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Exploiting non-uniform field effects for quantum sensing

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Miniature atomic vapor cells are a fundamental component in future-focused field-deployable quantum technology development. Here, we explore the physics of diffusive alkali metal-noble gas spin systems magnetization in a mm-sized wafer-fabricated vapor cell, engineered with an eye towards room temperature atomic magnetometry, co-magnetometry and gyroscope setups. Through a systematic survey of magnetic resonance spectra over a range of optical pump powers, vapor cell temperatures, and experimental geometry, we identify regimes of optimal sensor operation [2]. We discuss the specific spectral features effected by non-uniform electromagnetic fields in these systems and demonstrate a symmetry-breaking phase transition of the noble gas using engineered optically induced linear field gradients [2, 3, 4]. We further investigate the use of more complex spatial modes of light to interface the spatial diffusive modes of alkali atoms, demonstrating temporal and spatial manipulation of spin precession and relaxation. These results offer insight into the complex physics of collective atomic spins displayed by miniature vapor cells and will drive fundamental advances for metrology and sensing.

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