Quantum Coherence Techniques for Biosensing and Fusion Energy

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Quantum coherence is the central feature of multiple techniques, and corresponds to a situation where atoms or molecules of a sample are prepared in a coherent superposition state. High degree of coherence can lead to amazing results. Atomic coherence has earlier been used in electromagnetically induced transparency, ultraslow light propagation, and lasing without inversion. Molecular coherence enables a variety of applications, including, for example, a technique termed molecular modulation, which produces a coherent optical bandwidth spanning infrared, visible, and ultraviolet spectral regions, allowing arbitrary ultrafast space- and time-tailored sub-cycle optical field synthesis. Another remarkable example is the use of molecular coherence for the purpose of combining high-power laser beams through stimulated Raman scattering – a technique adopted by the laser-fusion community. Furthermore, an increased and cleverly manipulated molecular coherence leads to enhanced sensitivity and speed in optical label-free bio-imaging. These unique tools show promise to applications in environmental and plant studies, animal sciences, as well as in materials research addressing the structure and function of novel systems, including topological and reduced-dimensionality materials. The next level of improvements in signal-to-noise ratio will come with the use of properly engineered non-classical states of light. Quantum superposition and photon entanglement, as well as squeezed light, will enable quantum-enhanced spectroscopy and imaging, particularly in those scenarios where the applied laser power is limited, either by the sample sensitivity or by the damage threshold of the tools used – as is often the case when working with biological samples and/or utilizing plasmonic nano-structures for micro- and nano-spectroscopy.