

Quantum Computing, Quantum Information Research

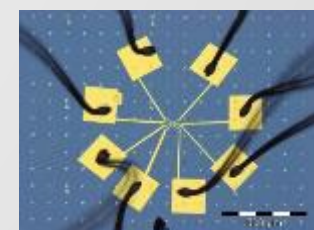
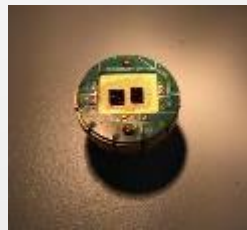
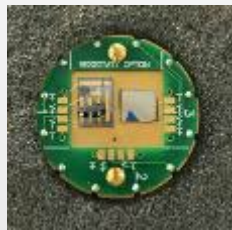
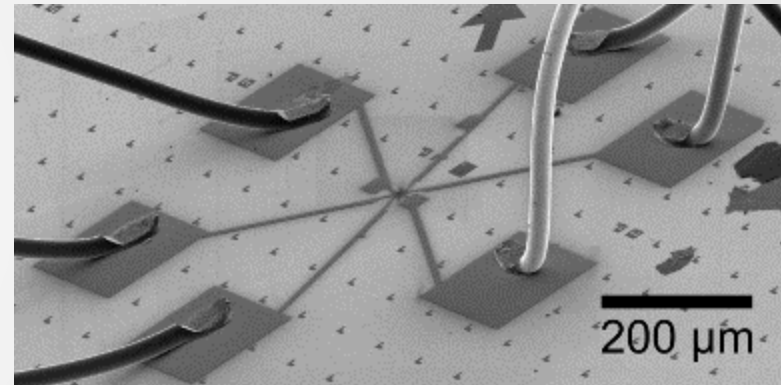
Island – Quantum computing, quantum sensing



The Nanoscale Physics Group @ **UNLV**

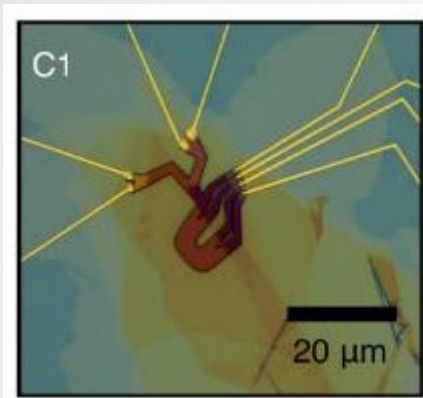
Areas of Research

- Nanotechnology, device physics
- Photodetection and quantum sensing
- Quantum computing, topological qubits
- Non-equilibrium, driven systems
- Superconductivity, proximity effects
- Low dimensional materials

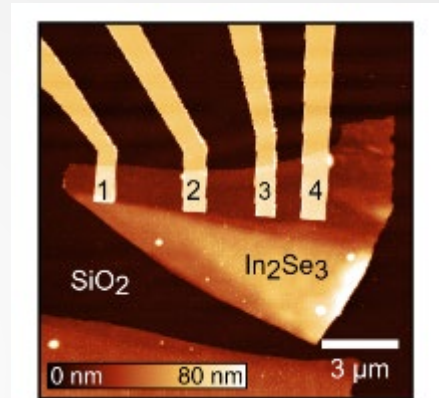


Island – Quantum computing, quantum sensing

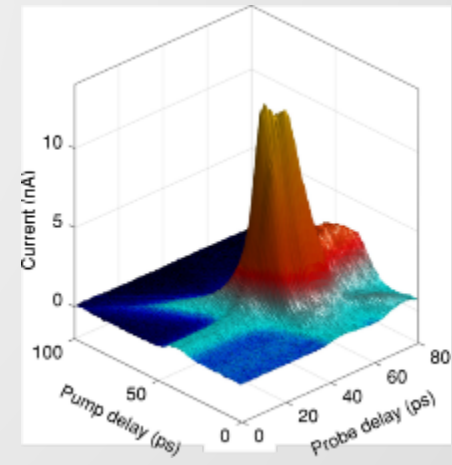
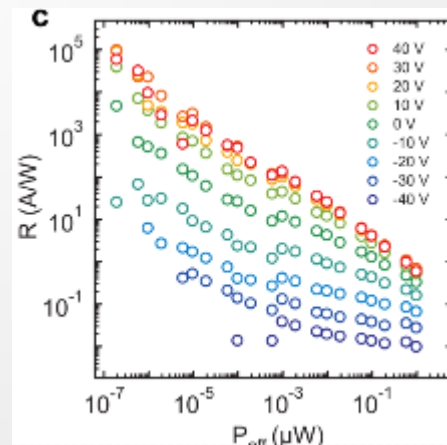
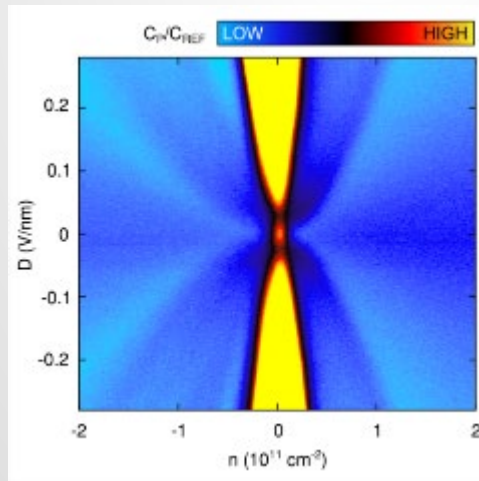
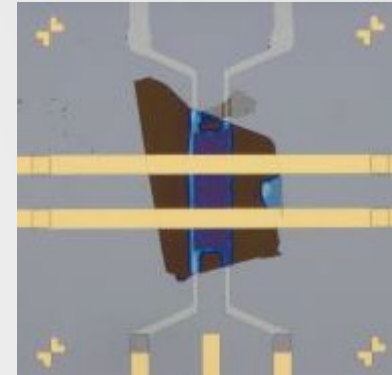
Quantum computing:
Topological phases for fault-tolerant, universal quantum computing.



Industry-disruptive photodetectors: Ultra-sensitive phototransistors designed with 2D materials and heterostructures.



Transient phases of driven systems: Non-equilibrium response of pumped nanomaterials below the diffraction limit.



Island, J. O., et al. *Nature* **571** (2019): 85–89.

Island, J. O., et al. *Nano Letters* **15** (2015): 7853-7858.

Island – Quantum computing, quantum sensing

Journal publications:

Spin-orbit-driven band inversion in bilayer graphene by van der Waals proximity effect

J.O. Island, X. Cui, C. Lewandowski, J.Y. Khoo, E.M. Spanton, H. Zhou, D. Rhodes, J.C. Hone, T. Taniguchi, K. Watanabe, L.S. Levitov, M.P. Zaletel, A.F. Young, *Nature*, **571**, 85-89 (2019). (arXiv)

Enhanced superconductivity in atomically thin TaS₂

E. Navano-Moiatalla*, J.O. Island*, S. Manas-Valero, E. Pinilla-Cienfuegos, A. Castellanos-Gomez, J. Queieda, G. Rubio-Bollinger, L. Chirolli, J.A. Silva-Guilin, N. Agrat, G.A. Steele, F. Guinea, H.S.J. van der Zant, E. Coronado, *Nature Communications*, **15**, 7853 (2016). (arXiv)

Proximity-induced Shiba states in a molecular junction

J. O. Island, R. Gaudenzi, J. de Bruijckere, E. Burzuri, C. Franco, M. Mas-Torrent, C. Rovira, J. Veciana, T. M. Klapwijk, R. Aguado, H.S.J. van der Zant, *Physical Review Letters*, **118**, 117001 (2017). (arXiv)

TiS₃ transistors with tailored morphology and electrical properties

J.O. Island, M. Barawi, R. Biele, A. Almazan, J.M. Clamagirand, J.R. Ares, C. Sanchez, H.S.J. van der Zant, J.V. Alvarez, R. D'Agosta, I.J. Ferrer, A. Castellanos-Gomez, *Advanced Materials*, **27**, 2595 (2015). (arXiv)

Environmental instability of few-layer black phosphorus

J.O. Island, G.A. Steele, H.S.J. van der Zant, and A. Castellanos-Gomez, *2D Materials*, **2**, 011002 (2015). (arXiv)

Ultrahigh photoresponse of few-layer TiS₃ nanoribbon transistors

J.O. Island, M. Buscema, M. Barawi, J.M. Clamagirand, J.R. Ares, C. Sanchez, I.J. Ferrer, G.A. Steele, H.S. J van der Zant, and A. Castellanos-Gomez, *Advanced Optical Materials*, **2**, 641 (2014). (arXiv)

Gate controlled photocurrent generation mechanisms in high-gain In₂Se₃ phototransistors

J.O. Island*, S.I. Blanter*, M. Buscema, H.S.J. van der Zant, and A. Castellanos-Gomez, *Nano Letters*, **15**, 7853(2015). (arXiv)

Precise and reversible band gap tuning In single-layer MoSe₂ by uniaxial strain

J.O. Island, A. Kuc, E.U. Diependaal, H.S.J. van der Zant, T. Heine, and A. Castellanos-Gomez, *Nanoscale*, **8**, 2589 (2016). (arXiv)

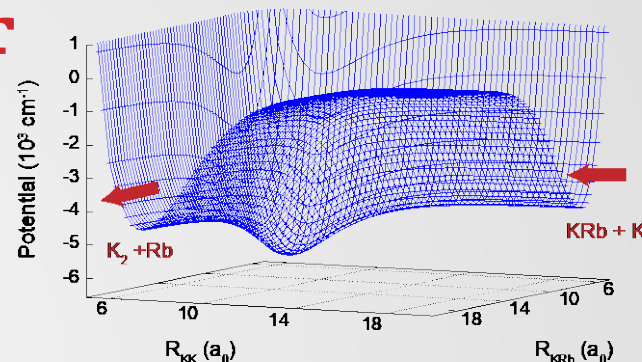
Quantum Information and Quantum Control of Chemical Reactions

Balakrishnan Naduvalath

Department of Chemistry & Biochemistry,
UNLV

Areas of Expertise

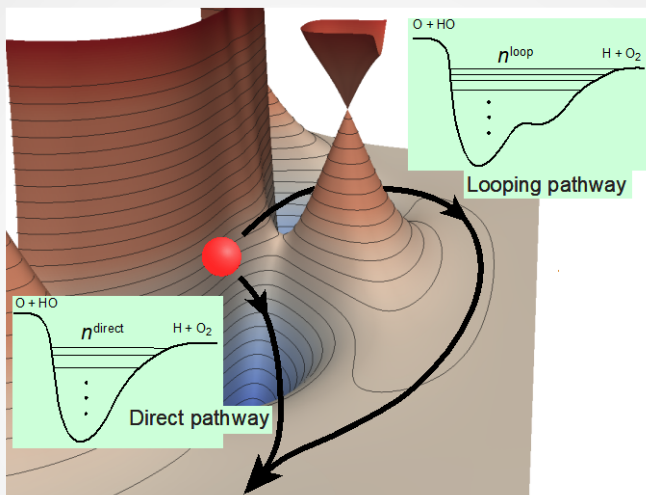
- Ultracold Molecules
- Ultracold Quantum Engineered Chemistry
- Quantum control of chemical reactions
- Geometric phase effect in chemistry
- Stereodynamic control of chemical reactions



Chemical reaction pathway in ultracold $K + KRb$ collisions. Quantum engineered KRb molecules have been prepared at 300 nK. Ultracold polar molecules such as KRb are potential candidates for quantum computing and quantum information processing.

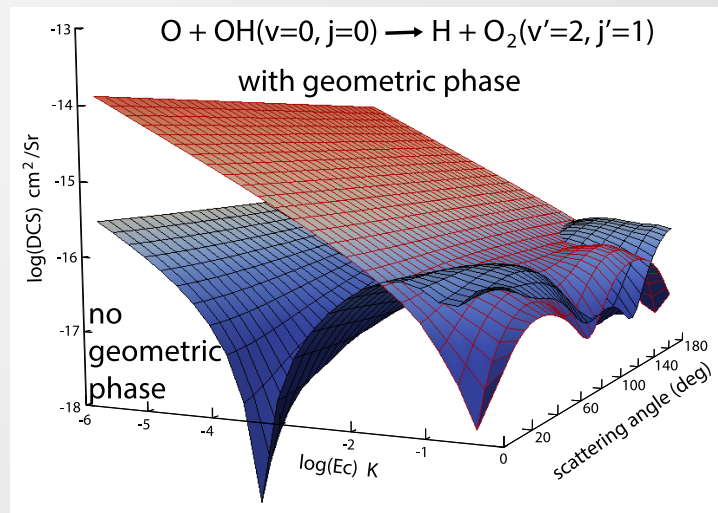
\$\$\$: NSF, DOD, NASA

Controlling reaction outcome through quantum interference



Right panel: The nature of the interference can be controlled by including “geometric phase”. In the image on the right, inclusion of the geometric phase enhances the reactivity. The geometric phase (that correctly describes the sign of the wave function near a conical intersection with an excited electronic state) acts as a “quantum switch” (Hazra, Balakrishnan, and Kendrick, J. Phys. A **119**, 12291 (2015))

Left panel: Two paths for a chemical reaction. These two paths can interfere constructively or destructively, maximizing or minimizing the reaction rate. This quantum effect becomes magnified in the ultracold regime (Kendrick, Hazra, and Balakrishnan, Nature Comm. **6**, 7918 (2015)).

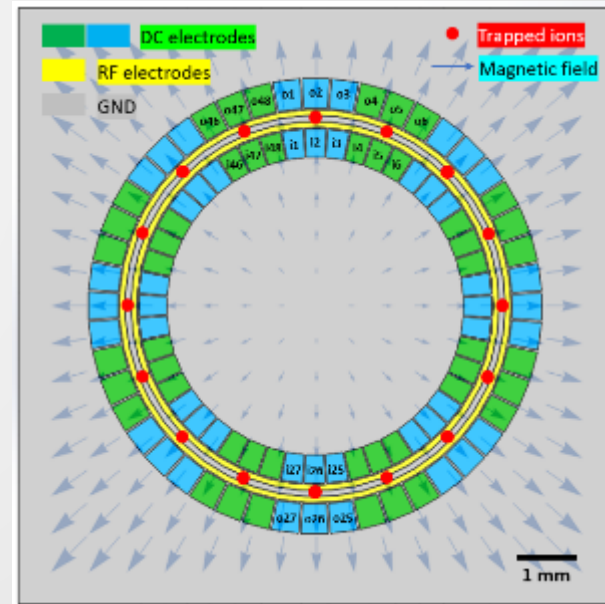
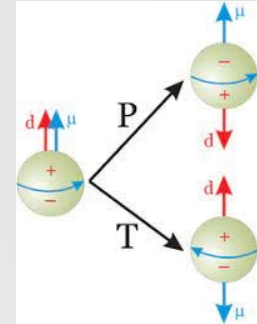


References

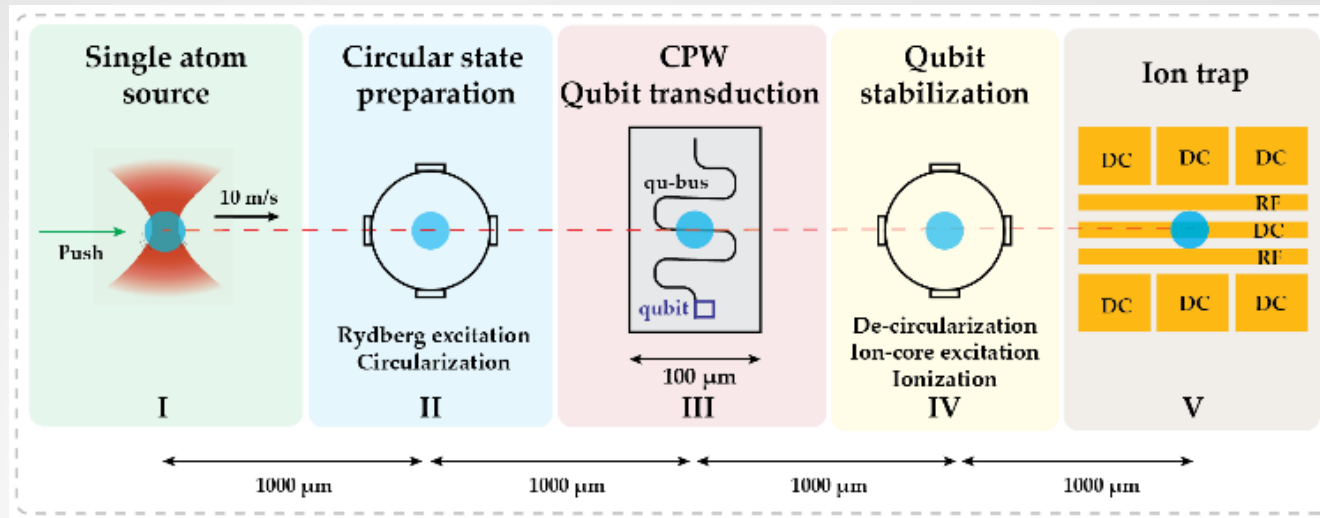
- P. G. Jambrina, J. F. E. Croft, H. Guo, M. Brouard, N. Balakrishnan, and F. J. Aoiz, Stereodynamical control of a quantum scattering resonance in cold molecular collisions, *Phys. Rev. Lett.* **123**, 043401 (2019).
- J. F. E. Croft and N. Balakrishnan, Controlling rotational quenching rates in cold molecular collisions, *J. Chem. Phys.* **150**, 164302 (2019).
- K. Hilsabeck, J. Meiser, M. Sneha, N. Balakrishnan, and R. N. Zare, Photon Catalysis of Deuterium iodide photodissociation, *Phys. Chem. Chem. Phys.* **21**, 14195 (2019).
- J. F. E. Croft, N. Balakrishnan, M. Huang, and H. Guo, Unrevealing the stereodynamics of cold controlled HD-H₂ collisions, *Phys. Rev. Lett.* **121**, 113401 (2018). (**Editor's choice**).
- J. F. E. Croft, C. Makrides, M. Li, A. Petrov, B. K. Kendrick, N. Balakrishnan, and S. Kotochigova, Universality and chaoticity in ultracold K+KRb chemical reactions, *Nature Comm.* **8**, 15897 (2017).
- N. Balakrishnan, Perspective: Ultracold molecules and the dawn of cold controlled chemistry, *J. Chem. Phys.* **145**, 150901 (2016).
- B. K. Kendrick, J. Hazra, and N. Balakrishnan, The Geometric Phase Appears in the Ultracold Hydrogen Exchange Reaction, *Phys. Rev. Lett.* **115**, 153201 (2015).
- B. K. Kendrick, J. Hazra, and N. Balakrishnan, The Geometric Phase Controls Ultracold Chemistry, *Nature Communications* **6**, 7918 (2015).

Zhou Group– Precision measurements, quantum computation, and cold chemistry

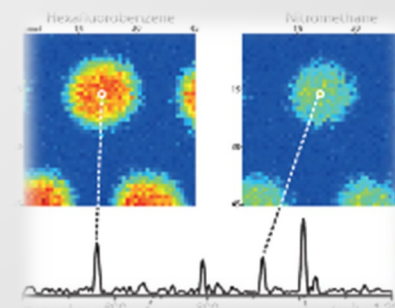
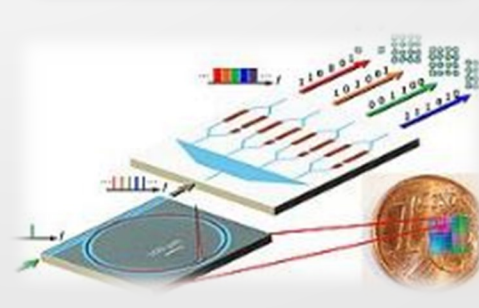
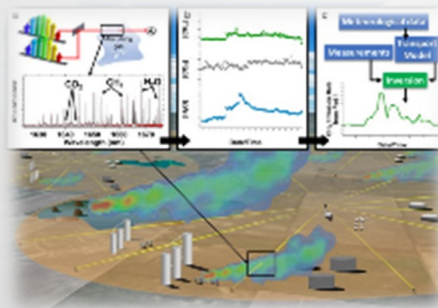
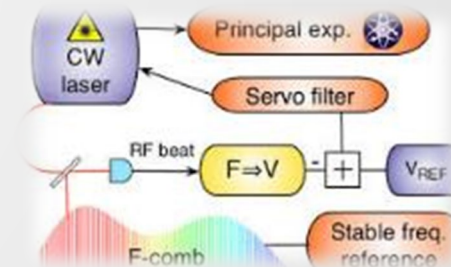
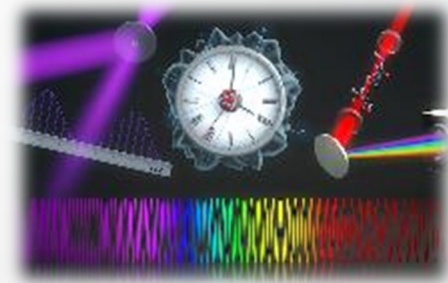
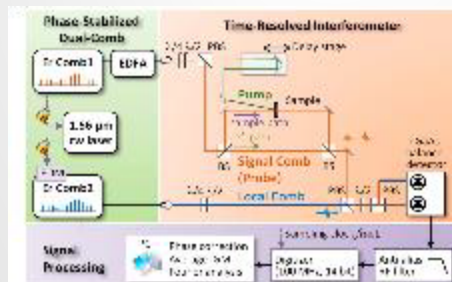
- Explore new physics beyond the Standard model by precision measurements
- Develop a quantum transducer bridging ion trap and superconducting quantum computers
- Cold and ultracold ion-radical collisions
- Dual optical frequency comb high-resolution and ultrafast spectroscopy



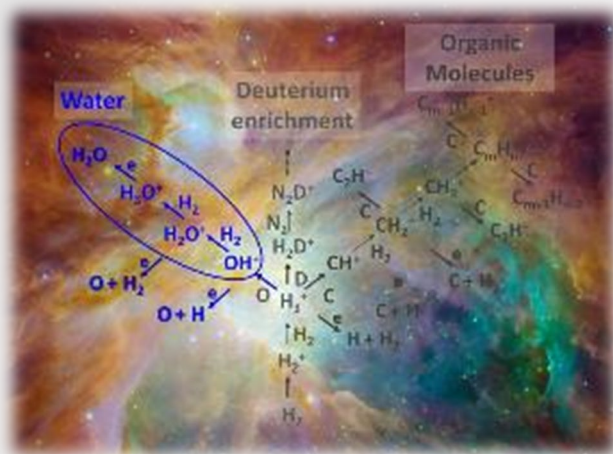
Quantum transducer bridging ion trap and superconducting quantum computers



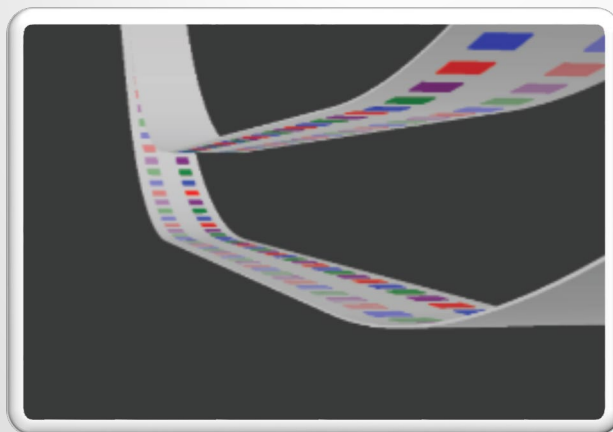
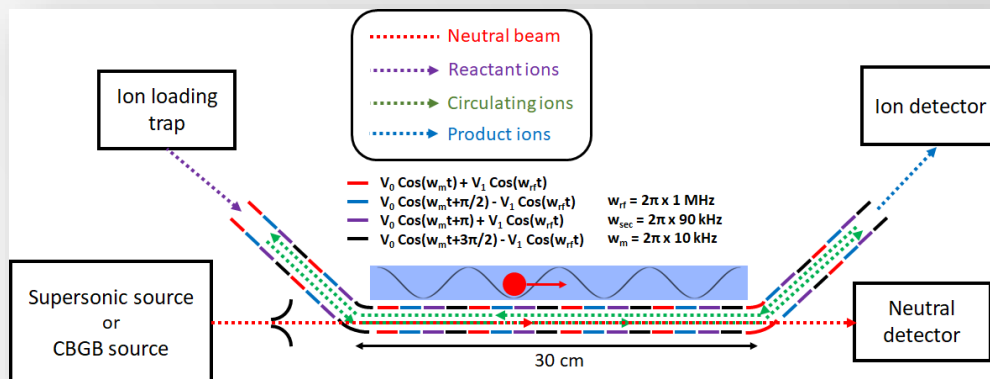
Dual phase stabilized optical frequency combs



Revealing mechanisms of universe evolutions by studying cold ion-radical reactions



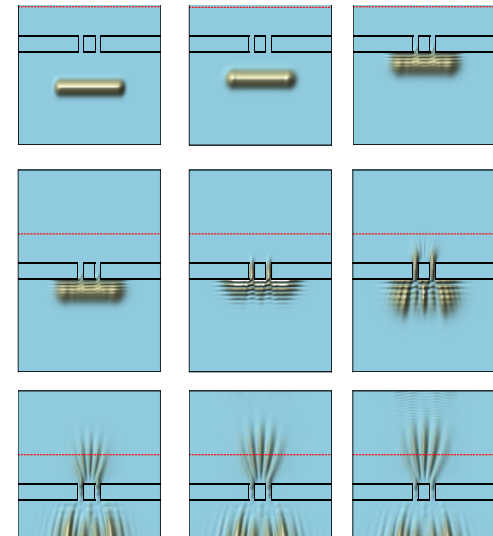
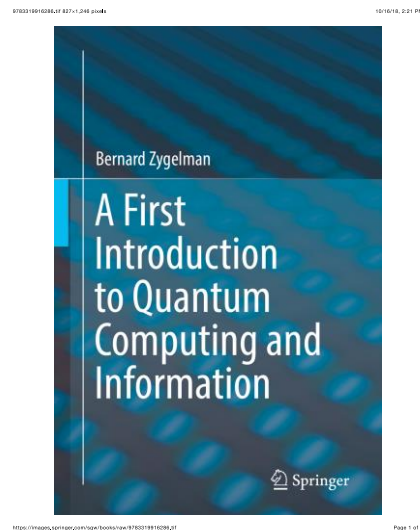
- Chain reactions
- Radiative association
- Tunneling resonances
- Collisional resonances



Parameters	Expected specifications
Interaction arm length	30 cm
Ion beam velocity	0-1000 m/s
Collision energy range	<0.1 meV to >100 meV
Energy resolution	<0.1 meV
Effective reaction duration	1 s
Detection sensitivity	$1 \times 10^{-16} \text{ cm}^{-3}\text{s}^{-1}$

Bernard Zygelman

- Quantum Computing and Information
- Computational Physics
- Atomic and Molecular Processes in Plasmas
- Quantum Workforce Development



Research Expertise and Activities

- Over 70 publications, h-index 27-Google Scholar
- Work funded by AFOSR, DOE, IAEA, NSF, NASA, W. M. Keck Foundation
- Topics include remote sensing of the thermosphere, matter-anti-matter interactions, QED, radiative and non-radiative charge transfer in hot plasmas, atomic processes in the early universe, ultra-cold physics, geometric phase and magnetism, quantum computing and information

Relevant Publications

1. B. Zygelman, *Appearance of gauge potentials in atomic collision physics*, Physics Letters A, 125, 476, 1987; (Re-printed in Geometric Phases in Physics ed. A. Shapere and F. Wilczek (Nobel laureate in Physics)).
2. Sharma, R, Zygelman, von Esse, F., Dalgarno, A., Geophys. *On the relationship between the population of the fine structure levels of the ground electronic state of atomic oxygen and the translational temperature*, Geophysics Res. Lett., 21, 1731, 1994
3. Stancil, P. C. and Zygelman, B., *Kinematic Isotope Effects in Low Energy Electron Capture*, Phys. Rev. Lett. 75, 1495, 1995
4. Zygelman, B. Saenz, A. Froelich, P. and Jonsell, S., *Cold collisions of atomic hydrogen with anti-hydrogen atoms: An optical potential approach*, Phys Rev A. 69, 042715, 2005
5. Zygelman, B. *Hyperfine Level-changing Collisions of Hydrogen Atoms and Tomography of the Dark Age Universe*, Ap. J, 622, 1356, 2005
6. Zygelman B. Lucic Z., and Hudson E., *Cold ion-atom chemistry driven by spontaneous radiative relaxation: a case study for the formation of the YbCa+molecular ion*, J. Phys. B 47, 015301, 2013
7. B. Zygelman, *Geometric-phase atom optics and interferometry*, Phys. Rev. A., 92, 043620, 2015
8. B. Zygelman, *A First Introduction to Quantum Computing and Information*, Springer-Nature, 2018.