

# Department of Physics

Condensed Matter Physics

Clarendon Laboratory, Parks Road, Oxford OX1 3PU



## CONDENSED MATTER SEMINAR

Thursday 1<sup>st</sup> November at 2.15pm

*“Solid-state room-temperature masers: a 21st century review”*

**Dr Jonathan Breeze**

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The solid-state masers, invented in the 1950s, had a much less impressive career than its younger sibling the laser, mainly due to its dependence on cryogenic refrigeration and high-vacuum systems. Despite this, masers found niche application in deep-space communications and radio astronomy due to their unparalleled performance as low-noise amplifiers and oscillators. In 2012, the first room-temperature solid-state maser was demonstrated, exploiting an ensemble of inverted triplet states in photo-excited pentacene molecules doped into a p-terphenyl host [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, the p-terphenyl host is volatile, has very poor thermal properties and unfavourable triplet sublevel decay rates – so that only pulsed operation lasting less than a millisecond has been observed to date. Alternative inorganic materials containing spin-polarizable defects such as diamond nitrogen-vacancy (NV) centres and [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 this seminar, I will discuss how the organic pentacene solid-state room-temperature maser came about, its subsequent development and how the quest for continuous operation naturally led towards diamond and nitrogen-vacancy centres. I will report on the recently reported continuous-wave room-temperature maser based on optically pumped charged nitrogen-vacancy (NV) defect centres in diamond [8]. I will also discuss prospects for the macroscopic quantum (Dicke) states supported by the maser [9].

[1] M. Oxborrow, J. D. Breeze, N. Alford, *Nature*, 488, pp. 353–356 (2012)

[2] J. Breeze et al, *Nature Communications*, 6 (2015)

[3] E. Salvadori, J.D. Breeze et al, *Scientific Reports*, 7, 41836 (2017)

[4] J.D. Breeze et al, *npj Quantum Information*, 3, 40 (2017)

[5] J.H.N Loubser and J A van Wyk, *Diamond Research*, pp. 11-14, (1977)

[6] L. Jin et al, *Nature Communications*, 6 (2015)

[7] H. Kraus et al, *Nature Physics*, 10, pp. 157–162 (2014)

[8] J.D. Breeze et al, *Nature*, 555, pp. 493–496 (2018)

[9] R.-B. Liu, *Nature News & Views*, 555 (2018)

**Host: Prof Donal Bradley**

**Audrey Wood Seminar Room, Clarendon Laboratory**