Coherent Raman spectroscopy: From stand-off detection to nano-sensing

Alexei V. Sokolov

Institute for Quantum Science & Engineering, Texas A&M Univ., College Station, TX 77843, and Baylor Research and Innovation Collaborative, Baylor Univ., Waco, TX 76704, USA

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 remarkable results. Atomic coherence has earlier been used in electromagnetically induced transparency, ultraslow light propagation, and lasing without inversion. Recent work has shown that an increased and cleverly manipulated molecular coherence enables improvements in optical detection and sensing [1], including the possibility of remote sensing via femtosecond laser filaments and optically-pumped atmospheric lasing [2]. At the nanoscale, an additional (multiplicative) improvement can be obtained due to enhancement via plasmonic resonances and nanoantenna effects [3]. Another example is a technique termed molecular modulation, which enables generation of a coherent optical bandwidth spanning infrared, visible, and ultraviolet spectral regions, producing bursts of light synchronized with respect to the molecular oscillations [4]. Controlled spectral, temporal, and spatial shaping of the generated multi-color waveform may lead to arbitrary ultrafast space- and time-tailored sub-cycle optical field synthesis.

[1] D. Pestov et al., PNAS 105, 422 (2008); Science 319, 5862 (2008).

[2] P. Hemmer et al., PNAS 108, 3130 (2011); M. M. Springer et al., JoVE e58207 (2019).

[3] D. V. Voronine et al., Sci. Rep. 2, 891 (2012); Zhe He et al., JACS 141, 753 (2019).

[4] A. V. Sokolov et al., JMO 52, 285 (2005); M. Shutova et al., Sci. Rep. 9, 1565 (2019).