Motivation
Quantum information processing (QIP) could revolutionize cryptography, many body simulations, and advanced computing algorithms. In bulk InP we propose to study the spin characteristics of neutral donors for QIP.

Bound Electrons and Excitons
- A donor impurity may bind:
  - An electron to become neutral - D^0
    - Neutral donors have hydrogenic effective mass wave functions.
  - An electron and an electron-hole pair, exciton (X), to form a short-lived excited state - D^0 X

D^0 Lambda System
- D^0 X state can be used to optically couple D^0 spin states
- D^0 Electronic Spin Qubit
  - Classical bit – 0 or 1
  - Quantum bit – 0 and 1
  - Information is stored in a superposition of the electronic states
    - |ψ⟩ = α|0⟩ + β|1⟩
  - Storage time limited by
    - Spin relaxation and decoherence

D^0 Energy Diagram
- Spin states are degenerate in absence of a magnetic field.
- D^0 X states are 4-fold degenerate due to hole spin.
- TES – ‘Two Electron Satellite’ transitions
- Energy separation of D^0 X and D^0 is .0057 eV.
- TES PL from resonant excitation at 1.4173 eV.

Primary Optical Transitions
- Optical transitions are polarization specific.
- Transitions to the D^0 2s, 2p states (TES transitions) have smaller oscillator strengths.
- Phonon-assisted transitions may occur between spin states.

Experiment
- Intensity and polarization of light is determined by excited state population.
- Measure emitted light to calculate the spin polarization and relaxation rate.

Population Modeling
- Steady state populations determined by
  - T_1 – spin relaxation
  - Excited state relaxation
  - Optical oscillator strengths

Exciton Polarization
We probe D^0 X spin polarization while resonantly exciting the free-exciton state with both linearly and circularly polarized light. We do not observe any dependence of the emitted polarization on the excitation polarization. This indicates that it is not possible to obtain spin-polarized D^0 X through free exciton polarization, which is expected if the exciton hole-relaxation time is sufficiently fast. It may be the case that we have obtained electron spin-polarized D^0 but we currently cannot probe this state. Next, we would like to repeat this experiment resonantly exciting the D^0 X state.

Current Work and Future Plans
Currently we are installing a magnet cryostat to split degenerate spin states. Combining frequency selective and polarization specific optical pumping techniques will provide a powerful tool for measuring the T_1 time of the neutral donor bound electron spin state. T_1 time is the fundamental upper limit for the quantum decoherence time, T_2.

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