

# Energy Resources & Infrastructure Research

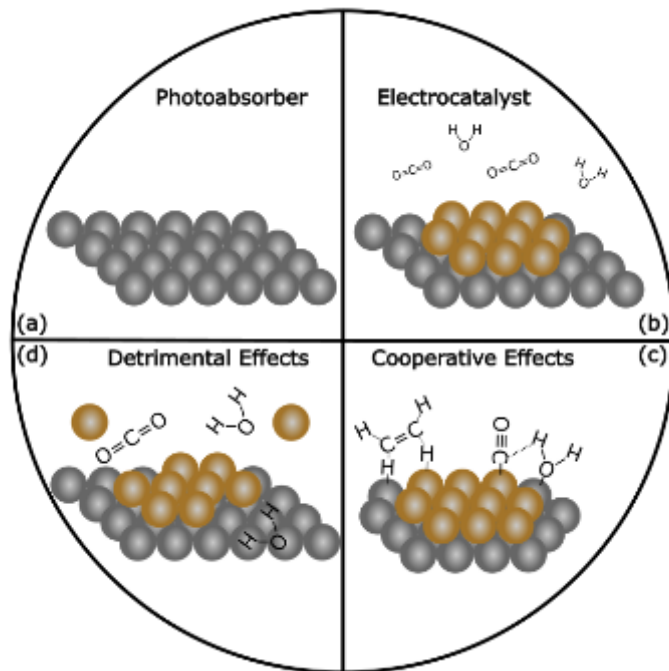
# Interfacial Photochemistry

- **Dr. Jared P. Bruce**
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- Department of Chemistry and Biochemistry
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## Expertise

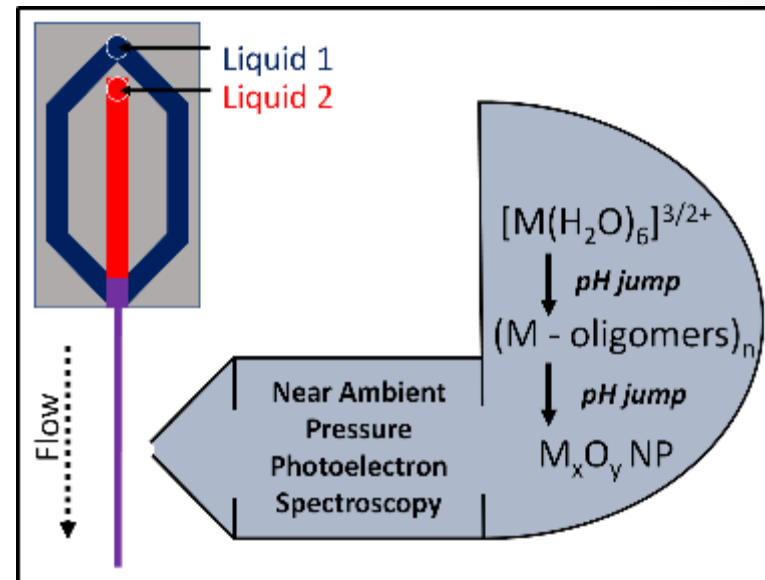
- Heterogeneous Photochemistry
- Electrocatalysis
- Photocatalysis
- Atmospheric Chemistry
- Surface Chemistry and Interfacial Characterization
- Near Ambient Pressure Photoelectron Spectroscopy

## Hybrid Co-Catalyst/Photoabsorber Photochemical Interfaces



- Metals often make good electrocatalysts
- Semiconductors make good photoabsorbers
- The combination of the two create a new, complex interface that can be leveraged to increase the efficiency of co-catalyst/photoabsorber devices

## Mixing Liquid Jet Photoelectron Spectroscopy



- Dynamic processes are tricky to study at the liquid surface
- A small liquid jet (20 $\mu\text{m}$  dia.) is used to investigate the liquid surface
- Microfluidic chips provide mixing chamber to induce chemical reactions

# Electronic and Magnetic Properties at High Pressure

**Dr. Andrew Cornelius**

Department of Physics & Astronomy

Phone (702) 895-1727

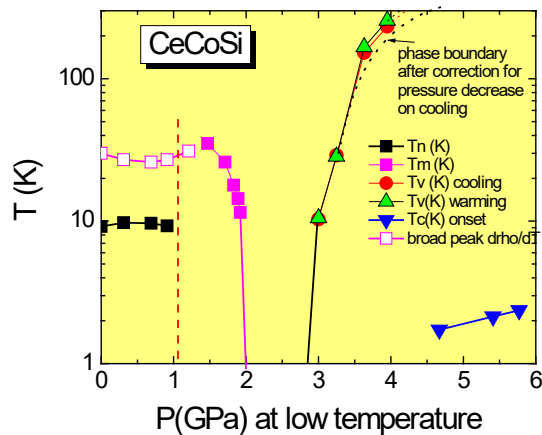
## **Expertise:**

- Experimental high pressure measurements
- Magnetism
- Superconductivity

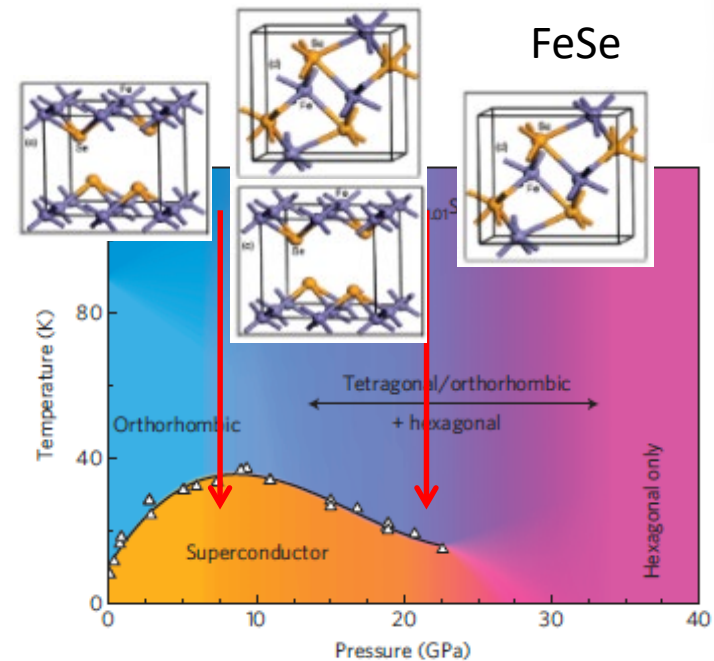
# Superconductivity

## Quantum Design PPMS at UNLV

- Measurements from 0.3 K to 400 K
  - Heat capacity, electric and thermal transport, and AC/DC magnetization
- Pressure cells to measure electrical properties (clamp to 3 GPa and diamond anvil cell to >100 GPa)



Addition of high pressure synchrotron experiments (diffraction and X-ray absorption) allows mapping of complex superconducting phase diagrams



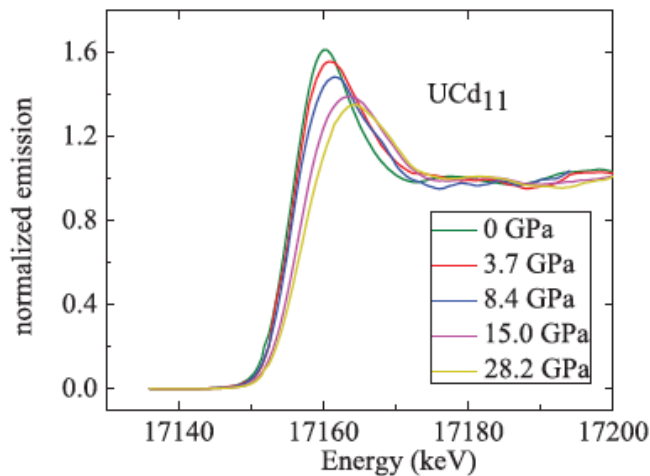
# Correlated-Electron Systems

Modified periodic table

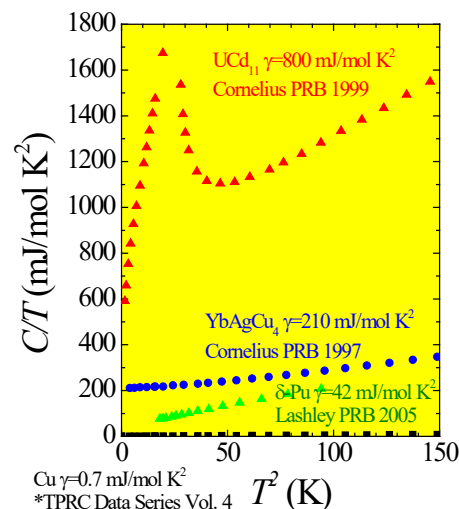
Empty Shell	Partially Filled Shell														Full Shell		
4f	La	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu		
5f	Ac	Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr		
3d	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn						
4d	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd						
5d	Ba	La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg						

↑ Increasing Localization

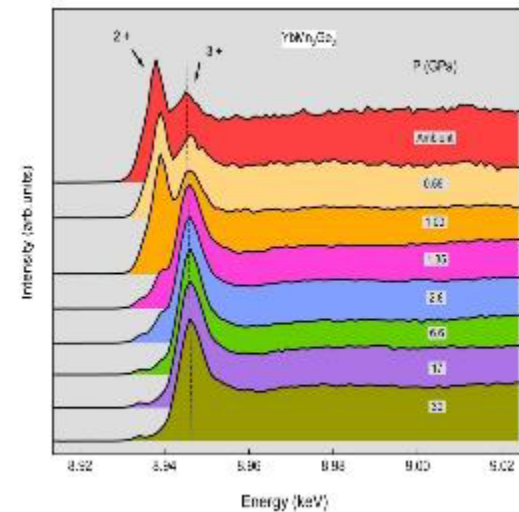
- Going from localized to delocalized electrons one often finds strong electron-electron correlations
- Correlated electron systems can yield interesting behavior: fluctuating valence, superconductivity, non-Fermi liquid, heavy fermion and many more



f-electron delocalization  
X-ray absorption



Heavy fermions  
Heat Capacity



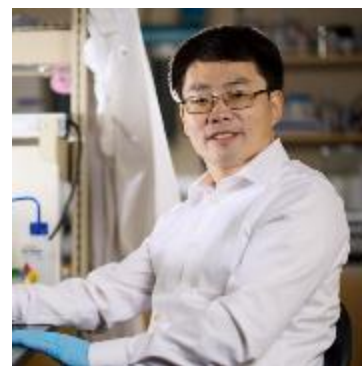
Fluctuating valence  
X-ray fluorescence

# Electrochemistry for Energy Storage, Environmental Remediation, and Biomedical Applications

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## Expertise

- Water and soil remediation
- Rechargeable batteries
- Electrocatalysis
- Electrosynthesis
- Electrochemical Manufacturing
- Electrical neural stimulation



**A combination of electrochemistry, *in situ* spectroscopy, and theoretical calculations to study electrified interfaces**

# Surface and Interface Characterization of Materials for Energy Conversion

**Dr. Clemens Heske**

Professor

Department of Chemistry and Biochemistry

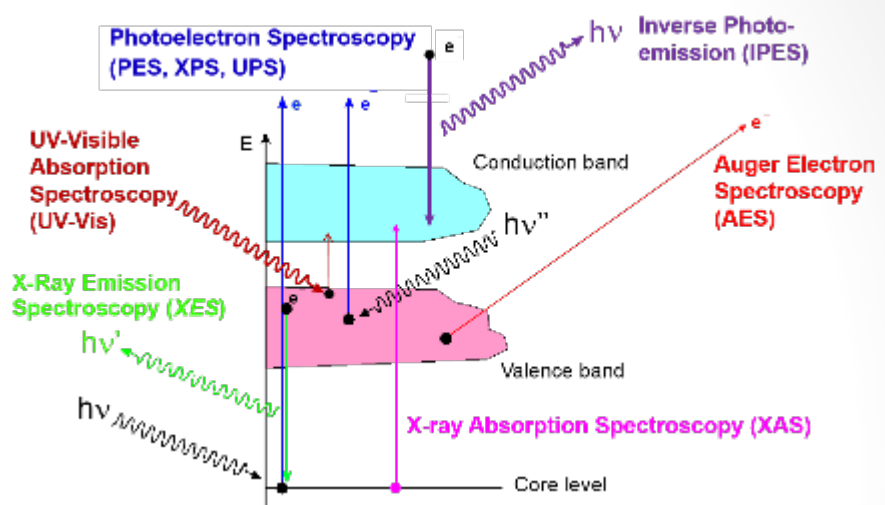
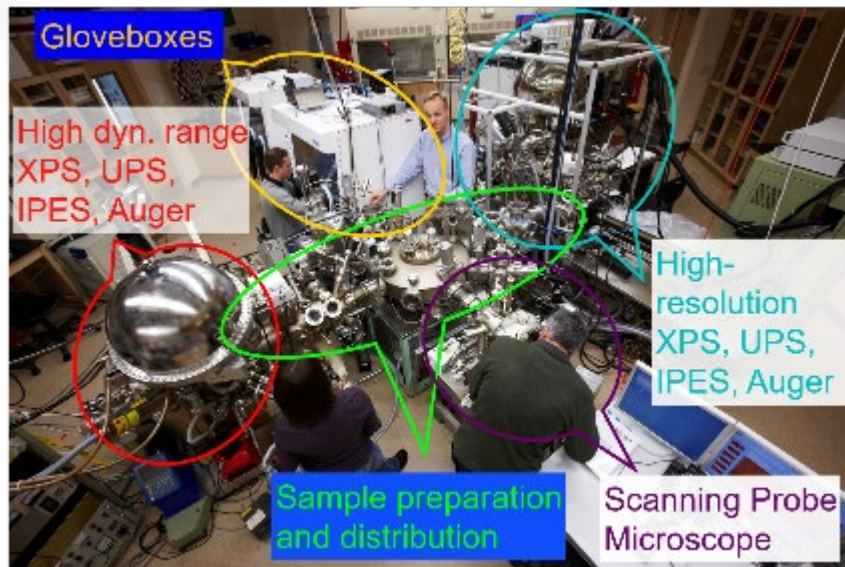
heske@unlv.nevada.edu

## **Expertise**

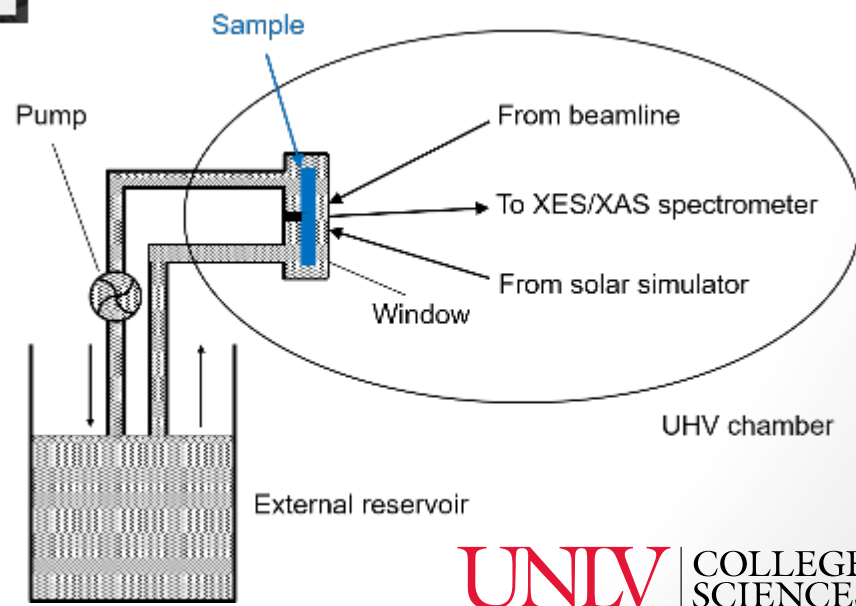
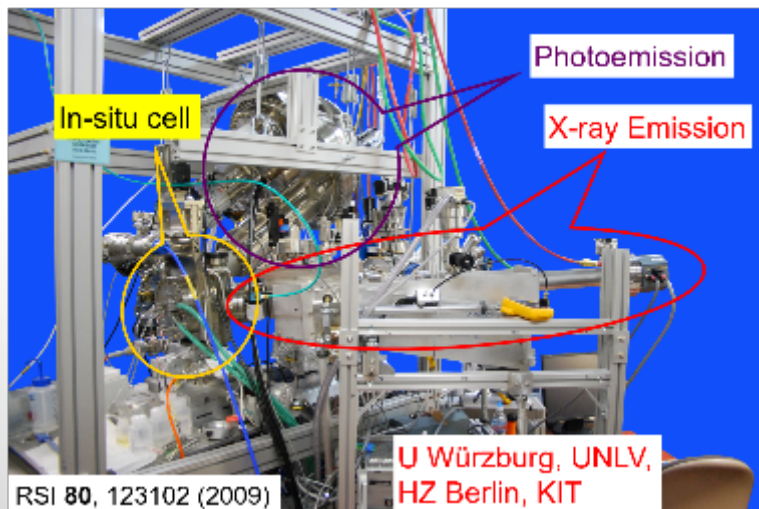
- Electronic and Chemical Structure of Energy-Conversion Materials
- Surface and Interface Characterization
- Soft x-ray and Electron Spectroscopy
- Scanning Probe Microscopy
- Synchrotron Radiation



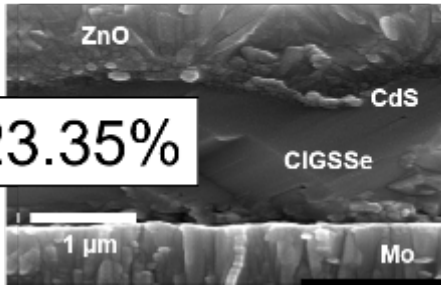
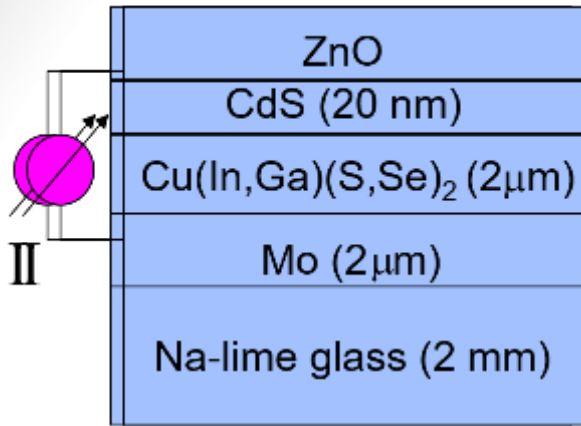
# Surface and Interface Characterization



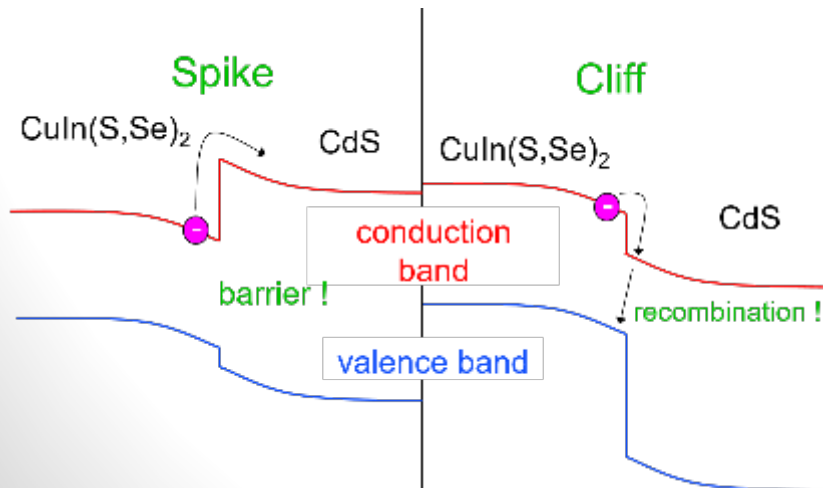
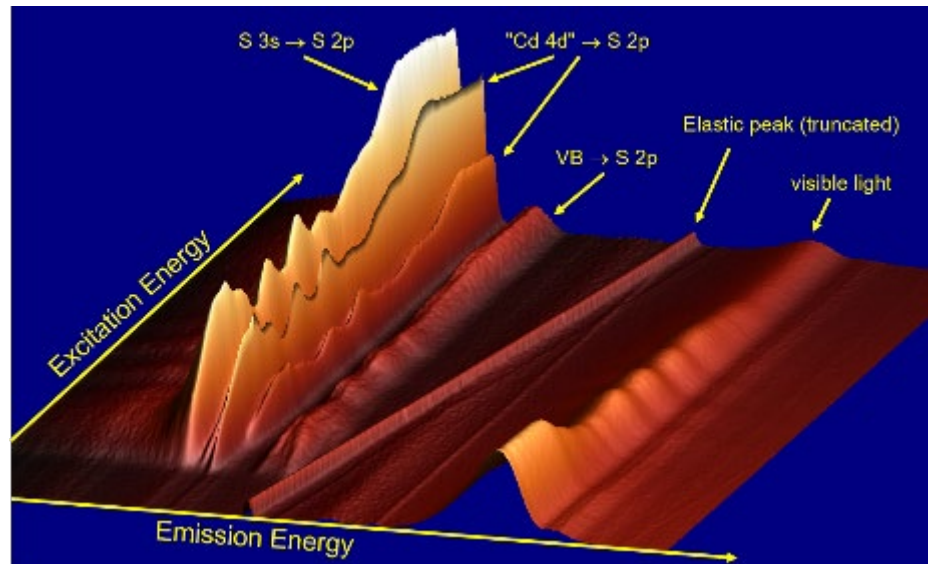
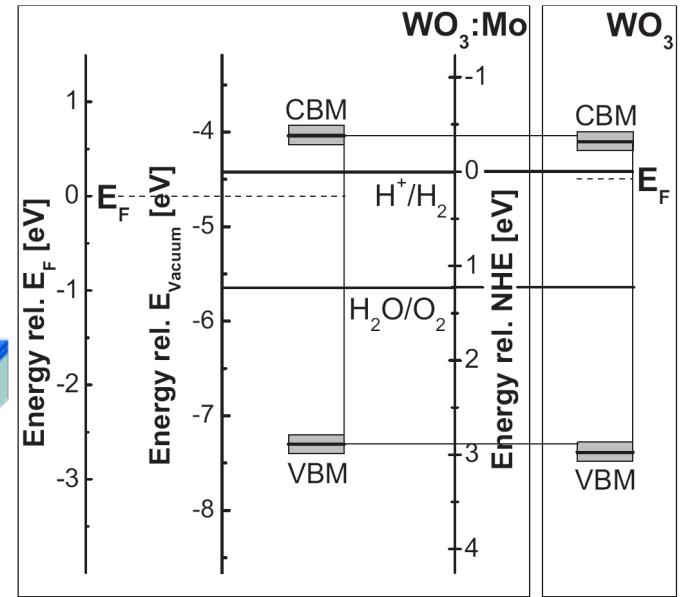
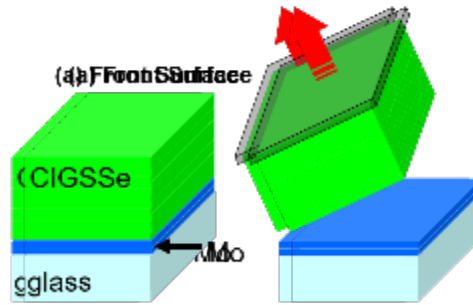
**SALSA: Solid And Liquid Spectroscopic Analysis**



# Materials for Energy Conversion



$\eta = 23.35\%$





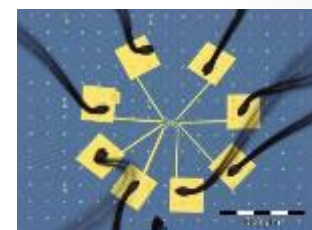
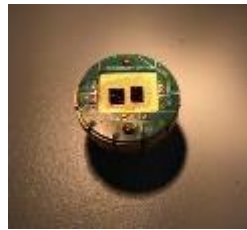
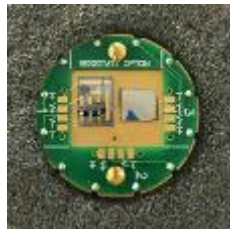
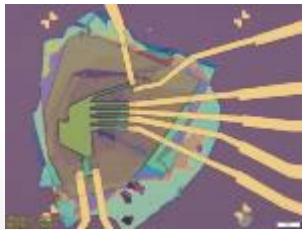
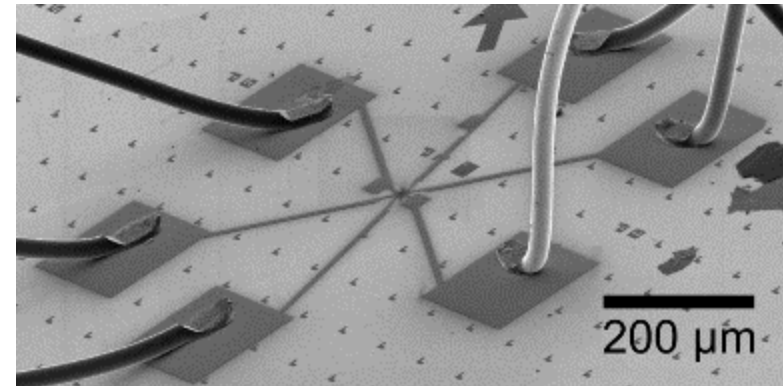
# Island – Quantum computing, quantum sensing



The Nanoscale Physics Group @ UNLV

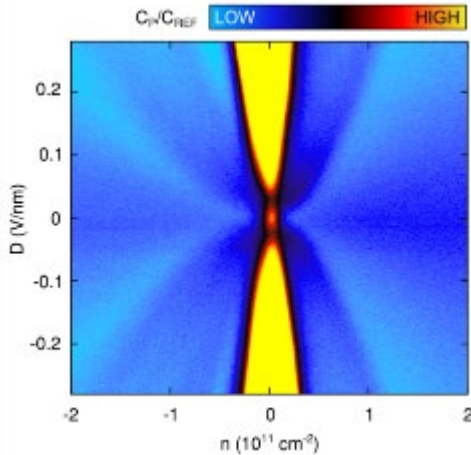
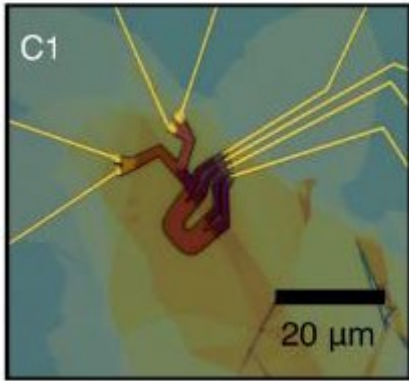
## Areas of Research

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



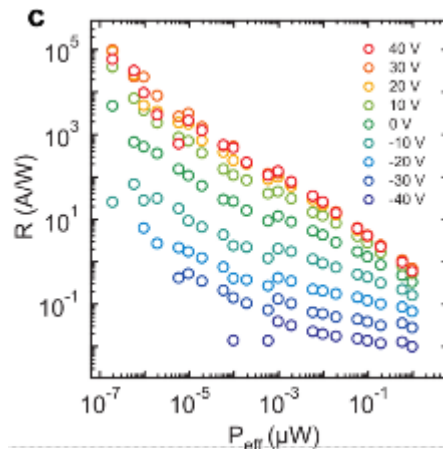
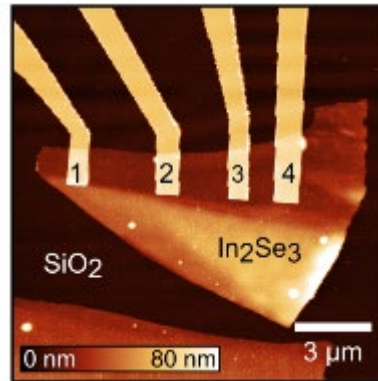
# Island – Quantum computing, quantum sensing

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



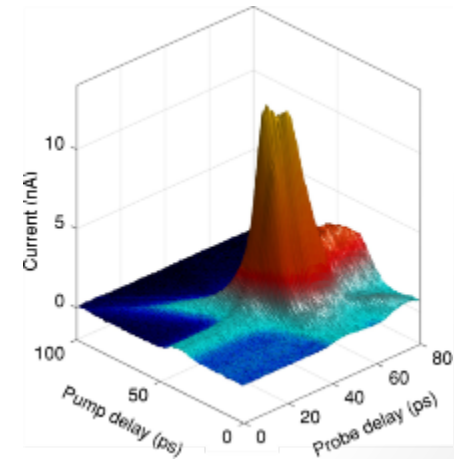
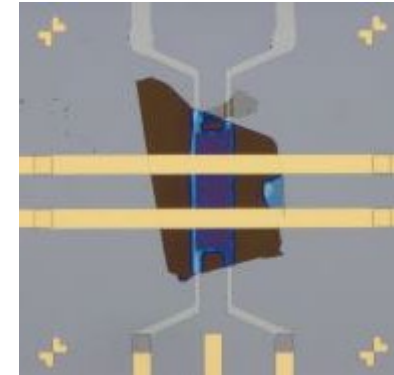
Island, J. O., et al. *Nature* **571** (2019): 85–89.

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



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

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



# 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 TaS<sub>2</sub>**

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)

## **TiS<sub>3</sub> 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 TiS<sub>3</sub> 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 In<sub>2</sub>Se<sub>3</sub> 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 MoSe<sub>2</sub> 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)

# Organic Materials Chemistry

## Dong-Chan Lee, Ph.D.

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## Expertise

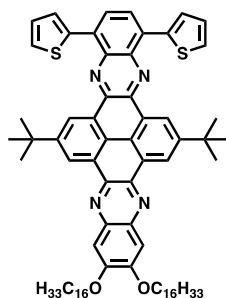
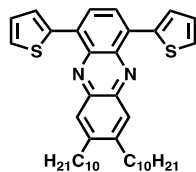
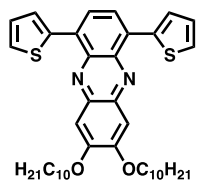
- Organic semiconductors with tunable electronic properties
- Self-assembly (nanomaterials, organogels, etc.)
- All organic room-temperature phosphors
- Materials development for solid-state emission with high quantum yield

# Electronic-Property Tuning with Smart Molecular Design

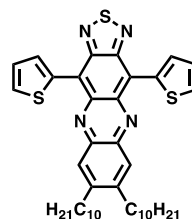
$E_{\text{LUMO}}$  -3.16 eV

-3.26 eV

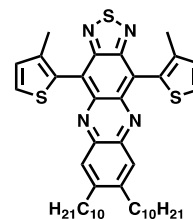
-3.22 eV



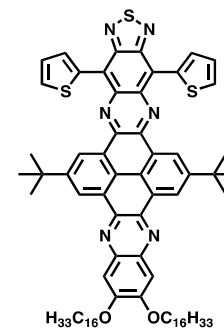
-3.89 eV



-3.80 eV



-3.84 eV



$E_{\text{HOMO}}$  -5.43 eV

-5.45 eV

-5.49 eV

-5.32 eV

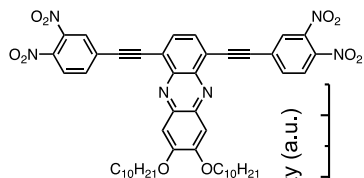
-5.51 eV

-5.40 eV

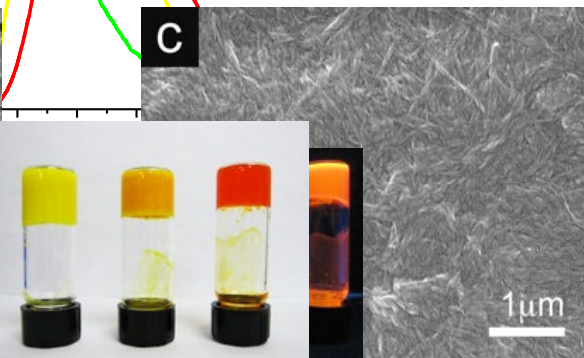




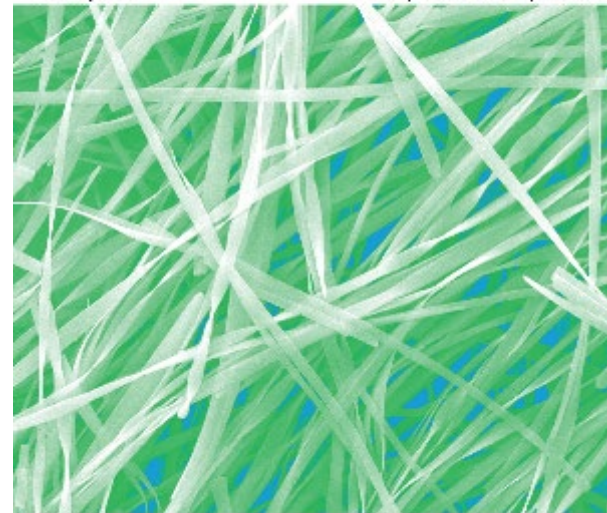
## Solvent-Dependent Morphology Control through Organogelation



Normalized FL Intensity (a.u.)



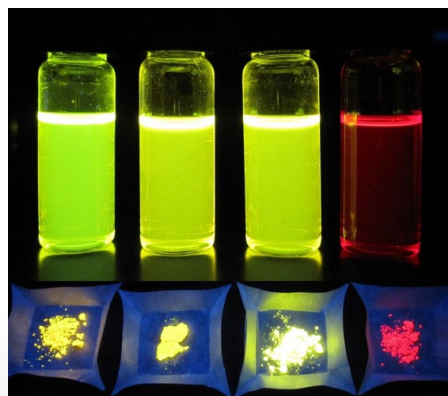
## Journal of Materials Chemistry



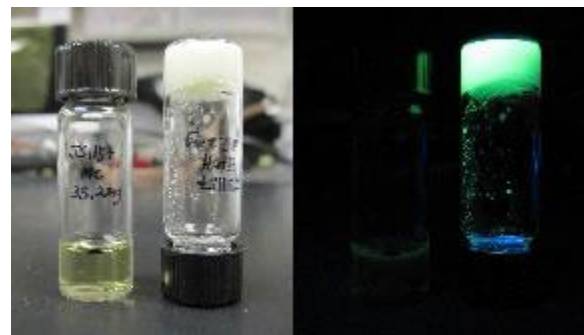
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Solid-State Emission with High Quantum Yield



Gel-Induced Room Temperature Phosphorescence



# Economic Geology Research Group



- **Dr. Andrew Martin**
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## Expertise

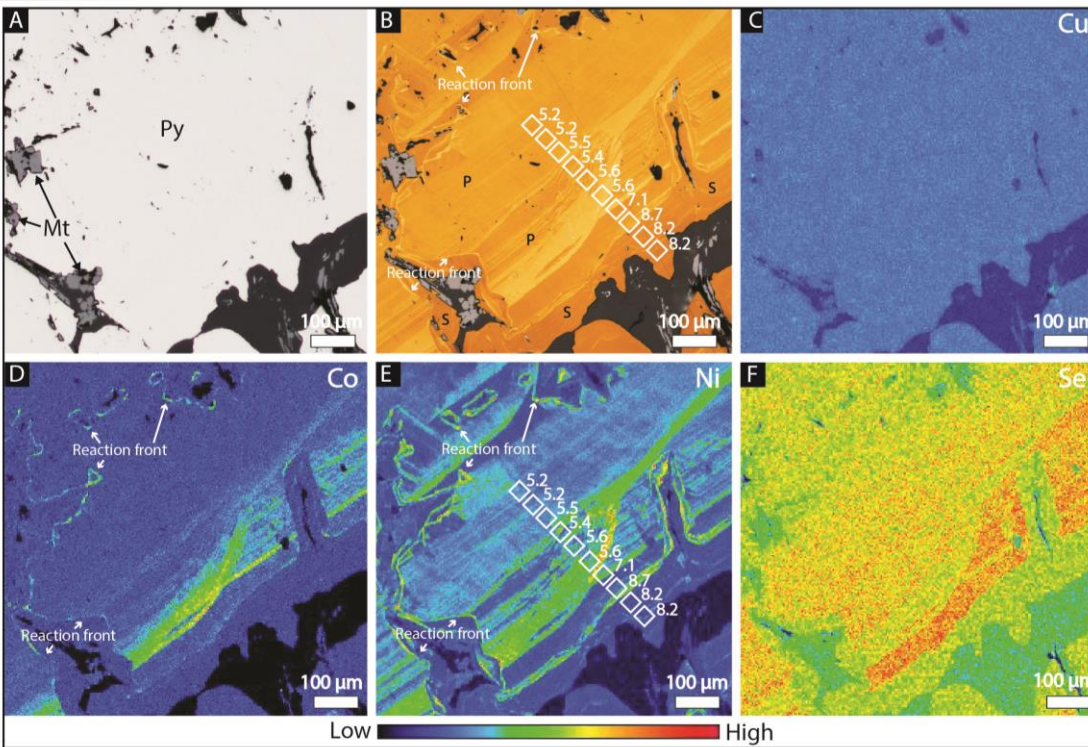
**Geochemical Research:** Studying hydrothermal mineral deposits using mineralogy, geochemistry and stable isotopes.

**Temporal Tracking:** Expertise in in situ microanalysis of sulfide minerals.

**Integrated Methods:** Combining mineral-scale observations with bulk-rock geochemistry, mineralogy and field mapping.

**Specialization:** Expertise in critical metals, volcanogenic massive sulfide (VMS), seafloor massive sulfide (SMS) deposits and Carlin-type Au mineralization.

# Understanding evolving metal and sulfur sources in mineral deposits



- As minerals grow they record changes - just like rings on a tree.
- My research group combines mineralogy with geochemical and isotopic studies to understand how these changes relate to the formation of an ore deposit.
- Above is an example from deep below the ocean, this sample was collected from the Semenov vent field on the Mid-Atlantic Ridge.

# Hydrology

## **Dr. Michael Nicholl**

Department of Geoscience

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## **Expertise:**

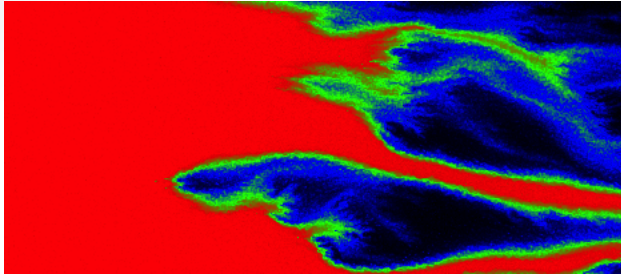
Unsaturated zone hydrology

Fractured rock hydrology

Environmental fluid mechanics



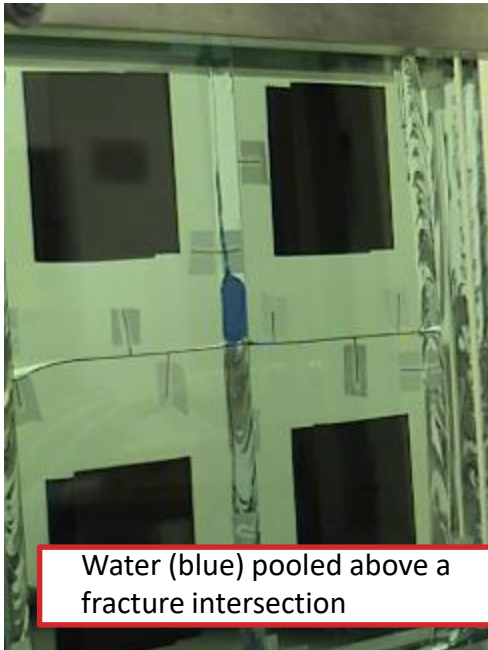
# Fractured Rock Hydrology



False color image of a miscible displacement experiment in a single fracture



Field mapping of fracture networks  
blue dye (right foreground) is from an infiltration test



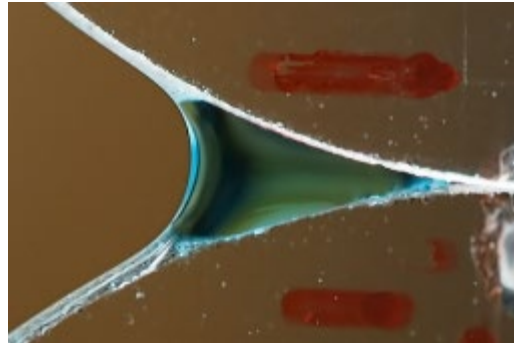
Water (blue) pooled above a fracture intersection



Isothermal flow across a single rock fracture (matrix-to-matrix flow)

- ❑ Two-phase flow and transport in fractured rock
- ❑ Laboratory experimentation, field mapping, numerical simulations
- ❑ Contaminant transport, geothermal energy, enhanced petroleum recovery

# Unsaturated Porous Media



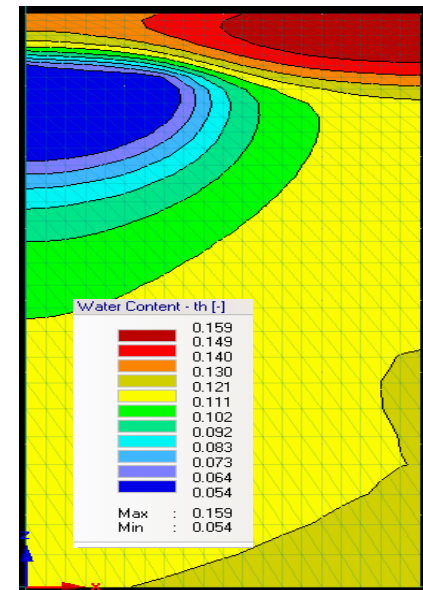
Millimeter-scale transport experiment



Hydraulic conductivity of a rock slab



Sampling Chloride as a proxy for root-driven horizontal flow



2D simulation of root-driven transport

- ❑ Challenging existing conceptual models for unsaturated and two-phase flow
- ❑ Design and execution of critical laboratory/field/numerical experiments

# Climate Change; Renewable Energy; Astronomy

**Dr George Rhee**

Department of Physics and Astronomy

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**“Expertise:”**

Observational Astronomy/Cosmology

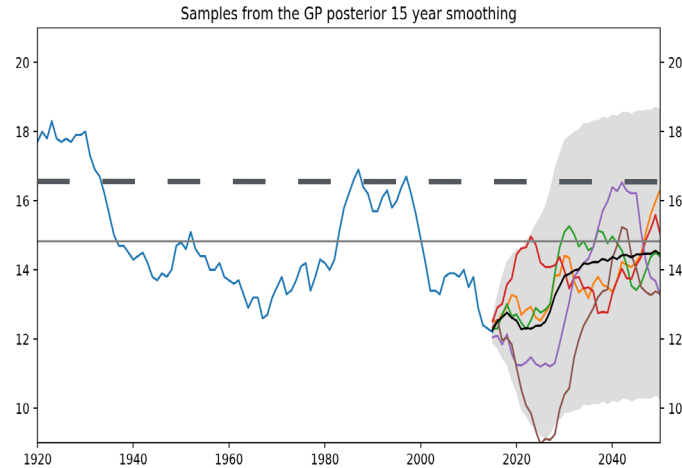
Renewable Energy

Colorado River flow projections



# Climate Change

River flow projections using statistics from tree ring data from the upper Colorado River Basin. Gaussian processes with known covariance can be used to predict properties of river flows. Figure shows predictions for Colorado river flow 2015-2050.



# Astrophysics

Interested in:

Dark matter distribution in galaxies inferred from the rotation of neutral hydrogen gas in disks

Properties of galaxies in extreme low density environments (voids)

Measuring the masses of black holes using the variability of the central region in Seyfert galaxies and quasars. spectral and brightness measurements

# Renewable Energy

Created an online calculator allowing the user to choose supply and demand options to make plans to zero out emissions in Nevada by 2050.

<http://nv2050.physics.unlv.edu/>. |

Interview on KPNR and writeup describing the idea:

<https://knpr.org/desert-companion/2018-12/do-math>

## Supply Choices

- Nuclear Energy .....
- Wind energy .....
- Hydroelectric power .....
- Geothermal Energy .....
- Rooftop Solar power .....
- Solar PV power plants .....
- Concentrating Solar Power .....
- Solar Thermal (hot water) .....
- Electricity imports .....
- Carbon Capture and Storage .....

## Demand Choices

- International aviation .....
- Nevada transport .....
- Nevada freight .....
- Industry growth .....
- Commercial heating and cooling .....
- Commercial light and appliances .....
- Home heating and cooling .....
- Home lighting and appliances .....
- Home insulation .....
- Average home temperature .....



# Advanced Numerical Methods for Moving Domain/Interface Multi-Physics Problems

**Dr. Pengtao Sun**

Professor

Department of Mathematical Sciences

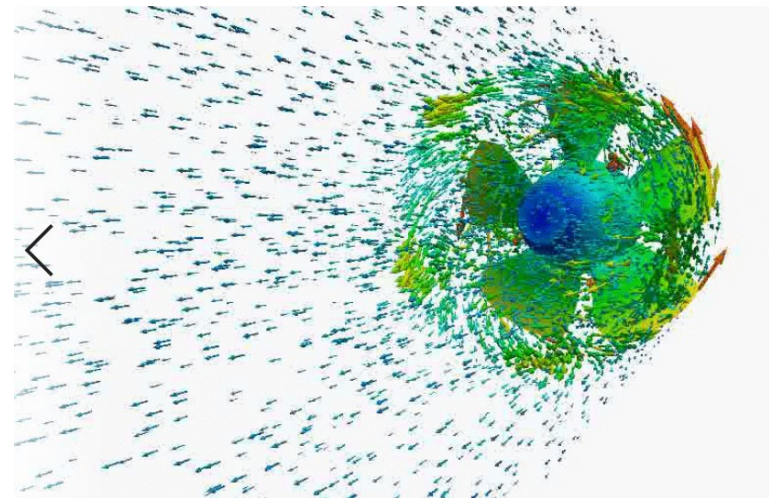
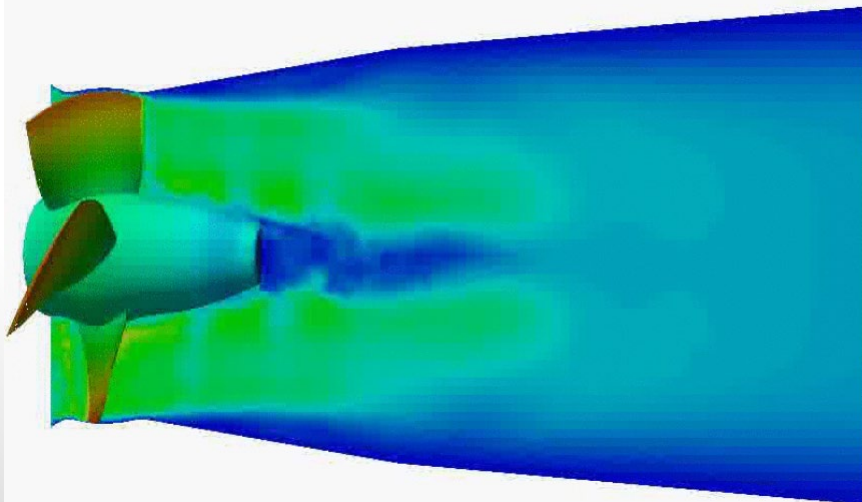
Email: [pengtao.sun@unlv.edu](mailto:pengtao.sun@unlv.edu) ; URL: <https://faculty.unlv.edu/sun/>

## Expertise

- Numerical Solutions of Partial Differential Equations (PDE)
- Numerical Analysis (Well-posedness, Stability, Convergence)
- Finite Element/Volume/Difference Methods
- Scientific and Engineering Computing
- Fluid-Structure Interaction (FSI) Modeling and Simulation
- Fuel Cell Dynamics, Fluid Dynamics, Electrohydrodynamics

# Fluid-Hydro Turbine Interaction Problems

- Hydroelectric power generating system produces renewable energy and remains crucial for society and industry. The most significant part of this system is the hydro turbine interacting with the water flow, which involves elastic solid materials and viscous fluids and belongs to the category of fluid-structure interaction (FSI). The developments of mathematical models and numerical methodologies are critical in practice for efficient simulations of the hydro turbine, which in turn guides the design and evaluation.
- We approach the challenges in different aspects. First, based on the observation that the hydro turbine, although exhibiting large rotations, has relatively small deformation, we develop linearized elasticity equations that alleviate the burden on nonlinear solver and improves the well-posedness of spatial discretization. Second, we propose a new approach to solve the arbitrary Lagrangian-Eulerian mesh motion for rotating structure. Moreover, we analyzed the well-posedness and convergence of the finite element discretization and demonstrated the discretization is solver friendly.



# Hemodynamic Fluid-Structure Interaction (FSI) Problems

- FSI simulation has become the most promising solution method to solve the hemodynamic problem existing in the clinical cardiovascular system. However, the complexity of cardiovascular environment, the artificial heart pump model, the vascular rupture, the aneurysm progression and the aortic dissection cause the deficiency of the existing FSI simulation package towards the clinical demands.
- We devoted our research to the new modeling and numerical techniques for the bloodstream-vascular-stent graft/artificial heart pump interaction problems, aiming at overcoming numerical difficulties and challenges, and developed advanced numerical methodologies to improve the efficiency and accuracy of corresponding FSI simulations. and to deliver more instructive numerical results to medical professionals for helping out patients on an efficient and accurate diagnosis and treatment.

