Professor R.J. Dwayne Miller
Max Planck Director and Distinguished Faculty Research Chair and University Professor,
University of Toronto
Canada

PROFESSOR J. C. POLANYI, F.R.S.

DEPARTMENT OF CHEMISTRY, UNIVERSITY OF TORONTO

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November 30, 2017

Selection Committee
"Albert Einstein" World Award of Science
World Cultural Council
11002 México City
México

Dear Colleagues,

I appreciate the difficult task you have, to identify the most significant scientific work and the impact this has had. It is often impossible to draw a line from breakthroughs in science to their effect . You only have to look at how long the invention of the transistor or laser took to reach the average person. Now everyone's lives are entangled through telecommunication and microelectronics using hand-held computers to access the world's information. In this respect, I wish to draw your attention to the accomplishments of my colleague **R. J. Dwayne Miller**, which – along with the work of Manfred Eigen and Ahmed Zewail – holds the potential to one day have a large impact on the quality of life.

We can view the quest to study chemistry as an imaging problem, tracking the racing of atoms to form new molecules. This limit has been achieved by Miller. His advance was made possible using "ultrabright" electron sources to light up atomic motions as they occur. The high brightness was the key. Prior to his work, it was impossible to attain sufficient brightness with an electron source due to the coulomb repulsion between electrons ($1Bs invested in XFELs stand testimony to this statement). This achievement was realized by solving the coupled equations of motion for some 10,000 electrons (JAP 2002) that found that the spatial coherence for imaging could be conserved with sufficient electrons for single-shot structure determination. This new insight led to the first atomic movie of the melting of a metal (Science 2003). To put this achievement in perspective, the electron sources developed by the Miller group were 12 years ahead of 4th Generation Light Sources, major international facilities, to meet this objective (invited review, Science 2014). To date, his group has provided the highest spatial-temporal resolution in capturing atomically resolved dynamics – with a tabletop source.

Miller's work opened up structural and chemical dynamics to atomic-level inspection (Nature 2009, Science 2010, Nature 2010, J. Phys. Chem. 2011), and created a new field. His latest works (JPC B 2013, Nature 2013, Science 2015) have revealed the reduction in dimensionality that occurs during the barrier crossing events governing chemistry. The concept of key modes driving molecular

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reaction dynamics has been confirmed for complex many body systems. The most dramatic demonstration was the recent work of Ishakawa et al. (Science 2015) that solved the phasing problem in inverting diffraction to real space, a significant achievement in its own right. The process involves a metal-to-metal electron transfer process or redox chemistry. We can now directly observe the atomic motions leading to stabilizing the charge separation, the feature of Rudolf Marcus' Nobel Prize for the theory, now seen at the atomic level.

The 'movies' of the intermolecular electron transfer between Pt atoms in the organo-metallic complex Pt(dmit)2 are notable. One can observe the distillation of a 300 dimensional problem down to a few key modes. Equally impressive, the quantitative analysis shows that the Miller group has achieved a spatial resolution of .01 Å, which is on the order of the thermal motion of atoms. A space-time limit for imaging chemistry has been achieved. Resolving this physics is an unqualified milestone in science.

There is another important consideration. The "molecular movie" of a strongly driven phase transition illustrated how to arrest nucleation growth to just 10 atoms and avoid cavitation induced shock wave damage in laser ablation. This led to the development of a new laser concept for surgery that is the first method to cut without scar tissue formation (PLoS 2010). This has achieved the long held promise of the laser to achieve yet another fundamental limit, in this case to minimally invasive surgery that will have a major impact. Cornea transplants without risk of blindness, restoring hearing with microcochlea implants, perfect vocal cord repair, as well as molecular level imaging of tissue (Nanotech 2015) are all possible thanks to this work. The single application for cornea transplants was awarded the Baun Prize (2016) for the most outstanding work (PLoS 2015) in ophthalmology in the last 2 years.

Added to this, Miller founded *Science Rendezvous* (www.sciencerendezvous.ca) with over 350 sites. This is one of the largest events for the promotion of the importance of science to the general public with attendance figures now over 250,000, involving some 5000 volunteers. This event has even brought science to remote communities of Indigenous people in Canada.

R. J. Dwayne Miller has made a leading contribution to science with the development of ultrabright electron sources to achieve the fundamental space-time limit to imaging chemistry. The fact that such a breakthrough in basic science could find its way so soon to important applications in medicine is a marvel.

The Albert Einstein World Award of Science is a deserved ovation for an outstanding performance. I wholeheartedly recommend him for this honour.

Sincerely,

J. C. Polanyi

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STANFORD UNIVERSITY
STANFORD, CALIFORNIA 94305-5080

MICHAEL D. FAYER
DAVID MULVANE EHRSAM AND
EDWARD CURTIS FRANKLIN
PROFESSOR OF CHEMISTRY

DEPARTMENT OF CHEMISTRY
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August 25, 2016

Selection Committee
Albert Einstein World Award of Science

Dear Colleagues,

I am delighted to support the nomination of Professor R. J. Dwayne Miller for the Albert Einstein World Award of Science. He is a leading figure in optical and imaging sciences, in particular, ultrafast investigations of chemical dynamics. I have known Dwayne for well over three decades, since he was one of my graduate students in the Department of Chemistry, Stanford University. I have kept in close contact with Dwayne over these many years, and I know him and his work very well. I work in scientific fields with considerable overlap with Dwayne's work, so I am in an excellent position to comment on his talents and accomplishments. He was a brilliant student, and he is a brilliant scientist.

Dwayne is extremely smart and passionate about science, but his most important attribute is his creativity. His creativity has led Dwayne to be a pioneer in a variety of scientific fields. While his entire career is marked by scientific success and leadership in ultrafast laser spectroscopy from the infrared to the ultraviolet, his work on the development and application of ultrafast electron techniques, which are based on ultrafast optical pulses, for atomically resolved structural dynamics is leading the field in a new and fundamentally important direction.

Dwayne's accomplishments make possible the ability to see the very essence of chemistry and biology. The relevant time scales of chemistry are femtoseconds to picoseconds, which are governed by nuclear motions (vibrations) and sampling of configurations. Dwayne is able to capture atomic motions with the requisite time and spatial resolution using a new concept in ultrabright electron sources. This breakthrough was first reported as the cover story in Science (Siwick et al., Science 2003). Dwayne's work using a very short accelerator was many years ahead of rather enormous investments in major facilities to do the same thing. Rather than beginning with a

massive electron accelerator, Dwayne's approach is based on the use of ultrafast optical pulses.

The first spatial and time resolved experiments conducted by the Miller group were on melting. There was a long standing debate on the timescales and length scales of melting that go back to the days of Born. By using a femtosecond laser, Miller's group could heat up solids at heating rates of 10^{15} ^{0}C/s. At the atomic level, Dwayne found that the solid underwent a solid to liquid phase transition within 1 ps once it reached a critical threshold. Rather than melting from the "outside-in", matter melts from the inside out in a process known as homogeneous nucleation. These findings were the first observations in real time of an atomically resolved structural change in which bonds were broken and atoms reassembled into a new state. Since then he has extended the method so that he is currently imaging actual chemical reactions. In some sense, this is the holy grail of chemistry, to what in real time chemical transformations.

Dwayne is also dedicated to the promotion of science education to the general public. He founded Science Rendezvous that has brought nearly all research institutions and nonprofits across the Greater Toronto Area to collectively promote and make science accessible. Through his leadership, Science Rendezvous went national, across Canada in 2011, as part his initial vision to scale the event in size to give voice to the importance of science to our society. Over 100,000 people from across North America being enthralled by what our scientists have discovered and the passion for their discipline. The seeds for our next generation of scientists are being sown by Dwayne Miller.

R. J. Dwayne Miller has left an indelible mark on optical science through his vast range of developments in ultrafast laser spectroscopy, ranging from the infrared to the visible and ultraviolet, and his use of ultrafast lasers to generate electrons for dynamical structural determinations. His achievements have paved the way for major advances in understanding structural dynamics. The scope of his accomplishments and leadership certainly qualify him for recognition through the Albert Einstein World Award of Science.

Sincerely,

UNIVERSITY OF CALIFORNIA

BERKELEY • DAVIS • IRVINE • LOS ANGELES • MERCED • RIVERSIDE • SAN DIEGO • SAN FRANCISCO SANTA BARBARA • SANTA CRUZ

SHAUL MUKAMEL

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IRVINE, CA 92697-2025
smukamel@uci.edu

November 3, 2017

The "Albert Einstein" World Award of Science.
Selection committee

I am delighted to support the nomination of R. J. Dwayne Miller for the Albert Einstein World Award of Science.

Miller has an outstanding track record in the ingenious use of optics to the study of molecular vibrations. His work on the development of diffractive optics nonlinear spectroscopy, specifically, the means to correlate noise, gave phase locked pulse pairs that was instrumental in the development of 2D photon echo spectroscopy in the IR regime.

Early in his career, Dwayne Miller discovered that protein response functions involved global rearrangements of the protein on timescales orders of magnitude faster than previous envisaged within previous proposals of glass like dynamics for protein behavior (Genberg et al Science 1991, Miller, Acc Chem Res 1994). He proposed the Collective Mode Coupling Model as the underlying mechanism by which proteins coarse grain sample their highly complex potential energy surface to execute functions so efficiently. The ultimate experiment to test this concept would be to directly observe the structural dynamics, and correlations, during biological and chemical processes as they actually occur --- direct observation of atomic motions during transition state processes. The observation of atomic motions in real time is one of the great dream experiments in science and effectively gives a direct observation of the the very essence of chemistry. This objective has been the driving force of his research career. To this end, Miller has pioneered the development of ultra bright electron sources to sufficient brightness to literally light up atomic motions in a single shot (flash). The first experiments to atomically resolve structural dynamics on the prerequisite subpicosecond time scale were achieved by the Miller group (Siwick et al. Science 2003). This work constituted the first atomically resolved dynamics of homogeneous nucleation phenomena. This new level of scrutiny demonstrated that under appropriate driving conditions nucleation phenomena could be arrested at the 1 nm length scale. This rather simple observation solved the last remaining hurdle to the use of lasers in surgery by eliminating shock wave production associated with runaway nucleation growth and collapse (think of the violent nucleation with boiling water). This new insight led to the demonstration that it was possible to do surgery at the level of the single cell and most importantly without scar tissue formation — for the first time by any method (S. Amini-Nik et al PLoS 2010). The long held promise of the laser to achieve the fundamental (single cell) limit for minimally invasive surgery has finally been realized. This work gives testimony to the importance of basic science as the research was striving for an atomic level understanding of critical phenomena and not medical application of this importance.

Miller and his group have continued to pioneer even brighter electron sources and have extended atomic level perspectives of structural dynamics from the formation of extreme states of matter to chemical reactions with conserved stereochemistry where the specific reaction modes have been identified (Jean-Ruel et al, J. Phys. Chem. B. 2011 and 2013).

Miller's greatest achievement is the direct observation of actual vibrational motions in molecules with atomistic resolution. One of the long-time dream experiments in science has been to directly observe atomic motions as they occur during the primary events governing chemistry and biology. The enormous challenges have been achieving simultaneously femtosecond time resolution and atomic spatial resolution Miller was able to capture atomic motions on the prerequisite time and spatial resolution using new ultra-bright electron sources to literally light up atomic motions as they occur thus, recording movies of elementary chemical events. The first atomic movie of a structural transition was reported in (Science 2003). The electron sources developed by the Miller group were 12 years ahead of 4th Generation Light Sources, major international facilities, to meet this objective (invited review, Science 2014). To date, his group has provided the highest spatial-temporal resolution in capturing atomically resolved dynamics with a tabletop electron source.

Miller's work that first enabled to atomically resolve ultrafast structural dynamics by electron diffraction has opened up structural and chemical dynamics to atomic level inspection (Nature 2009, Science 2010, Nature 2010, J. Phys. Chem. 2011). His latest works (JPC B 2013, Nature 2013, and Science 2015) have directly revealed the enormous reduction in dimensionality that occurs during the barrier crossing events governing chemistry by identifying and detecting collective nuclear coordinates.

Miller has published over 260 research articles, and trained over 50 Ph. D. students and postdoctoral students who are now at top research institutions. His research accomplishments have been recognized through a Sloan Fellowship, Dreyfus Award, NSF Presidential Young Investigator Award, a Guggenheim, Humboldt Award, Polanyi Lecture Award, The Rutherford Medal in Chemistry from the RSC, and the CIC Medal (2009). Most recently, he was awarded the McNeil Medal from the RSC for his work in scientific outreach. He founded Science Rendezvous that is now a nationwide event in Canada through which the public directly engages in discussion with scientists to learn firsthand the importance of science to society and the joys of science. This high energy event has attracted over 160,000 attendees with over 4000 volunteers and stands him apart as a both a world leading researcher and champion for promoting the greater cause of science.

In summary, Miller has opened up new vistas to atomic exploration that will have a profound impact in how we think about chemistry. He has left an indelible mark on physical chemistry and laser surgery and has paved the way for major advances in understanding structural dynamics.

These remarkable accomplishments and leadership record uniquely qualify Dwayne Miller for recognition with the Albert Einstein World Award of Science.

Sincerely,

Shaul Mukamel
Distinguished Professor of Chemistry and Physics and Astronomy

Grounds for Nomination: One of the great dream experiments in science has been to directly observe atomic motions as they occur during the primary events governing chemistry and biology – to observe the very essence of chemistry. The visualization of the relative atomic motions during a chemical process is the classic gedanken experiment that binds all the disciplines of chemistry together. Given the enormous challenges for achieving simultaneously femtosecond time resolution and atomic spatial resolution, this was thought to be the purest form of a thought experiment. This grand challenge has been met. R. J. Dwayne Miller was able to capture atomic motions on the prerequisite time and spatial resolution using a new concept in "ultrabright" electron sources to literally light up atomic motions as they occur. The high brightness was the key enabling feature. Prior to his work, it was thought that it would never be possible to attain sufficient brightness with an electron source due to the inherent coulomb repulsion between electrons ($1Bs invested in XFELs stand testimony to this statement). This achievement was realized by solving the coupled equations of motion for some 10,000 electrons (JAP 2002) that found that the spatial coherence for imaging could be conserved with sufficient electrons for single shot structure determination. This new insight led to the first atomic movie of a structural transition (Science 2003). To put this achievement in perspective, the electron sources developed by the Miller group were 12 years ahead of 4th Generation Light Sources, major international facilities, to meet this objective (invited review, Science 2014). To date, his group has still provided the highest spatial-temporal resolution in capturing atomically resolved dynamics with a table top source.

R. J. Dwayne Miller's work, that first broke this barrier to atomically resolved structural dynamics has opened up structural and chemical dynamics to atomic level inspection (Nature 2009, Science 2010, Nature 2010, J. Phys. Chem. 2011) and has created a new field. His latest works (JPC B 2013, Nature 2013, Science 2015) have directly revealed the enormous reduction in dimensionality that occurs during the barrier crossing events governing chemistry. The concept of key modes driving molecular reaction dynamics has long been debated. Not only has this notion been confirmed even for complex many body systems, we can now observe the very motions involved. The most dramatic demonstration was the recent work of Ishakawa et al (Science 2015) in which this work solved the phasing problem in inverting diffraction to real space, a significant achievement in its own right. The movies of the intermolecular electron transfer between Pt atoms in the organo-metallic complex Pt(dmit)2 should not be missed. This work is the first full atomic resolved chemical reaction. It is not a model or theoretically refined movie of structural dynamics. It is the directly observed atomic motions. This work shows the atoms as stars in a night sky with no "balls and springs" to bias the observation. One can literally observe by eye the distillation of a 300 dimensional problem down to a few key modes. If a large number were involved, the motions would appear as a blur. Instead, with no detailed mathematical analysis one can clearly see the key modes involved. Equally impressive, the quantitative analysis shows that the Miller group has achieved a spatial resolution of .01 Å, which for calibration is on the order of the zero point motion or quantum limit. These are extraordinary accomplishments. Further, it is this reduction in dimensionality during the far from equilibrium nuclear motions involved in barrier crossing, now made directly observable, that makes chemistry a transferrable concept. It is the "magic of chemistry" that enables synthetic chemists to exploit a wide variety of reaction mechanisms to make virtually any molecule imaginable, regardless of complexity. Resolving this bit of physics is an unqualified major milestone.

There is another important consideration that makes the accomplishments of R. J. Dwayne Miller stand out even more. The very first "molecular movie" of a strongly driven phase transition illustrated how to arrest nucleation growth to just 10 atoms and completely avoid cavitation induced shock wave damage in laser ablation. This discovery led to the development of a new laser concept for surgery that is the first method by any means to cut without scar tissue formation (PLoS 2010). This work has achieved the long held promise of the laser to achieve the fundamental limit to minimally invasive surgery that surely will have a major impact on potentially millions of people's lives. Cornea transplants without risk of blindness, restoring hearing/microchoclea implants, perfect vocal cord repair, as well as molecular level imaging of tissue (Nanotech 2015) are all possible thanks to this work. The single application for cornea transplants was awarded the Baun Prize (2016) for the most outstanding work (PLoS 2015) in ophthalmology in the last 2 years. If these accomplishments were not enough, he founded Science Rendezvous (www.sciencerendezvous.ca) with over 350 sites. This is one of the largest events for the promotion of the importance of science to the general public with attendance figures now over 250,000, involving some 5000 volunteers.

R. J. Dwayne Miller has made an indelible mark in spectroscopy through a unique combination of coherent multidimensional spectroscopy (not discussed) and ultrabright electron source development that uniquely qualifies him for the Earle K. Plyler Prize for Molecular Spectroscopy & Dynamics. He has answered the grand challenge, particularly relevant to this award, to directly observe molecular dynamics at the fundamental time and length scales – and the realization of the chemists' gendanken experiment.

Curriculum vitae

Prof. Dr. R.J. Dwayne Miller

Personal data

Date and place of birth	18.04.1956; Winnipeg, Canada
Institute address	Max Planck Institute for the Structure and Dynamics of Matter Atomically Resolved Dynamics Department Bldg. 99 (CFEL) Luruper Chaussee 149 22761 Hamburg and Departments of Chemistry and Physics University of Toronto, 80 St. George Street Toronto M5S 3H6 Email: dwayne.miller@mpsd.mpg.de
Position	Max Planck Director and Distinguished Faculty Research Chair and University Professor, University of Toronto

Academic career

2010-present	Director: Atomically Resolved Dynamics Division, Co-Founding Director Max Planck Institute for the Structure and Dynamics of Matter
2012-present	Lead PI/Co-Director: Hamburg Centre for Ultrafast Imaging, University of Hamburg
2008-present	Dinstinguished Faculty Research Chair in Chemical and Biological Physics, University of Toronto
2007-present	Distinguished University Professor, University of Toronto
2005-2010	Director of the Institute for Optical Sciences, University of Toronto
1995-present	Professor of Chemistry and Physics, University of Toronto
1992-1995	Professor of Chemistry and Optics, University of Rochester
1988-1992	Associate Professor of Chemistry and Optics, University of Rochester
1984-1988	Assistant Professor of Chemistry, University of Rochester
1983-1984	Université Joseph Fourier, Laboratoire de Spectrometrie Physique
1978-1983	Stanford University, Ph.D.
1974-1978	University of Manitoba, B.Sc. Honours, 1978

Academic awards

2017	Honourary Degree of Science, University of Waterloo
2016	Centenary Prize, Royal Society of Chemistry/UK
2016	Arthur D. Little Lectures, MIT
2016	Parrat Lecturer, Cornell University
2016	Honourary Alumni Award/Lectures University of Manitoba
2015	Fellow of the Optical Society of America
2015	Bright E. Wilson Award for Spectroscopy, American Chemical Society
2011	McNeil Medal for Science Promotion, Royal Society of Canada
2007	Closs Lecturer, University of Chicago

2005	Charles A. McDowell Lecturer, University of British Columbia
	Armes Lecturer, University of Manitoba
2002	Humboldt Award
2002	Canada Research Chair in Femtoscience
2000	Huggins Lecturer, Acadia University
2000	John Charles Polanyi Lecturer, Canada. Society for Chemistry, Calgary
1998	Society of Imaging and Science Technology – Science Award
1997	Royal Society of Canada Rutherford Medal in Chemistry
1995	NSERC Lumonics Research Chair in Quantum Optics
1992	John Simon Guggenheim Fellow
1988	Camille and Henry Dreyfus Teacher-Scholar Award
1988	Alfred P. Sloan Research Fellow
1987	National Science Foundation Presidential Young Investigator
1983-1984	NATO Science Fellow
1978-1983	NSERC Postgraduate Fellowship
1978	"1967" Science Postgraduate Scholarship
1978	Chemical Institute of Canada Medal for Excellence
1977	Allied Chemical Scholarship
1977	David R. Petrie Scholarship
1976-1977	Chemical Institute of Canada Award

Invited/Named Lectures

From 2012– present, over 100 invited lectures were given, including named Lectures - A. D. Little Lectures (MIT), Paratt Lecture (Cornell). Over 600 invited lectures given in total at Gordon Conferences, Faraday Discussions, U. Kyoto, U. Tokyo, Columbia, Yale, UC Boulder Distinguished Lecturer, Princeton, Stanford, Global Lecturer (Japan), Student Invited Colloquia (Chicago, Emory, Stanford), named lectures (Closs. Armes, McDowell, Huggins).

Outreach/Public Service

Founder of the Nonprofit Science Rendezvous (2005, incorporated 2011). This organization is responsible for taking the promotion of science nationally. Nearly every research institute and university, and nonprofit promoting the importance of science in Canada is involved. The event now draws over 200,000 attendees with over 5000 volunteers actively engaged in making science accessible to the general public, answering the classic question "So what's it good for?". This work has led to a new collective effort all across Canada to improve the communication skills of researchers to showcase the importance of science and to give back to the general public for their support. This work earned RJDM the McNeil medal from the Royal Society of Canada for the promotion of science in 2011. Since then the event has gone to remote communities to help bring science to Canada's indigenous people, fully respecting traditional knowledge, to help create opportunities and stewardship of the land for maintaining the rich cultural heritages of the First People.

TOP PUBLICATIONS:

1. L. Genberg, L. Richard, G. McLendon, and R. J. D. Miller, "Direct Observation of Global Protein Motion in Hemoglobin and Myoglobin on Picosecond Time Scales," *Science* **1991**, *251*, 1051-1054. First experimental observation of the involvement of collective modes directing biological functions. New advances in phase grating spectroscopy.
2. R. J. D. Miller, "Energetics and Dynamics of Deterministic Protein Motion," *Accounts Chem. Res.* **1994**, *27*, 145-150. Details the Collective Mode Mechanism as the key to the Structure-Function Correlation in Biological Systems. This insight has been the driving force for the development of ultrabright electron sources to fully resolve the structure-function correlation of biological systems to test this model.
3. B.J. Siwick, J.R. Dwyer, R.E. Jordan, R.J.D. Miller "Ultrafast Electron Optics: Propagation Dynamics of Femtosecond Electron Packets," *J. Appl. Phys.* **2002**, *92(3)*, 1643-1648. This work provided an exact numerical solution to electron pulse propagation that led to the development of ultrabright electron sources to light up atomic motions with single shot capabilities. This put table top electron source technology on par with major international facilities based on x-rays.
4. B.J. Siwick et al., "An Atomic-Level View of Melting Using Femtosecond Electron Diffraction," *Science* **2003**, *302(5649)*, 1382-1385. First direct observation of atomic motions on the relevant timescale, faster than other processes blur out the atomic motions – First "Molecular Movie".
5. M.L. Cowan et al., "Ultrafast Memory Loss and Energy Redistribution in the Hydrogen Bond Network of Liquid H_2O," *Nature* 2005, *434(7030)*, 199–202. Solved 100 year old problem in spectroscopy, enabling 100 nm liquid pathlengths (for reasonable OD for the direct observation of pure H_2O and fully resonant hydrogen bond network that imparts water's special properties.
6. Saeid Amini-Nik, Darren Kraemer, Michael L. Cowan, Keith Gunaratne, Puviindran Nadesan, Benjamin A. Alman, and R. J. Dwayne Miller, "Ultrafast Mid-IR Laser Scalpel: Protein Signals of the Fundamental Limits to Minimally Invasive Surgery" *PLoS One*, **2010**; 5(9): e13053. This work finally achieved the promise of the laser for surgery, cutting at the precision of the single cell without shock wave damage and scar tissue formation. Major research program has been launched to advance surgery to fundamental limits to minimally invasive surgery. A Consensus medical report identifies this new concept as the most promising method for precision surgery.
7. M. Gao et al. "Mapping Molecular Motions Leading to Charge Delocalization Using Ultrabright Electrons", Nature 2013 (496), 343-346. This work represents a breakthrough in which it was possible to capture the key motions leading to charge transfer and delocalization. This work showed at the atomic level how chemistry reduces to a few strongly correlated modes that propagate the system through the transition state region. The ability to directly observe the far from equilibrium motions involved in structural transitions has the potential to change how we think about chemistry.
8. H. Jean-Ruel et al. "Ring Closing Reaction in Diarylethene Captured by Femtosecond Electron Crystallography", J. Phys. Chem. B 2013, 117, 15894-15902. This work represents a milestone as it was able to resolve the specific reaction modes involved in ring cyclization with conserved stereochemistry – for even weakly scattering organic systems. This work could be argued to be the first true molecular movie of chemical reaction re: having sufficient space-time resolution to follow the key reaction modes.
9. Ishikawa, T.; Hayes, S.; Keskin, S.; Corthey, G.; Hada, M.; Pichugin, K.; Marx, A.; Hirscht, J.; Shionuma, K.; Onda, K. ; Okimoto, Y.; Koshihara, S.-y.; Yamamoto, T.; Cui, H.; Nomura, M.; Oshima, Y.; Abdel-Jawad, M.; Kato, R.; Miller, R. J. D, "Direct observation of collective modes coupled to molecular orbital–driven charge transfer", *Science* Volume 350 (6267), pp. 1501-1505, **2015.** First full atom resolved chemical reaction. The phase problem was solved by taking advantage of the known initial

structure to obtain unique solutions. This new mathematical procedure for inversion is a significant advance. The movies (in the SOM) should not be missed. One can see by eye the reduction of 100's of possible nuclear degrees of freedom collapse to just a few – fully confirming this conceptual basis for understanding chemistry at a new level.

10. Ren, L.; Robertson, W.; Reimer, R.; Heinze, C.; Schneider, C.; Eggert, D.; Truschow, P.; Hansen, N.-O.; Krötz, P.; Zou, J.; Miller, R. J. Dwayne:"Towards instantaneous cellular level bio diagnosis: laser extraction and imaging of biological entities with conserved integrity and activity." Nanotechnology 26 (28), 284001 (2015). This work showed that the Picosecond InfraRed Laser (PIRL) scalpel not only cuts without scar tissue formation (see Amini-Nik et al PLoS 2010 and Petersen et al Lasers in Surgery and Medicine 2016) but ejects entire proteins intact into the gas phase enabling *in situ* mass spectroscopy with unparalleled sensitivity. The proteins are found to be collected with 80% collection efficiency and full retention of biological activity, a first for laser driven ablation and mass spectroscopy. Molecular signatures for surgical guidance and cancer border detection is born.

Publications

271. **Ischenko,A. A.; Weber,P. M.; Miller, R, J. Dwayne:**
Transient structures and chemical reaction dynamics
Russian Chemical Reviews 86 (12), pp. 1173–1253 (2017).

270. **Duan, H.-G.; Prokhorenko, V. I.; Cogdell, R. J.; Ashraf, K.; Stevens, A. L.; Thorwart, M.; Miller, R. J. Dwayne:**
Nature Does Not Rely on Long-Lived Electronic Quantum Coherence for Photosynthetic Energy Transfer.
Proceedings of the National Academy of Sciences 114 (32), pp. 8493–8498 (2017).

269. **Ischenko, A. A.; Weber, P. M.; Miller, R. J. Dwayne:**
Capturing Chemistry in Action with Electrons: Realization of Atomically Resolved Reaction Dynamics.
Chemical Reviews 117 (16), pp. 11066–11124 (2017).

268. **Jiang, Y.; Liu, L. C.; Müller-Werkmeister, H.; Lu, C.; Zhang, D.; Field, R. L.; Sarracini, A.; Moriena, G.; Collet, E.; Miller, R. J. Dwayne:**
Structural Dynamics upon Photoexcitation in a Spin Crossover Crystal Probed with Femtosecond Electron Diffraction.
Angewandte Chemie, International Edition in English, 56 (25). pp.7130–7134 (2017).

267. **Liu, L. C.; Jiang, Y.; Müller-Werkmeister, H.; Lu, C.; Moriena, G.; Ishikawa, M.; Nakano, Y.; Yamochi, H.; Miller, R. J. Dwayne:**
Ultrafast electron diffraction study of single-crystal (EDO-TTF)2SbF6: Counterion effect and dimensionality reduction.
Chemical Physics Letters 683, pp. 160–165 (2017).

266. **Daoud, H.; Floettmann, K.; Miller, R. J. Dwayne:**
Compression of high-density 0.16 pC electron bunches through high field gradients for ultrafast single shot electron diffraction: The Compact RF Gun.
Structural Dynamics 4 (4), 044016 (2017).

265. **Owen, R. L.; Axford, D.; Sherrell, D. A.; Kuo, A.; Ernst, O. P.; Schulz, E.-C.; Miller, R. J. Dwayne; Müller-Werkmeister, H.:**
Low-dose fixed-target serial synchrotron crystallography.
Acta Crystallographica Section D: Structural Biology (2017).

264. **Krötz, P.; Ruehl, A.; Calendron, A.-L.; Chatterjee, G.; Cankaya, H.; Murari, K.; Kärtner, F. X.; Hartl, I.; Miller, R. J. Dwayne:**
Study on laser characteristics of Ho:YLF regenerative amplifiers: Operation regimes, gain dynamics, and highly stable operation points.
Applied Physics B: Lasers and Optics 123 (4), 126 (2017).

263. **Johnson, P. J. M.; Farag, M.; Halpin, A.; Morizumi, T.; Prokhorenko, V.; Knoester, J.; Jansen, T. L. C.; Ernst, O. P.; Miller, R. J. Dwayne:**
The Primary Photochemistry of Vision Occurs at the Molecular Speed Limit.
The Journal of Physical Chemistry B (2017).

262. **Xian, R.; Corthey, G.; Rogers, D. M.; Morrison, C. A.; Prokhorenko, V.; Hayes, S. A.; Miller, R. J. Dwayne:**
Coherent ultrafast lattice-directed reaction dynamics of triiodide anion photodissociation.
Nature Chemistry 9 (6), pp. 516–522 (2017).

261. Besztejan, S.; Keskin, S.; Manz, S.; Kassier, G.; Bücker, R.; Venegas-Rojas, D.; Trieu, H. K.; Rentmeister , A.; Miller, R. J. Dwayne:
Visualization of Cellular Components in a Mammalian Cell with Liquid-Cell Transmission Electron Microscopy.
Microscopy and Microanalysis 23 (1), pp. 46–55 (2017).

260. Tsujino, S.; Kanungo, D. P.; Monshipouri, M.; Lee, C.; Miller, R. J. Dwayne:
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