

CURRICULUM VITAE

William Esco (W. E.) Moerner
Harry S. Mosher Professor and Professor, by courtesy, of Applied Physics
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Education

1975	B.S. Physics (Final Honors) B.S. Electrical Engineering (Final Honors) A.B. Mathematics (summa cum laude)	Washington University St. Louis, Missouri
1978	M.S. (Physics)	Cornell University Ithaca, New York
1982	Ph.D. (Physics)	Cornell University Ithaca, New York

Thesis Topic: Vibrational Relaxation Dynamics of an IR-Laser-Excited
Molecular Impurity Mode in Alkali Halide Lattices
Thesis Advisor: Professor A. J. Sievers

Academic Honors

1963-82	Grade Point Average of All A's (4.0)
1971-75	Alexander S. Langsdorf Engineering Fellow, Washington University
1975	Dean's Award for Unusually Exceptional Academic Achievement
1975	Ethan A. H. Shepley Award for Outstanding Achievement (university-wide)
1975-79	National Science Foundation Graduate Fellow

Career Summary

2016-	Affiliated Faculty Member, Stanford Neurosciences Institute
2014-	Faculty Fellow, ChEM-H at Stanford
2011-2014	Chemistry Department Chair
2005-	Professor, by courtesy, of Applied Physics
2002-	Harry S. Mosher Professor of Chemistry
1998-	Professor of Chemistry Department of Chemistry Stanford University

Multidisciplinary education and research program on single-molecule spectroscopy, imaging, and quantum optics in solids, proteins, and liquids; single-molecule biophysics in cells; nanophotonics of metallic nanoantennas; and photoactive polymer materials with emphasis on photorefractive polymers. Major milestones include: first room-temperature single-molecule source of single photons, antibunching for a single CdSe/ZnSe nanocrystal, observation of nucleotide-dependent orientational flexibility of single kinesin motors bound to microtubules, single-pair FRET for a dual-GFP sensor of calcium ion concentrations, full characterization of the single-copy properties of DsRed fluorescent proteins, first analysis of diffusion of single MHCII transmembrane protein complexes in cells, discovery of a new class of single-molecule fluorophores and development of these for cellular imaging, direct measurement of local electromagnetic field enhancement for bowtie nanoantennas and their use in surface-enhanced Raman scattering and in enhancing single-molecule fluorescence, observation of single GFP fusions in bacteria acting as nanoscale, photoswitchable light sources to show super-resolved cellular structures, invention of a new trap for nanoscale objects and single biomolecules in solution, observation of specific ATP-induced conformational changes for a model substrate interacting with the chaperonin GroEL/ES, determination of ADP number distributions for single multi-subunit enzymes in solution, cellular imaging of huntingtin protein aggregates and behavior of signaling proteins in the Hedgehog pathway of the primary cilium, and demonstration of 3D superresolution imaging and tracking of single photoactivatable molecules, cellular structures, DNA loci in yeast chromatin, and cellular mRNA particles with a double-helix point-spread function microscope. Numerous studies of protein and oligonucleotide motions and distributions in *Caulobacter crescentus* beyond the diffraction limit. First method for correction of dipole-induced shifts in single-molecule localization imaging, analysis of the impact of orientation flexibility on this effect. Development of various pupil-plane phase modulation strategies to extract additional information from single-molecule images, and invention of TILT-3D super-resolution microscope for thick cells. Application of the ABEL trap to the analysis of photosynthetic antenna protein photodynamics, G-protein-coupled receptors, single fluorophores, single electron-transfer enzymes in solution, and direct detection of mobility and diffusion coefficient of single biomolecules. Trapping of single nanoscale objects without fluorescence. Correlative low-temperature single-molecule localizations to provide single-molecule annotations of cryo-electron tomography images. Applications of deep neural nets for phase retrieval and structured background estimation for single-molecule localization microscopy in 3D.

1995-1998 First Holder, Distinguished Chair in Physical Chemistry
 Professor of Chemistry
 Department of Chemistry and Biochemistry
 University of California San Diego

Multidisciplinary education and research program on single-molecule spectroscopy and quantum optics in solids, proteins, and liquids; single-molecule biophysics, near-field microscopy; and photoactive polymer materials with emphasis on photorefractive polymers. Major milestones include 3-D studies of single molecules diffusing in gels, observation of blinking and switching in single GFP molecules, pumping of single molecules with whispering gallery modes of microspheres, and beam fanning and self-pumped phase conjugation in new

extremely high gain photorefractive polymers. Research group included four postdoctoral research associates, three graduate students, and three undergraduates.

1994-95 Research Staff Member and Project Leader
IBM Almaden Research Center
San Jose, California

Multidisciplinary research program on single-molecule spectroscopy, near-field optics, and photorefractive (PR) polymers. Project leader for ARPA contract on PR polymers.

1993-1994 Visiting Guest Professor and IBM Research Staff Member
Laboratory for Physical Chemistry
ETH Zentrum (Swiss Federal Institute of Technology)
Zürich, Switzerland

Research program in single-molecule spectroscopy, spectral hole-burning, and near-field optics. Educated and supervised 4 Ph.D. students and two visiting scientists; lectured on single-molecule laser spectroscopy and photorefractive polymers. Major accomplishments included discovery and imaging of single molecules in Shpol'skii matrices and the first near-field single-molecule spectroscopy. Continued as consultant on IBM project on photorefractive polymer materials research and development.

1989-1993 Research Staff Member and Project Leader
IBM Almaden Research Center
San Jose, California

Multidisciplinary research program in Organic Optoelectronic Materials Department with two main thrust areas: (i) precision fundamental spectroscopy of defect centers in solids including single-molecule detection and spectroscopy, statistical fine structure, and spectral hole-burning, and (ii) optical and physical properties of nonlinear materials, including organic photorefractive polymeric materials.

Novel accomplishments:

Single-Molecule Spectroscopy and Spectral Hole-Burning:

Phase-sensitive, time-resolved study of ballistic phonon propagation in a solid; direct observation of spectral diffusion in a solid using a single-molecule probe; observation of lifetime-limited linewidths, dephasing, and nonlinear saturation for a single molecule; observation of hole-burning and spectral diffusion for a single molecule in a polymer; observation of photoinduced reaction kinetics for a single molecule; observation of photon antibunching for a single molecule in a solid; measurement of vibrationally dispersed fluorescence from a single molecule in a crystal and in a polymer; and magnetic resonance of a single molecular spin.

Organic Nonlinear Materials:

Intracavity second harmonic generation in an organic crystal; observation of photorefractivity in a polymer; demonstration of two-beam coupling in a photorefractive polymer; subsecond photorefractive response in a polymer; sensitization of a photorefractive polymer with C₆₀; development of photorefractive polymers with net gain

and efficiency sufficient to surpass some conventional inorganic crystals; and image storage in a photorefractive polymer.

1988-1989 Manager, Laser-Materials Interactions
 IBM Almaden Research Center
 San Jose, California

Managed Research Staff Members in Laser-Materials Interactions Project which concentrated on laser spectroscopy of solids and quantum optics. Continued research on statistical properties of inhomogeneously broadened lines and on mechanisms of the photorefractive effect in electro-optic crystals. Major accomplishment: first optical detection and spectroscopy of a single impurity molecule in a solid.

1981-1988 Research Staff Member
 IBM Almaden Research Center
 San Jose, California

Performed individual research on materials and mechanisms for frequency domain optical storage using high resolution, low temperature laser spectroscopy and photochemical and nonphotochemical hole-burning spectroscopy. Developed high sensitivity measurement techniques such as laser frequency modulation, optical normalization, and ultrasonic modulation to measure extremely small changes in optical absorption.

Novel accomplishments:

Photochemical hole burning at GaAs laser wavelengths, observation of high efficiency photochemistry for an infrared color center; observation of two-photon absorption for linear polyenes in crystals using cw lasers; detailed studies of hole-burning bottlenecks for organic and inorganic systems; use of the quantum-limited sensitivity of FM spectroscopy to measure the stimulated Raman gain in deuterium; use of high resolution ultrasonic modulation to detect photochemical holes; observation of photochemical hole production in 100 ns; complete analysis of coupled reading-writing constraints for single-photon hole-burning materials leading to the need for photon-gating; observation of photon-gated hole-burning in an organic system; development of photon-gating via a donor-acceptor electron transfer mechanism, which allowed fast (30 ns) hole formation in small focused laser spots; and observation of statistical fine structure in an inhomogeneously broadened spectral line.

1975-1981 Graduate Research Assistant and NSF Graduate Fellow
 Laboratory for Atomic and Solid State Physics,
 Cornell University, Ithaca, New York

Performed basic research on the vibrational relaxation dynamics of molecular impurities in alkali halides. Principal techniques included low temperature laser saturation, high resolution spectral hole burning, and coherent transient spectroscopy with CO₂ and PbSnTe diode lasers. Major accomplishments were the first measurements of T₁ and T₂ for ReO₄⁻ molecules in a variety of alkali halide hosts, and the discovery of persistent nonphotochemical spectral hole burning for a molecular vibrational mode in a crystalline lattice.

1972-1975 Research Assistant
 Department of Physics
 Washington University, St. Louis, Missouri

Performed experiments, computer simulations, and theory to develop more accurate formulae for the determination of ultrasonic propagation velocity and dispersion in composite resonators. Assisted in ultrasonic studies of the magnetoelastic properties of single crystal Co and Ni.

Honors and Awards

Hall of Honor, Sigma Xi, The Scientific Research Honor Society, 2018
Wu Zheng Kai Chemistry Prize, Fudan University, 2018
Distinguished Eagle Scout Award, National Eagle Scout Association, 2017
Photonics Pioneer Award, Duke University Fitzpatrick Institute for Photonics, 2016
Distinguished Alumnus Award, Washington University, St. Louis, 2015
Julio Palmaz Award for Innovation in Healthcare and Biosciences, Biomed SA, 2015
Fellow, SPIE-The International Society for Optics and Photonics, 2015
Honorary Fellow, Royal Society of Chemistry, 2015
Nobel Prize in Chemistry, 2014
John Gamble Kirkwood Medal for Outstanding Achievement in Science, from Yale University and the New Haven Section of the American Chemical Society, 2013
Engineering Alumni Achievement Award, Washington University, 2013
Peter Debye Award in Physical Chemistry, 2013
Pittsburgh Spectroscopy Award, 2012
Irving Langmuir Prize in Chemical Physics, 2009
Wolf Prize in Chemistry, 2008
Member, National Academy of Sciences, 2007
Fellow, American Association for the Advancement of Science, 2004
Geoffrey Frew Fellow, Australian Academy of Sciences, 2003
Fellow, American Academy of Arts and Sciences, 2001
Earle K. Plyler Prize for Molecular Spectroscopy, American Physical Society, 2001
Robert Burns Woodward Visiting Professor, Department of Chemistry, Harvard University, 1997-1998
IBM Outstanding Technical Achievement Award for Single-Molecule Detection and Spectroscopy, November 22, 1992
Fellow, American Physical Society, November 16, 1992
Fellow, Optical Society of America, May 28, 1992
Senior Member, Institute of Electrical and Electronics Engineers, June 17, 1988
IBM Outstanding Technical Achievement Award (with R. M. Macfarlane and R. M. Shelby) for Photon-Gated Spectral Hole-Burning, July 11, 1988
National Winner of the Roger I. Wilkinson Outstanding Young Electrical Engineer Award for 1984, from the electrical engineering honorary society, Eta Kappa Nu, April 22, 1985

Doctor Honoris Causa

University Aix Marseille, November 9, 2016
University of Chile, December 10, 2015

Honorary Professorships

Huazhong University of Science and Technology, Wuhan, China, November 2019
Moscow State Pedagogical University, August 2018
Fudan University, July 2018

Named Lectureships

Oliver Smithies Nobel Lecture, University of North Carolina, September 2020
Purdue College of Engineering Distinguished Lecture, Purdue University, February 2020
Physical Chemistry Student Select Lecture, University of Illinois at Urbana-Champaign, December 2019
J. T. Donald Lecturer, Chemistry Department, McGill University, Montreal, Canada, September, 2019
Jin Si Lecture, Fudan University, China, July 2018
Hermann Anton Haus Lecture, Massachusetts Institute of Technology, April 2018
Nelson Lecture, The University of Miami, April 2018
E. U. Condon Lecture, University of Colorado, Boulder, Colorado, February 2018
Munushian Lecture, Ming Hsieh Department of Electrical Engineering, Viterbi School of Engineering, University of Southern California, February 2017
Morris Travers Memorial Lecture, Indian Institute of Science, Bangalore, January 2017
Andreas C. Albrecht Memorial Lecture, Department of Chemistry and Chemical Biology, Cornell University, April 2016
Hightower Lecture, Department of Physics, Emory University, April 2016
Fred J. Robbins Memorial Lectures, Department of Chemistry, Pomona College, March 2016
Provost Lecture, Temple University, Philadelphia, Pennsylvania, March 2016
Wallace H. Coulter Lecture, Pittcon, Atlanta, Georgia, March 2016
Paul D. Gottlieb Lecture, Institute of Cellular and Molecular Biology, The University of Texas at Austin, February 2016
Sir Ernst Chain Lecture, Imperial College of London, November 2015
Samuel I. Weissman Memorial Lectures, Department of Chemistry, Washington University, St. Louis, Missouri, November 2015
Presidential Distinguished Lecture, The University of Texas Health Science Center at San Antonio, September 2015
Presidential Distinguished Lecture, The University of Texas at San Antonio, September 2015
Paul C. Cross Lecture, Department of Chemistry, University of Washington, May 2015
George B. Kistiakowsky Lecturer, Department of Chemistry and Chemical Biology, Harvard University, March 2015
John Gamble Kirkwood Lecturer, Department of Chemistry, Yale University, September 2013
Walter Kauzmann Lecturer in Biophysical Chemistry, Princeton University, September 2013
E. K. C. Lee Lecturer, Department of Chemistry, University of California, Irvine, May 2013
Samuel Krimm Lecture in Biophysics, University of Michigan, April 2013
Ehrenfest Colloquium Lecturer (repeat), University of Leiden, The Netherlands, June 2012
Pittsburgh Conference Lecturer, Department of Chemistry, University of Pittsburgh, 2011
Leica Scientific Forum United Kingdom Lecturer, June 2011
Willis Flygare Memorial Lecturer, Department of Chemistry, University of Illinois at Urbana-Champaign, 2011

Joe L. Franklin Lecturer, Department of Chemistry, Rice University, 2010
William Lloyd Evans Lecturer, Department of Chemistry, The Ohio State University, 2009
Karl Friedrich Bonhoeffer Lecturer, Max Planck Institute for Biophysical Chemistry, Göttingen, Germany, 2009
Neil Gordon Frontiers in Chemistry Lecturer, Department of Chemistry, Wayne State University, 2009
A. S. Noyes Lecturer, Department of Chemistry and Biochemistry, University of Texas at Austin, 2009
DuPont-Marshall Lecturer, Department of Chemistry, University of Pennsylvania, 2008
Herbert H. King Lecturer, Department of Chemistry, Kansas State University, 2006
Edwin Yunker Lecturer, Department of Physics, Oregon State University, 2006
A. R. Gordon Distinguished Lecturer, Department of Chemistry, University of Toronto, 2006
Lecturer, Summer School on Visualization, Manipulation, and Modeling of Single Biomolecules, ENS Paris, France, 2005
Geoffrey Frew Fellowship Lecturer, Australian Academy of Sciences (University of Queensland, Australian National University, Swinburne Institute of Technology, University of Melbourne), 2003
International Invited Lecturer (Basel, Berne, Lausanne, Geneva): Conference Universitaire de Suisse Occidentale du 3ème Cycle en Chimie, 2003
Moses Gomberg Lecturer, Department of Chemistry, University of Michigan, 2001
William Draper Harkins Lecturer, Department of Chemistry, University of Chicago, 2001
Guest Lecturer in Frontiers in Spectroscopy, Ohio State University, 1999
Arthur D. Little Lecturer, Department of Chemistry, Massachusetts Institute of Technology, 1995
Ehrenfest Colloquium Lecturer, University of Leiden, The Netherlands, March 1994
Samuel M. McElvain Lecturer, Department of Chemistry, University of Wisconsin, 1993

Patents

U. S. Patent 4,614,116: "Phase Sensitive Ultrasonic Modulation Method for the Detection of Strain-Sensitive Spectral Features", September 30, 1986.
U. S. Patent 5,064,264: "Photorefractive Materials", November 12, 1991.
U. S. Patent 5,361,148: "Apparatus for Photorefractive Two-Beam Coupling," November 1, 1994.
U. S. Patent 5,460,907: "Photorefractive Materials", October 24, 1995.
U. S. Patent 5,607,799: "Optical Photorefractive Article," March 4, 1997.
U. S. Patent 6,046,925: "Photochromic Fluorescent Proteins and Optical Memory Storage Devices Based on Fluorescent Proteins," April 4, 2000.
U. S. Patent 6,280,884: "Process for Photorefractive Index Grating Formation," August 28, 2001.
U. S. Patent 7,068,698 "Room-Temperature Source of Single Photons Based on a Single Molecule in a Condensed Matter Host," June 27, 2006.
U. S. Patent 8,057,655: "Sub-Micron Object Control Arrangement and Approach Therefor," Nov. 15, 2011 (provisional application filed August 20, 2004).
U. S. Patent 8,153,446 B2: "Fluorogenic Compounds Converted to Fluorophores by Photochemical or Chemical Means and Their Use in Biological Systems," April 10, 2012 (provisional application filed May 23, 2008).

- U. S. Patent 8,693,742 B2: “Three-Dimensional Single-Molecule Fluorescence Imaging Beyond the Diffraction Limit Using a Double-Helix Point Spread Function,” April 8, 2014 (provisional application filed December 17, 2008).
- U. S. Patent 8,772,048 B2: “Fluorogenic Compounds Converted to Fluorophores by Photochemical or Chemical Means and Their Use in Biological Systems,” July 8, 2014 (provisional application filed May 23, 2008).
- U. S. Patent 9,075,010 B2: “Enhancement of Molecular Emission Using Optical-Antenna Structures,” July 7, 2015 (provisional application filed October 15, 2010).
- U. S. Patent 9,693,034 B2: “Apparatus and Method for Localizing Objects for Distance and/or in Three Dimensions Using a Spiral Point Spread Function,” June 27, 2017, Disclosure filed May 17, 2012 (provisional filed December 13, 2011).
- U. S. Patent 10,187,626 B2: “Apparatuses and Methods for Three-Dimensional Imaging of an Object,” Issued January 22, 2019 (provisional filed April 10, 2015).
- U. S. Patent 10,341,640 B2: “Multi-Wavelength Phase Mask,” Issued July 2, 2019.
- U. S. Patent 10,638,112 B2: “Apparatuses and Methods for Three-Dimensional Imaging of an Object” Issued April 28, 2020 (amendment filed January 17, 2019).
- U. S. Patent 10,791,318 B2: “Multi-Wavelength Phase Mask,” Issued September 29, 2020.

Application: “Firefly Luciferin Analogues, Methods of Making Firefly Luciferin Analogues, and Methods of Imaging,” Provisional filed March 10, 2009.

Additional published disclosures in optics, frequency domain optical storage, single-molecule applications, microscopy, and photorefractive materials.

Professional Societies and Positions

Boards:

- Member, Scientific Advisory Board, Max-Planck Institute for Biochemistry Martinsried, 2019-
- Member, Advisory Board, Double Helix Optics, 2019-
- Member, Board of Trustees of the Society for Science and the Public, 2018-
- Member, Scientific Advisory Board, Welch Foundation, 2017-
- Member, World Laureates Association, 2017-2018, 2020
- Member, Advisory Board, Institute of Atomic and Molecular Sciences (IAMS) of Academia Sinica, Taiwan, 2005-

Journals:

- International Advisory Board, *Angewandte Chemie*, 2017-2020
- Associate Editor, *Quarterly Reviews of Biophysics-Discovery* 2015-2016
- Advisory Editor, *ChemPhysChem* 2004-2018
- Advisory Editor, *Chemical Physics Letters* 1998-2016
- Editorial Advisory Board, *Journal of Physical Chemistry* 2013-2015
- Advisory Editor, *Single Molecules* 2000-2002

American Academy of Arts and Sciences

American Association for the Advancement of Science

American Chemical Society

Program Committee, Symposium on Optical Properties of Polymers, August 1996

Single-Molecule Symposium Organizer, Physical Chemistry Division, April 1997
Co-Editor, Special Issue of *Accounts of Chemical Research* on Single Molecules and Ions,
December 1996

American Physical Society
Chair, Herbert P. Broida Prize Committee 2000
Member, Earle K. Plyler Prize Committee 2001
Member, Irving Langmuir Prize Committee 2010
Symposium Organizer for Laser Science Topical Group, 1992 March Meeting
Symposium Organizer for Laser Science Topical Group, 1993 March Meeting
Institute of Electrical and Electronic Engineers, Lasers and Electro-Optics Society
Assistant Treasurer, 1988 Annual Meeting
Treasurer and Program Committee Member, 1989 Annual Meeting
Symposium Organizer, LEOS 1989 Annual Meeting on Optical Memory and
Storage

Materials Research Society
National Academy of Sciences
Optical Society of America
Chair, Fundamental and Applied Spectroscopy Technical Group, 1992-1994
General Chair and Founder, OSA Topical Conference on Persistent Spectral
Hole-Burning Science and Applications, 1991
Co-Editor, 2 Special Issues of J. Opt. Soc. America B on Persistent Spectral
Hole-Burning
Advisory Chair and Program Committee Member, Topical Meeting on Spectral
Hole-Burning and Luminescence, 1993-1994
Assistant Chair, Fundamental and Applied Spectroscopy Technical Group,
1992

Society of Photo-Optical Instrumentation Engineers
Program Co-Chair, Symposium on Organic Photorefractive Materials, 1996, 1997, 1998
Program Committee, 1999-2003

Conference on Quantum Electronics and Laser Science
Program Committee, 1992 and 1993

Conference on Lasers and Electro-Optics
Program Committee, 1999

International Conference on Hole-Burning and Single-Molecule Spectroscopies
Program Committee, 1996, 1999, 2003

Gordon Research Conference on Single-Molecule Approaches to Biology,
Co-Vice Chair, 2008; Co-Chair, 2010.

Task Forces and Major University Committees

Chairman, IBM Task Force on Frequency Domain Optical Storage, 1984.
Physics and Mechanisms Member, IBM Task Force on Holographic Optical Storage, 1986.
Co-Chair, Systems and Applications, IBM Optical Storage Initiative, 1988.
Member, Appointments and Promotions Committee, Division of Humanities and Sciences,
Stanford University, 2002-2004.
Member, Nanoinitiative Committee, Stanford University, Winter 2006
Member, NSF Center for Probing the Nanoscale Executive Committee, Fall 2007
Member, Stanford University Committee on Health and Safety, 2007-2008

Chair, Stanford University Committee on Health and Safety, 2008-2009, 2009-2010
Member, Stanford University Emergency Management Steering Committee, 2009-2010
Member, Advisory Board, Center for Biological Imaging at Stanford, 2010-2015
Member, Corporation Visiting Committee, Department of Chemistry, Massachusetts Institute of Technology, 2013-2017.
Member, Review Panel, HHMI Janelia Research Campus, 2020

Study Panels and Governmental Committees

Member, NSF SBIR Study Panel, September, 1996.
Member, NIH Bioengineering Symposium Panel on Imaging at the Molecular and Cellular Levels, February 27-28, 1998.
Co-Chair, Toward Molecular Scale Devices Subgroup, NSF Integrating Themes Workshop for Physical Chemists, September 18-20, 1998, Keystone, Colorado.
Member, NIH Review Panel, November 1999; September 2000.
Member, FAMOS Update Panel, National Research Council, 1999-2002.
Member, NIH-NIGMS Workshop on Single Molecule Detection and Manipulation, 2000
Member, NSF-Intelligence Community Workshop on Approaches to Combat Terrorism, 2002.
Subgroup Chair, NIH-NIDA Workshop on Emerging Technologies: Analysis of Endogeneous Biomaterials and Single-Molecule Studies, 2002.
Member, International Review Committee for the Institute of Atomic and Molecular Sciences (IAMS) of Academia Sinica, Taiwan, 2003-2004
Member, NIH-BST Molecular Imaging Study Section, 2004.
Member, Pacific Northwest National Laboratory DOE-BES Review Panel, 2005.
Member, DOE Workshop on Single-Molecule Research in the New Millennium, 2005.
Session Chair: NIH Frontiers in Live Cell Imaging Conference, April 19-21, 2006
Member, NIH-NHGRI Study Section, July, 2006
Member, Board of Scientific Counselors, National Institute of Biomedical Imaging and Bioengineering, 2010-2014