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Physical Science & Engineering / Computational, Environmental, & Life Sciences QIS Seminar

PSE / CELS – QIS Seminar

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"Nature's Optimized Quantum Spin Coherences in Photosynthetic Proteins"

Host: Stephen Gray

Monday, June 20, 2022 @ 1:00 p.m.

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Abstract: A bottleneck for electron spin qubit applications is the creation of quantum entanglement of two or more electron spins, a state which is required for quantum computing and quantum communication. An entanglement of two spin-based qubits can readily be prepared by light excitation of photosynthetic reaction center proteins, which is followed by fast sequential steps of electron transfer (ET) and charge separation (CS). This fast CS generates an entangled electron spin pair, which is also called spin-correlated radical pair (SCRP). This SCRP is created in coherent superposition of two states: singlet and triplet, which oscillate due to the singlet-triplet mixing.

The SCRP phenomenon was first observed in natural photosynthetic systems in our research group at Argonne 40 years ago. Photosynthetic proteins play a central role in the spin chemistry field as a test case for theory motivated experimental confirmation owing to the clear manifestation of the consequences of spin-correlation effects in Electron Paramagnetic/Spin Resonance (EPR/ESR) and Optically Detected Magnetic Resonance (ODMR) techniques.

In my talk I will demonstrate how SCRP can be used for quantum sensing of protein structures and functions on the examples of ET pathways in type I and type II photosynthetic proteins. The ability of generation spin entangled radical pair state allows for coherent manipulation of this state not only for sensing but quantum communication and quantum teleportation. The "biological" SCRPs are not only found in photosystems, there is substantial evidence that electron spin entanglement is responsible for bird's navigation (avian compass). The navigation mechanism is based on a spin dependent recombination of the SCRP in the weak magnetic field of the earth, where the SCRP is created by light in certain proteins located within the bird's eye. The focus of our current research which factors determine their coherence spatial lengths and lifetime, their mechanisms for dephasing/decoherence, and how decoherence is related to the local and global protein structure. Our current research is focused on the extent to which quantum phenomena contribute to the efficiency of photosynthetic solar energy conversion and identify mechanisms that nature uses for preserving coherence and spin entanglement in photosynthesis.