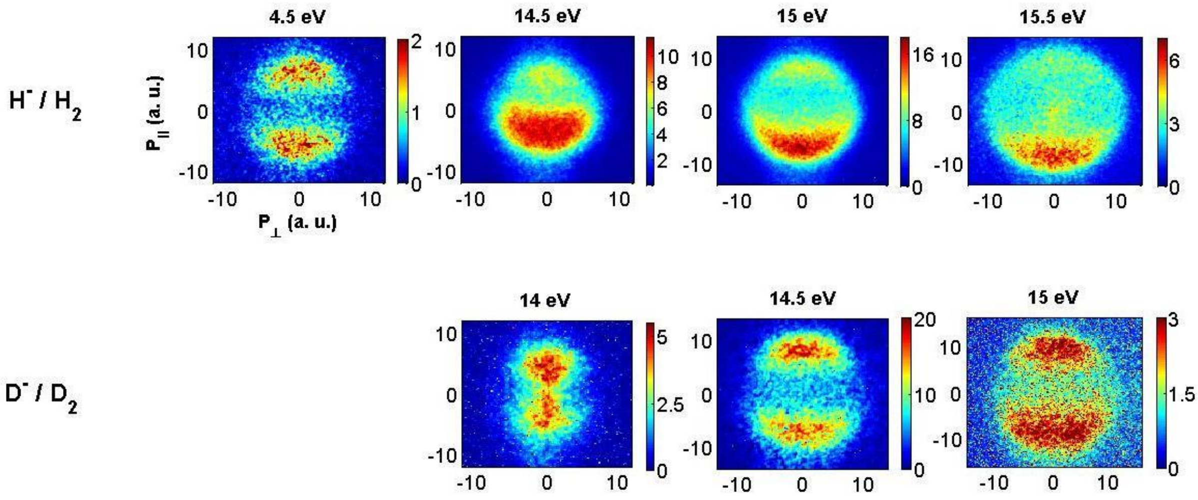
Creation of coherent states in molecules by incoherent electrons

In a breakthrough experiment, researchers from the Tata Institute of Fundamental Research, Mumbai India and Open University, Milton Keynes, U.K. have shown — for the first time — that incoherent electrons, displaying their quantum-mechanical nature, can induce coherence in a molecular system on attachment. Their latest results, published in the Journal *Nature Physics*, show that the coherence induced by the capture of a single electron by an H_2 molecule preferentially results in the ejection of an H^- ion in the backward direction with respect to the incoming electron beam. The other product of the dissociation is the H atom in its excited state. In other words, this coherence induced in the molecule segregates the charge and excess energy in the system in a preferred manner. Similar measurements in the isotopomer of H_2, namely D_2, does not show such a strong asymmetry in ejection of the fragment ion but shows the reversal of the asymmetry as a function of incoming electron energy.



So far, researchers have used such coherence induced by laser beams to control molecular dissociation but in that case, the coherence in the resulting excited molecular entity is understood to stem from the absorbed laser radiation. By demonstrating the presence of coherence resulting from a capture of an incoherent electron, Prof. Krishnakumar and co-workers have shown that such coherence can also stem from the transfer of more than one value of angular momentum quanta. On the capture of a low-energy electron, a relatively-unstable molecular negative ion is formed. Subsequently, this negative ion decays by ejecting the extra electron. However, if the ion survives against the electron ejection, it undergoes dissociation. This is known as dissociative attachment. According to Prof. Krishnakumar, though dissociative attachment has been traditionally linked with transfer of multiple values of angular momentum quanta in the molecular system, it is now for the first time that such a quantum-coherent response has been observed. These measurements were carried out by Prof. E. Krishnakumar, using an experiment built by him in Prof. Nigel Mason's lab in the U.K. The interpretation of data along with the model was given by Dr. V. Prabhudesai and Prof. Krishnakumar.

Low-energy electrons are ubiquitous and are known to play important roles in a variety of phenomena relevant to astrochemistry (where they participate in the synthesis of new molecules), radiation biology (where they cause chemical changes in living cells), plasma chemistry, atmospheric chemistry, radioactive waste management and nanolithography — to name but a few. In all these cases, dissociative attachment plays a critical role. The unstable excited molecular negative-ion states are at the core of this process. However, due to the very short lifetime of these species very little is known about them at present. These new results point to rich unexplored dynamics of excited molecular negative ions that might open up new possibilities in inducing chemical control. They also pose a challenge to theoreticians to come up with a detailed model for the negative-ion chemistry that is associated with low-energy free electron scattering.

The group led by Prof. Krishnakumar and Dr. Prabhudesai in TIFR specialises in low-energy electron interactions with molecules in gas and condensed phase with particular emphasis on the possibility of controlling chemical reactions using low-energy electrons.