Development of solid-state and vapour-based room-temperature masers

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Abstract

Recent advances in room-temperature masers based on nitrogen–vacancy (NV) centres in diamond have demonstrated the strong potential of this platform for ultra-low-noise microwave amplification [1] and for probing new regimes of spin quantum electrodynamics [2,3]. Although solid-state masers were originally pursued for compact, high-precision frequency generation, their performance as oscillators has been limited by the large inhomogeneous linewidths inherent to the NV spin ensemble. In contrast, alkali-metal atomic spin vapours, such as rubidium, offer exceptionally narrow electron spin linewidths - potentially approaching the hertz level [4] - making them highly attractive for precision frequency standards. Previous demonstrations of rubidium-based masers have highlighted their promise for timing and for investigating many-body quantum phenomena such as spin squeezing [5].

In this talk we will present the latest advances in a room-temperature NV diamond-based maser amplifier under development at UNSW. A series of recent system upgrades – including a reduction in resonator losses, improved thermal management, and larger diamond samples - have pushed the noise performance of the system to within reach of the best commercially available transistor-based microwave amplifiers. We will then introduce a new experimental platform currently under development that integrates high-quality-factor sapphire dielectric microwave resonators with rubidium vapour cells. This hybrid system aims to enable advances in precision timing while providing a versatile testbed to explore previously inaccessible regimes of light–matter interaction and collective spin dynamics.

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