Condensed Matter & Atomic, Molecular, and Optics (AMO) Research
Theoretical and Computational
Condensed Matter and Materials Physics

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Expertise

• Novel states of matter: topological insulators and semimetals
• Superior bonding structures: superhard and supertough materials
• Intriguing quantum phenomena: superconductivity and magnetism
• Extreme mechanics: stress responses to complex large strains
• Ultimate thermodynamics: materials inside Earth and other planets


Magnetic Dirac materials CaMnBi\textsubscript{2} and SrMnBi\textsubscript{2} [Zhang, et al., *Nature Commun.* **7**, 13833 (2016)].


Helium-bearing compound $\text{FeO}_2\text{He}$ predicted to stabilize at deep-Earth conditions [Zhang, et al., *Phys. Rev. Lett.* **121**, 255703 (2018)].


**Further Reading (selected papers by Chen Group, 2015-2020)**


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
- 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
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's Lab website
**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's Lab website
Island – Quantum computing, quantum sensing

Journal publications:

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

**Enhanced superconductivity in atomically thin TaS2**

**Proximity-induced Shiba states in a molecular junction**

**T1S3 transistors with tailored morphology and electrical properties**

**Environmental instability of few-layer black phosphorus**

**Ultrahigh photoresponse of few-layer TiS3 nanoribbon transistors**

**Gate controlled photocurrent generation mechanisms in high-gain In2Se3 phototransistors**

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

Island's Lab website
Condensed Matter Theory

Tao Pang

Department of Physics and Astronomy
University of Nevada, Las Vegas
Research Methods and Systems Studied

• **Analytical Approach**
  Quantum Hall effect; quantum transport phenomena, superconductor-insulator transitions; vibrational modes in glasses; and slow light in cold atoms.

• **Diffusion Quantum Monte Carlo Simulation**
  Negative donor centers in semiconductors; hydrogen molecules in confinement; ionic hydrogen clusters; and helium clusters with modified interactions.

• **Path Integral Quantum Monte Carlo Simulation**
  Bosons trapped in potential wells in one dimension or two dimensions; Bose-Einstein condensation of cold atoms; and asymmetric distributions of Bose-Einstein condensates of boson mixtures.
An Example: Asymmetry of the Mixed Bose Condensates:

Asymmetric distributions of two Bose-Einstein condensates in the same trap with different cluster parameters.

Novel chemistry and biology using highly ionizing radiation

Michael Pravica, Ph.D.
Professor of Physics
Department of Physics and Astronomy
Phone: (702)895-1723
Email: michael.Pravica@unlv.edu

Expertise:
* Useful Hard X-ray photochemistry
* High pressure Spectroscopy
* Ion Beam Nuclear Transmutation Doping
* High quality synthesis of vaccines using tuned hard x-rays
Pravica Group Research

A. Photochemistry

B. Novel materials synthesis

C. New Physics/Chemistry

D. Device applications

Optical mixer

Wide bandgap semiconductor

Radiation-hardened sensors/direct energy conversion devices for EXTREME CONDITIONS or tuned solar materials

Useful hard x-ray photochemistry

X-ray >16 keV

SrC$_2$O$_4$

X-ray >16 keV

Sr$^{x+}$

e$^{-}$

C$_2$O$_4^{x-}$

SrCO$_3$ + p-CO

Novel structures of known materials produced with hard x-rays and high pressure (e.g. CsO$_2$)
High Pressure Fluorine Chemistry

2F₂ + O₂ → 2OF₂ @ 3 GPa

XeF₂ → Xe + F₂ (in situ x-ray fluorination)

HgF₂ + F₂ → HgF₄

Inner shell chemistry at high pressure

Molecular mixtures at high pressure

Using tuned hard x-rays to damage viruses to create high quality vaccines by targeting specific molecular groups/bonds that resonantly absorb x-ray energy leading to decomposition chemistry.
Salamat Group – Collaboration with MSTS

Metrology – accurate mapping of P, V, T

High temperature modelling – understanding emissivity under extreme conditions
Warm dense matter – probed using EXAFS

- Development of a CO₂ laser heating
- Direct heating of non-metallic systems in a DAC
- First HTHP EXAFS measurements of insulators
- In situ and post heating measurements
- Determining absolute temperature from X-ray spectroscopy
Publications


Zhou Lab – Experimental AMO physics

- Dr. Yan Zhou
- Assistant Professor
- Department of Physics and Astronomy
- Email: yan.zhou@unlv.edu
- Website: https://www.physics.unlv.edu/~yanzhou/index.html

Research projects
- Explore new physics beyond the Standard Model by precision measurements using quantum logically controlled molecular ions
- Precision metrology and spectroscopy using optical frequency combs
- Quantum transducer – link ion trap and superconducting quantum computers
- Experimental astrochemistry – cold ion-radical collisions
Search for $T,P$-odd symmetry violation

- On-chip Quantum sensors
- Entanglement between atomic ions and molecular ions
- Scalability and multiplexing measurements
- New table-top platform to investigate nuclear physics
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


