



ARO Physics Division

26 August 2008



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ARO Physics Vision



To identify and enable basic research opportunities in physics that have the potential to transform Army capabilities and help maintain U.S. technological superiority

To lead the Army by embracing long-term, high-risk, high-payoff opportunities with special emphasis on Atomic and Molecular Physics, Condensed Matter Physics, Optical Physics and Imaging Science, and Quantum Information Science.

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ARO Physics Program

Program Manager

Atomic and Molecular

Dr. Peter Reynolds

Condensed Matter

Dr. Marc Ulrich

Optical Physics and Imaging Science

Dr. Rich Hammond

Quantum Information Sciences

Dr. TR Govindan



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Physics Army Impacts



Situational awareness

(Novel sensors, sensing modalities, guidance)

Sensor/Eye protection

(Novel materials)

Logistics

(Quantum information, reduced power requirements)

Command, Control, Comms, Computers, Intelligence

(Quantum information, advanced electronic materials)

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Atomic and Molecular Physics

Vision

Exploit quantum properties of atoms and molecules (superposition, entanglement, coherence, statistics...) to achieve opportunistic capabilities.

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Atomic and Molecular Physics Opportunities



Optical Lattices (Quantum simulations of intractable problems, novel materials design, discovering novel quantum phases)

- Loading lattices with atoms
- Hamiltonian design
- Low temperatures / entropy
- Handling external trap shape

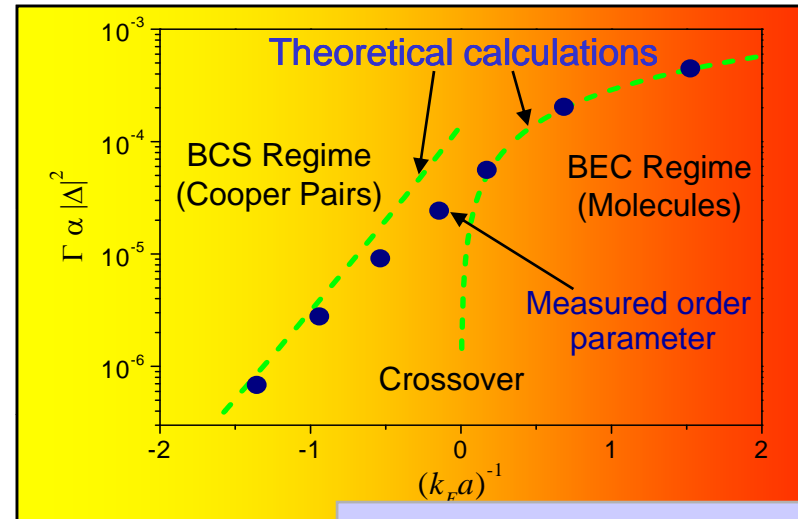
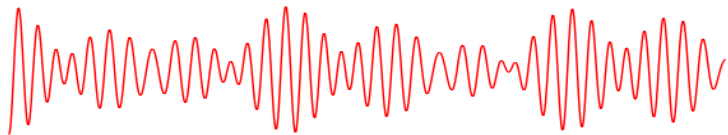
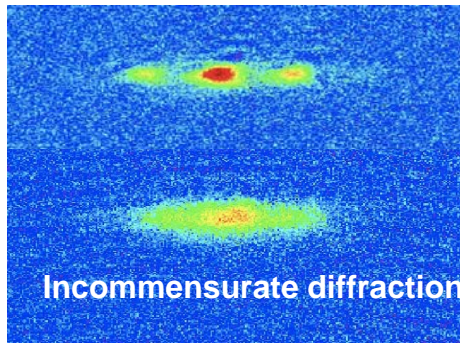
Cold Molecules (Exotic quantum phases, polar entities in optical lattices, ultracold chemistry)

- Direct cooling methods (buffer gas, Stark deceleration, collisions, etc)
- Indirect cooling methods (photoassociation, Feshbach, laser cooling)
- Handling the complex level structure

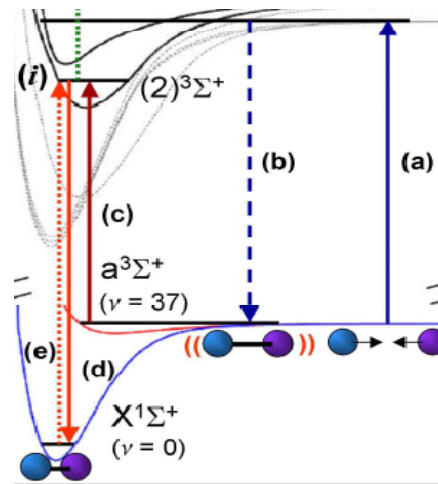
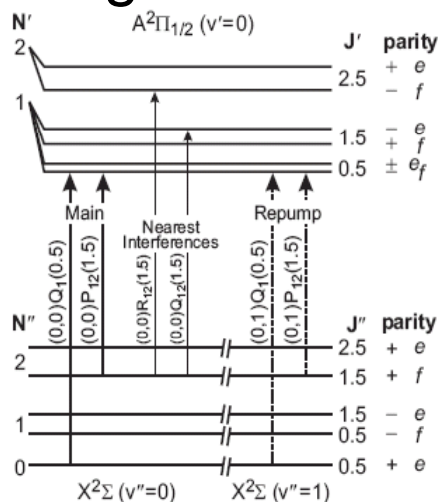
Fermi Degeneracy (Exotic quantum phases, quantum phase transitions, pairing mechanisms)

- Managing lack of collisions
- Theoretical development of unknown phases
- Achieving ultra-low temperatures

Disorder in optical lattices:



Cooling molecules:



Photoassociation

Investigating BCS/BEC crossover with Fermi degenerate gas.



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Condensed Matter Physics

Vision

To drive high-risk/high-payoff research toward the discovery and exploitation of exotic quantum phenomena in condensed matter.

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Condensed Matter Physics Opportunities



Novel Quantum Phases of Matter (discovering and engineering novel quantum phases, novel materials, understand and control quantum many-body interactions)

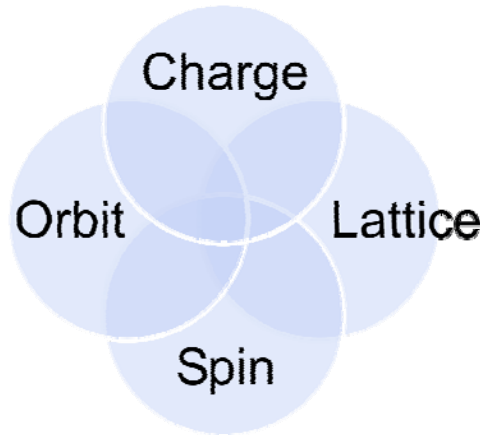
- Oxide heterojunctions focus
- Quantum many-body theory
- Defect understanding and control
- Handling external trap shape

New Spectroscopies for many-body phenomena (Probe and control interactions, understand physical origin of phenomena)

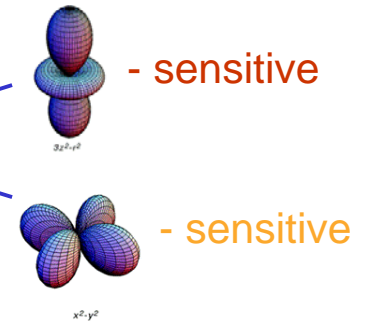
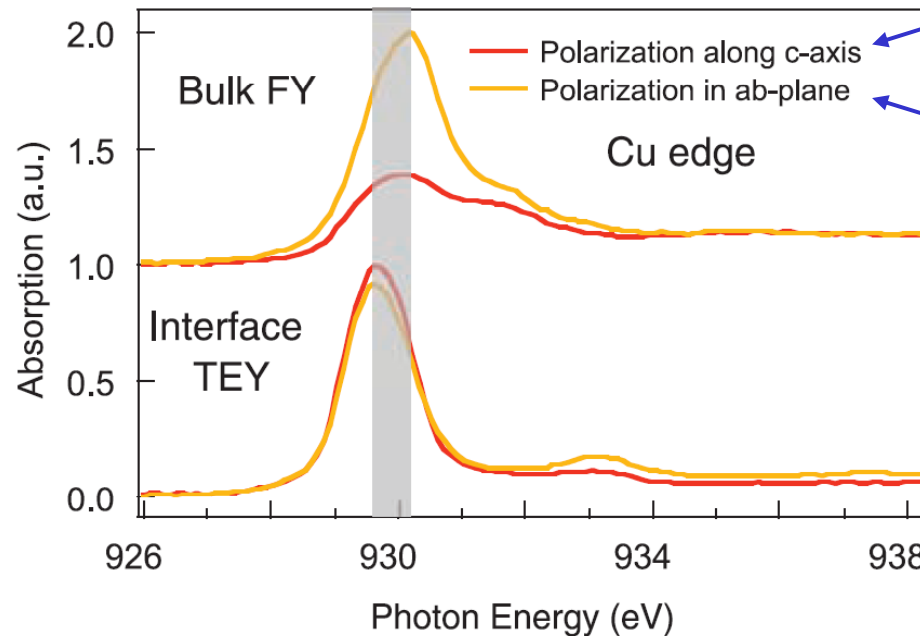
- Direct observation of many-body excitations
- Observe optically dark states

Complex oxides are a unique “sandbox” with four interacting and controllable degrees of freedom.

Oxide-oxide interfaces provide the potential to engineer quantum many-body effects.



Demonstration of orbital reconstruction at interfaces:





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Optical Physics and Imaging Science

Vision

Search for and develop new realms of optics to provide warfighters with breakthrough technological advantage.

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UNCLASSIFIED Optical Physics and Imaging Science Opportunities



Transformation Optics (spatial and temporal control of negative index optical properties)

- Visible and IR negative index materials
- Broadband materials
- Overcoming loss
- Tunability

Attosecond Physics (< single cycle optical pulses, extreme broadband, electron orbital tomography, new physics)

- Single pulse generation
- Sub-fs pulse measurement
- Reaching 25 asec

Slow Light (orders of magnitude less than the speed of light, multiple reflections, excitonic effects, etc.)

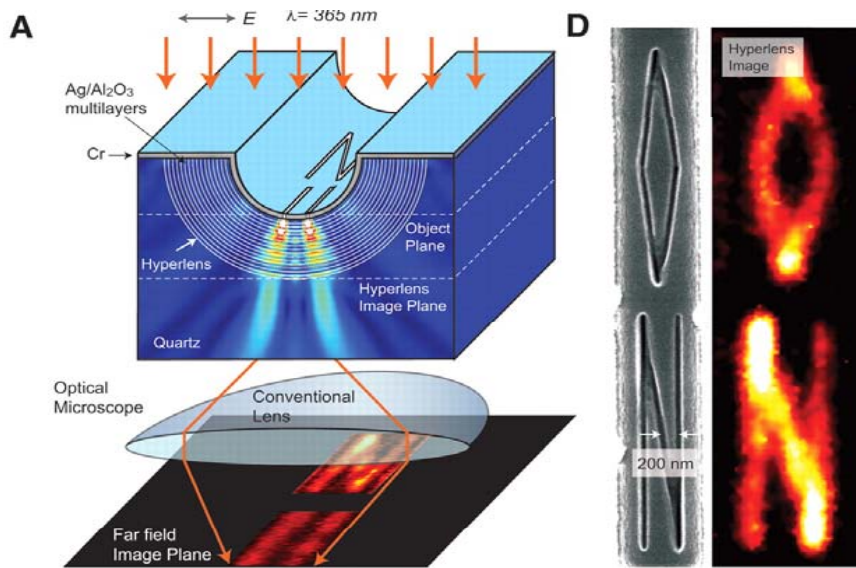
- Photonic materials for slow light
- Enhanced detector sensitivity

Non Electromagnetic long range forces (the scalar field, antisymmetric field)

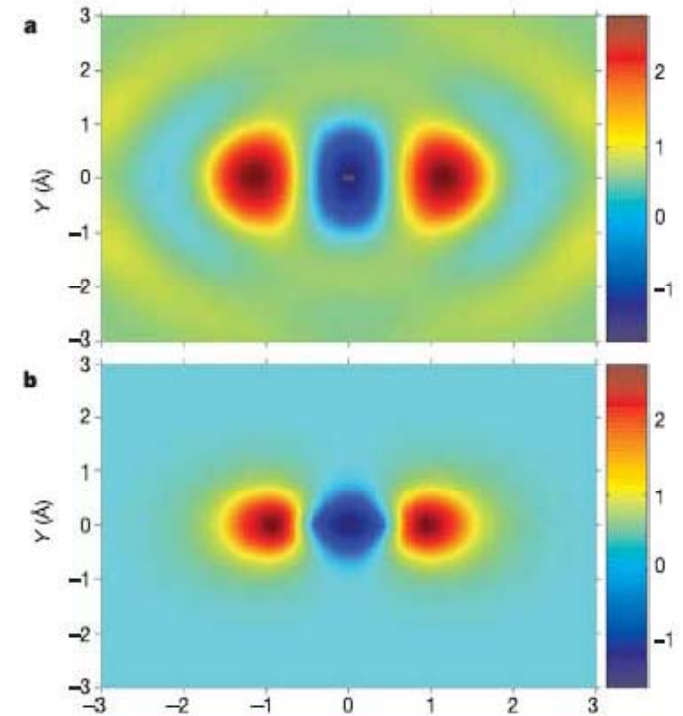
- Theory
- Measurement / Observation

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Transformation optics: curving optical space for hyperlensing.



Attosecond pulses for electron dynamics:





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Quantum Information Science

Vision

Explore and exploit quantum physics to enable advances in information science and technology beyond those possible with classical information processing.

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Quantum Information Science Opportunities



Quantum Computing (show me the qubits!)

- Managing decoherence
- Achieving scalability
- High fidelity operations
- Developing quantum algorithms

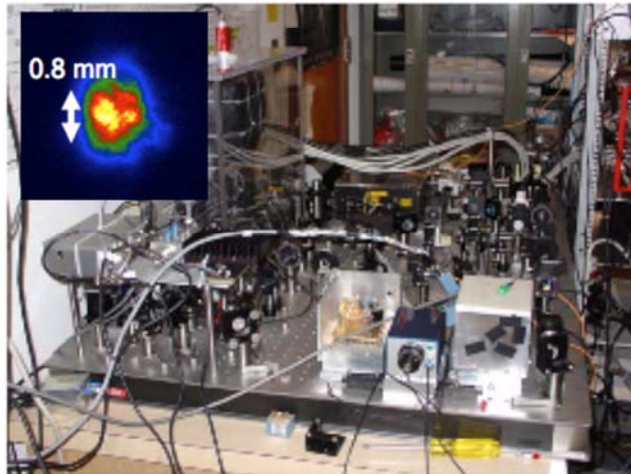
Quantum Communication (Ultrasecure transmission of information)

- Developing sources and detectors
- Memories and repeaters
- Protocols
- Exploit entanglement

Quantum enabled sensing, imaging and metrology (Exploit superposition and entanglement to beat classical resolution and sensitivity limits)

- Overcome shot noise limits
- Beat classical diffraction limits
- Non line of sight imaging

Atomic and Molecular physics for quantum computing

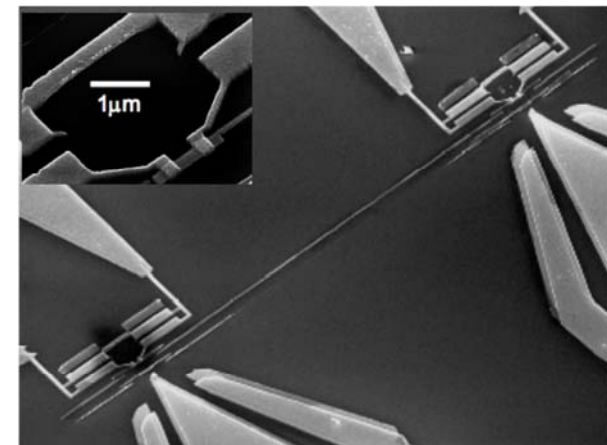
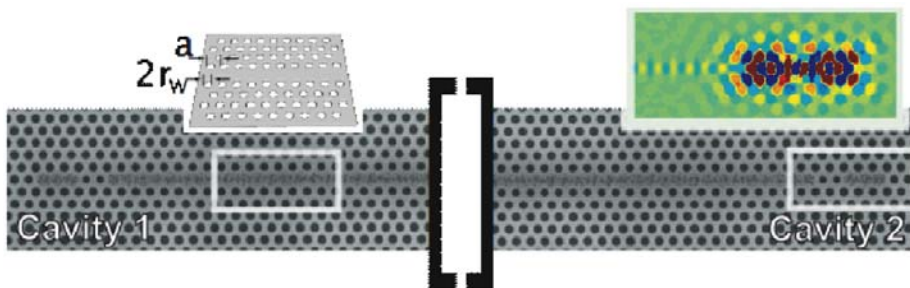


Algorithms for realistic quantum information systems



Circuit QED

Single Photon Sources & Detectors





UNCLASSIFIED Complimentary RDECOM Physics Research



Ultracold Atoms

- ARL SEDD
- AMRDEC

Negative Index Materials

- ARL SEDD
- AMRDEC
- TARDEC

Light Filaments

- ARO Electronics
- ARL SEDD
- AMRDEC

Complex Oxides

- ARO Materials Science
- ARL WMRD
- ARL SEDD
- CERDEC

Quantum Information

- ARO Mathematics
- ARL CISD
- ARL SEDD
- AMRDEC



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