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Decoherence-Free Rotational Degrees of Freedom for Quantum Applications

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Quantum metrology and sensing represent promising near term applications of quantum technologies as they require the control of a few or even single quantum systems. However, a central challenge common to all quantum sensor designs is the necessity to achieve both robustness to environmental noise and, at the same time, high sensitivity to a signal of interest. This task becomes even more challenging when considering massive particles whose translational degrees of freedom are highly susceptible to first order (gradient) fluctuations of external fields, thus inhibiting the generation of long-lived macroscopic quantum superpositions. In this talk, we address this challenge by designing the shape of rigid bodies such that their rotational degrees of freedom can be made robust against decoherence from distant sources, while at the same time allowing for interaction with signals from nearby sources. To this end we introduce a systematic method, based on the mathematical theory of spherical t-designs, to construct rigid bodies whose rotational states are degenerate up to a desired order of the multipole expansion of their energy in a perturbing potential. This allows for the generation of long-lived macroscopic quantum superpositions of rotational degrees of freedom and the robust generation of entanglement between two or more such solids with applications in robust quantum sensing and precision metrology as well as quantum registers.

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