Diamond masers

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The solid-state maser, invented in the 1950s, had a much less impressive career than its younger sibling the laser, mainly due to reliance on cryogenic refrigeration and high-vacuum systems. Despite this, the maser found application in deep-space communications and radio astronomy due to unparalleled performance as low-noise amplifiers. In 2012, the first room-temperature solid-state maser was demonstrated, exploiting an ensemble of inverted photo-excited triplet states in pentacene molecules doped into a *p*-terphenyl matrix[1]. Since then, this new class of maser has been miniaturized[2], characterized on nanosecond timescales[3] and shown to exhibit Rabi oscillations and normal-mode splitting, hallmarks of the strong-coupling regime of cavity quantum electrodynamics[4]. Unfortunately, *p*-terphenyl is volatile, has poor thermal properties and unfavourable spin-triplet sublevel decay rates – so only pulsed operation for less than a millisecond has been observed to date. Alternative inorganic materials containing spin-polarizable defects such as diamond nitrogen-vacancy (NV) centres[5,6] and vacancies in silicon carbide[7] have been proposed due to their slow spin-lattice relaxation and spin dephasing rates. These materials have the additional advantage of excellent thermal and mechanical properties. In 2018, the first continuous-wave room-temperature solid-state maser was reported[8] based on optically pumped nitrogen-vacancy (NV) defect centres in diamond. The maser operated at 9.2 GHz, with a linewidth of 50 Hz and with an optical pump power threshold of 140 mW (532 nm). In this talk we will present recent results and the outlook for macroscopic coherent quantum states, cavity quantum electrodynamics and discuss prospects for magnetometry and frequency standards.

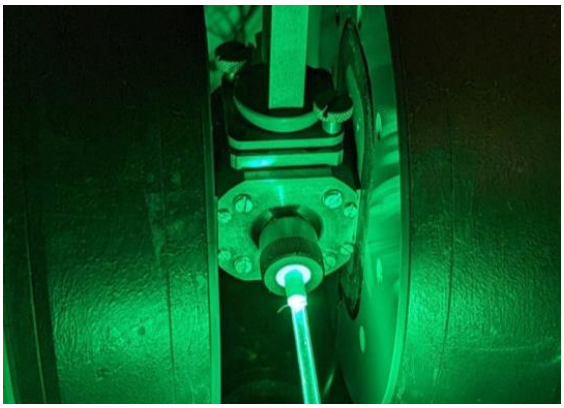

Fig. 1: Diamond maser in operation.

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