Superoscillations at Dark Ports: Interference-Engineered Sensing and Spectrally Constrained Light-Matter Control

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Superoscillations allow a band-limited optical field to display local behavior that appears to lie outside its global spectral content. I will discuss how such effects arise near engineered destructive-interference minima, where local wave vectors, weak values [1], and Fisher information densities [2] can become strongly concentrated. As a spatial example, I will begin with "optical ventriloquism" [3]: near a diffraction minimum, light can appear to originate from a displaced, nonexistent source, due to sharp transverse shifts of the local wave vector. I will connect this physics to sensing with dark-port interferometric encoders, where an ideal interference null can concentrate shot-noise Fisher information into a photon-poor region, while coherent leakage and stochastic phase noise reshape and ultimately limit the advantage. Next, I will turn to quantum light-matter interaction under spectral constraints. In protected quantum platforms, decoherence mitigation often imposes photonic bandgaps or filtered control lines. I will discuss how a superoscillatory pulse whose global spectrum avoids a two-level-system resonance can nevertheless produce a resonant-like response through a spectrally filtered multimode cavity. Finally, I will connect these ideas to interference-generated regularization from postselected superpositions of time evolutions [4]. The central message is that superoscillations redistribute response and information in unique ways that can be useful for quantum sensing and quantum control.

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