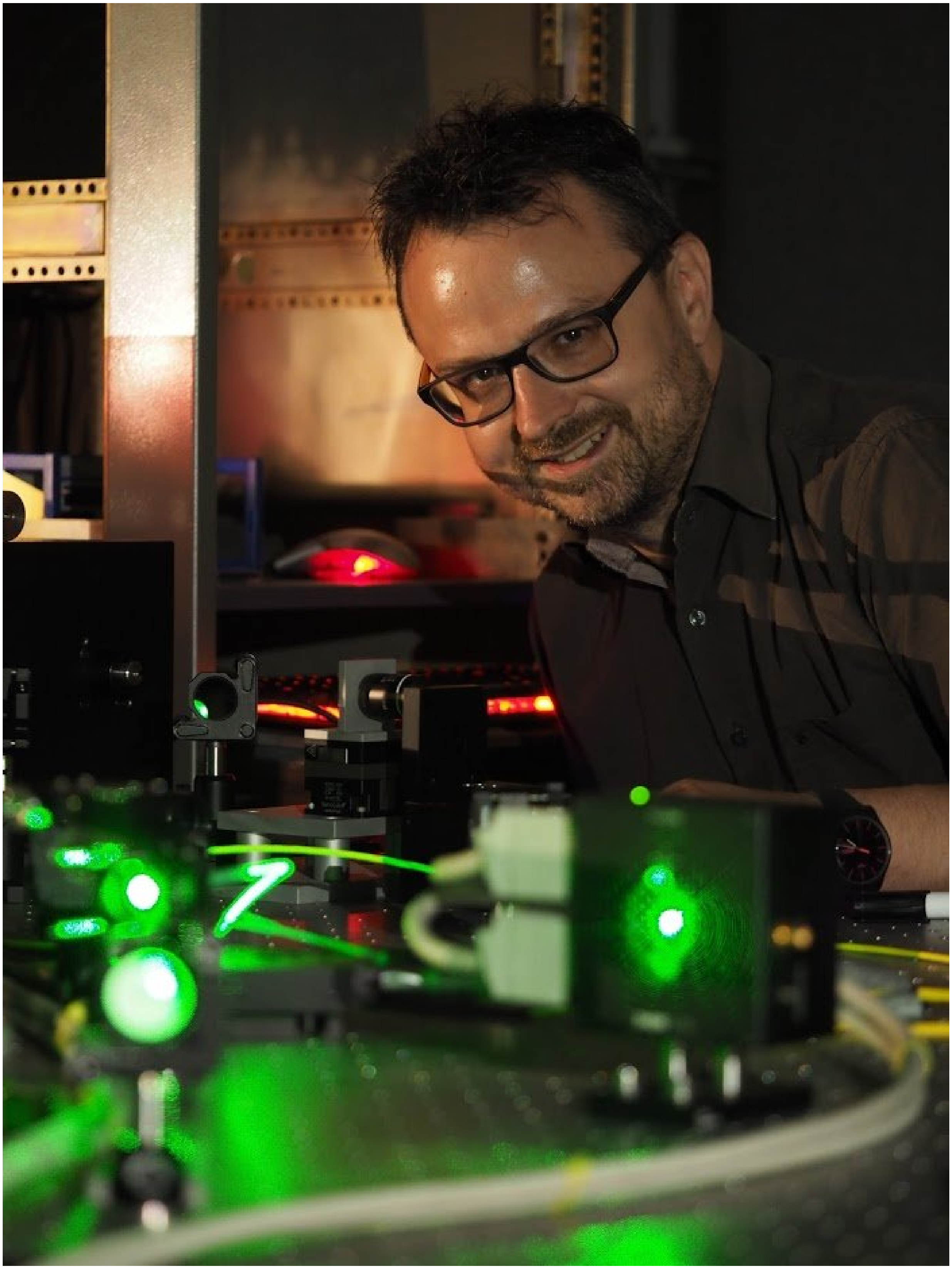
Tiny diamonds light the way for new quantum technologies

October 31 2017



Dr Thomas Volz in the Diamond Nanoscience Lab. Credit: Science in Public

Macquarie University researchers have made a single tiny diamond shine brightly at room temperature, a behaviour known as superradiance.

This is important because nanodiamonds have the potential to be used in all sorts of devices, such as minute compasses for navigation, in biomedical imaging and to potentially create better solar cells.

To date what's been holding back these applications is that superradiance has previously only been seen at very low temperatures or in very large samples. This is the first time it's been seen in diamonds.

The research by Macquarie's Diamond Nanoscience Laboratory was published tonight in *Nature Communications*.

Research leader Dr Thomas Volz says the team are now keen to make brighter nanodiamonds that can be used in biomedical applications, such as to track drug delivery pathways in the lab.

"You can attach drugs to nanodiamonds, and then use the concentrated pulse of light sent out by the nanodiamond to track where the drug is going in the sample," he says.

Nanodiamonds that send out a brighter burst of light will be more easily picked up by the detector, and tiny diamonds are much less toxic that some of the other drug markers we use today.

Nanodiamonds also have potential uses in navigation.

They act like tiny and very sensitive compass needles and will emit more or less light depending on how they are aligned with the Earth's magnetic field.

When the nanodiamonds are producing brighter pulses of light this effect is amplified.

This behaviour could be used to develop magnetic sensors which would work out the location of an aircraft for example, by mapping where it is in relation to the Earth's magnetic field rather than by satellite.

In the future they could be used to create better solar cells, by reversing the superradiance effect so that the nanodiamonds absorb more light, more quickly.

The team has already shown the potential for nanodiamonds to be used as ultra small scanning sensors to look at the processes going on inside living cells.

In a paper published last year in *Nature Physics* they showed that superradiant nanodiamonds (which are as small as one thousandth of the breadth of a human hair) can be better trapped and moved around using focussed laser light or tiny optical tweezers than non-superradiant ones.

The cause of this behaviour is the same as what causes nanodiamonds to produce these bright pulses of light—defects in their crystal lattice, in this case nitrogen atoms neighbouring vacant sites nested within the repeating carbon structure.

Similar defects are what give coloured diamonds their hue.

"Diamond is a material, a cage for what is happening inside," Thomas explains.

When these nitrogen-vacancy centres within the diamond lattice work together – in unison like a well-coordinated orchestra – you get superradiance, a faster and brighter burst of light that you would otherwise expect.

"The presence of this 'cooperative' behaviour is interesting from a fundamental point of view and will be followed up with further experimental and theoretical studies," says Associate Professor Gavin Brennen who oversees the theory for the work.

In particular, the team would like to work out how to create the brightest nanodiamonds possible.

The Diamond Nanoscience Laboratory is part of the Quantum Materials and Applications Group at Macquarie University, and is funded by the Australian Research Council Centre of Excellence for Engineered Quantum Systems.

Macquarie University has a strong tradition in diamond materials research with several groups investigating diamond lasers, diamond growth, and nanodiamond processing. There is also a very active group of researchers working on quantum engineering for new technologies with diamond and other systems.

More information: Carlo Bradac et al. Room-temperature spontaneous superradiance from single diamond nanocrystals, *Nature Communications* (2017). DOI: 10.1038/s41467-017-01397-4

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