us a name, lest we be scattered abroad upon the face of the whole earth. And the Lord came down to see the city and the tower, which the children of men had builded. And the Lord said, Behold, the people is one, and they have all one language; and this they begin to do: and now nothing will be restrained from them, which they have imagined to do. Go to, let us go down, and there confound their language, that they may not understand one another's speech. So the Lord scattered them abroad from thence upon the face of all the earth: and they left off to build the city. Therefore is the name of it called Babel; because the Lord did there confound the language of all the earth: and from thence did the Lord scatter them abroad upon the face of all the earth.'

Genesis **11**: 1–9

The mystery of the origins and development of the human languages has fascinated scholars for well over 300 years. Historically, one major line of argument has been that the study of linguistic development in children (language *ontogenesis*) would provide clues about the origins of language in