New technique introducing foreign atoms in optical trapping allows greater manipulation of nanoparticles

November 15 2016

Macquarie University researchers have demonstrated a new technique exploiting the presence of foreign atoms within a diamond crystal, using light to affect the motion of the entire nanoparticle – opening the door to applying powerful quantum technologies to the manipulation of ultrasmall nanoparticles and an unprecedented degree of control at the nanoscale.

The research, published in *Nature Physics*, measured the force on nanoscale diamond crystals (which are as small as one thousandth of the breadth of a human hair) that were immersed in water and optically trapped by a tightly focused laser beam-optical tweezers.

Dr Thomas Volz and colleagues from the Department of Physics and Astronomy and the ARC Centre of Excellence on Engineered Quantum Systems (EQuS), found that when tracking the motion of the individual nanodiamonds in the optical tweezers, the artificial atoms had a significant influence on the nanocrystal motion. This is remarkable, especially considering that only a few of these foreign atoms actually interact with the near-resonant laser light.

"Usually, the light in the optical tweezers interacts with the nanoparticle itself. In this study however a group of special foreign atoms were introduced in the diamond nanoparticle. When the laser light is chosen close to the transition of these foreign 'special' atoms, the motion of the

whole crystal is affected, despite there being only about 10,000 of these atoms within a crystal made of about 100 million carbons," said Dr Volz.

"These near-resonant forces are typically known from the manipulation of single atoms by light but not in the case of nanomanipulation. This research demonstrates for the first time the effect of these forces in the context of nanomanipulation. Even more interestingly, these forces are only measurable because of a unique effect which is seldom observed in nature: a cooperative interaction of the foreign atoms amongst each other. Only by these atoms acting together in a cooperative way can we see their effect," said first author Dr Mathieu Juan.

"Our research is motivated by the possibility to pioneer a technique well known from atom manipulation in the field of nanoparticle manipulation (in a liquid environment). The technique is powerful, and one can think of engineering nanodiamonds with different types of foreign atoms to make their effect even stronger and ultimately trap nanoparticles as small as a few nanometres in diameter while systematically moving them around in cells," said Dr Volz.

"The forces we observed have not been seen before and with these exciting possibilities at hand, this research could lead to a new type of optical tweezers being developed, which will have applications across different fields. Beyond applications in biology and medicine where near-resonant optical tweezers could be used for bio-imaging and drug delivery, this research could impact the fields of quantum nanotechnology and sensing," said Dr Carlo Bradac, joint first author.

More information: Mathieu L. Juan et al. Cooperatively enhanced dipole forces from artificial atoms in trapped nanodiamonds, *Nature Physics* (2016). DOI: 10.1038/nphys3940