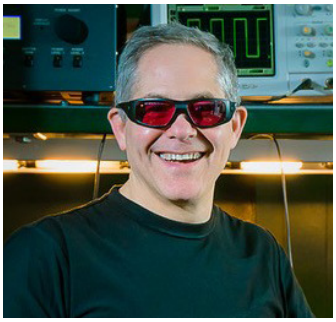


Marcos Dantus

Ultrafast Science

MSU Foundation Professor
and
University Distinguished Professor of Chemistry
and
Adjunct Professor of Physics

(b. 1962)

B.A. & M.A., 1985,
Brandeis Univ.;

Ph.D., 1991,
California Institute of Technology;

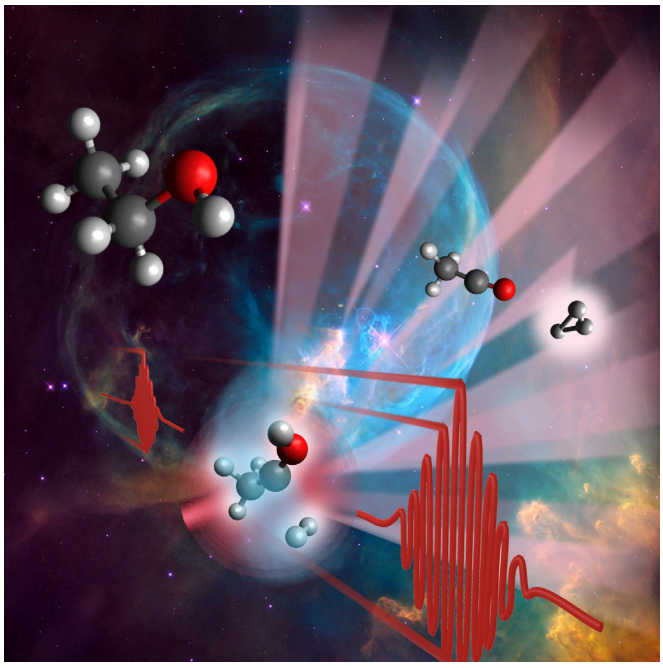
Postdoctoral Research Fellow, 1991-93,
California Institute of Technology;

Member, 2014–,
National Academy of Inventors.

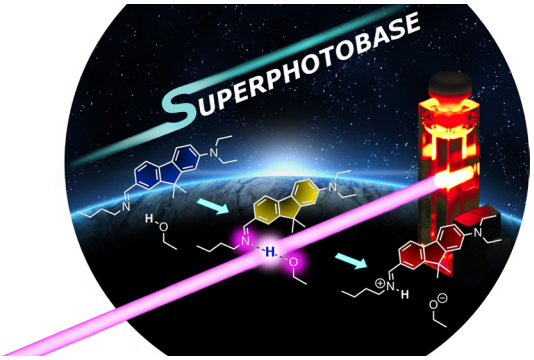
517-353-1191

Ultrafast lasers, with pulse durations shorter than 10^{-13} s, less time than it takes for atoms to move, have already led to Nobel Prizes in Chemistry and Physics. Our group has two well-funded thrust areas research: ***(a) Understanding and controlling chemistry under intense laser field radiation:*** Exploring exotic molecular dynamics and mechanisms. ***(b) Quantum control of chemical reactions:*** New laser sources, pulse shapers, and computers are revolutionizing how we study materials and their chemical reactions.

(a) Understanding and controlling chemistry under intense laser field radiation. Our common understanding of light-matter interactions fails at extreme intensities, especially when the field strength of the incident radiation is strong enough to liberate electrons. At intense enough fields those electrons become highly energetic, opening up an abundance of novel atomic and molecular processes to investigate. In our lab, we take advantage of laser sources and pulse shaping methods we have developed to understand and to control the dynamics of exotic chemical reactions in gas, liquids, and solids induced by strong laser fields. Our recent projects include study of exotic chemical reactions relevant to interstellar chemistry and the formation of H_3^+. H_3^+ is the most important ion in the universe because it is responsible for the formation of most organic molecules in the universe and perhaps responsible for life in the universe. Its formation from organic molecules requires dissociation and formation of multiple chemical bonds. Our research group is discovering fundamental processes which proceed through the formation of a neutral H_2 molecule that roams the precursor until it extracts an additional proton.



(b) Quantum control of chemical reactions. The ability to design light pulses that drive a specific chemical reaction enables technological advances in a range of fields from sensing to energy conversion, where control of energy and dynamics on quantum length scales could lead to greater efficiency and specificity. Thus, it is essential that new strategies towards this grand challenge are developed. This project is enhanced by close collaboration between synthesis, theory, and spectroscopy. A specific goal is to understand how to circumvent spontaneous energy flow to achieve chemical reactivity in excited states. The capabilities developed here will influence a range of fields that benefit from precise control of quantum objects, e.g. novel strategies for super-resolution microscopy, coherent control of chemical reactions, nano-photolythography, and strategies for creating luminescent centers in transparent materials that can be used for quantum information sciences.



This project implements novel strategies for quantum control of energy flow and reactivity in large organic molecules. Recognizing that different electronic excited states may be highly reactive, shaped laser pulses will be used to (a) populate electronic states with desirable reactivity, and (b) minimize the probability of spontaneous transition out of the desired electronic state. In pursuit of (b), quantum control strategies that range from semi-classical (driving the vibrational wave packet along a particular reaction coordinate) to quantum strategies with no classical analogue will be used. For example, topological effects near intersections between electronic states can be exploited to influence the reaction outcome and strong coupling, where the potential energy surfaces are dressed by the light field, can alter the natural energy flow enhancing coherence with the driving field.

Selected Publications

Quantum coherent control of H_3^+ formation in strong fields, M. J. Michie, *et al.*, *J. Chem. Phys*. **2019**, *150*, 044303.

H_2 roaming chemistry and the formation of H_3^+ from organic molecules in strong laser fields, N. Ekanayake, *et al.*, *Nat. Commun*. **2018**, *9*, 5186.

Ultrafast Dynamics of a "Super" Photobase, W. Shang, *et al.*, *Angew. Chem. Int. Ed*. **2018**, *57*, 14742 –14746.

M. Dantus, *Femtosecond Laser Shaping: From Laboratory to Industry*, CRC Press **2017**.

Time-resolved signatures across the intramolecular response in substituted cyanine dyes, M. Nairat, M. Webb; M.P. Esch, V.V. Lozovoy, B.G. Levine and M. Dantus, *Phys. Chem. Chem. Phys*. **2017**, *19*, 14085-14095.

Femtosecond real-time probing of reactions MMXVII: The predissociation of sodium iodide in the A 0$^+$ state, G. Rasskazov, M. Nairat, I. Magoulas, V.V. Lozovoy, P. Piecuch, and M. Dantus, *Chem. Phys. Lett*. **2017**, in press.