Researchers examine the deliberate switching of individual photochromic molecules

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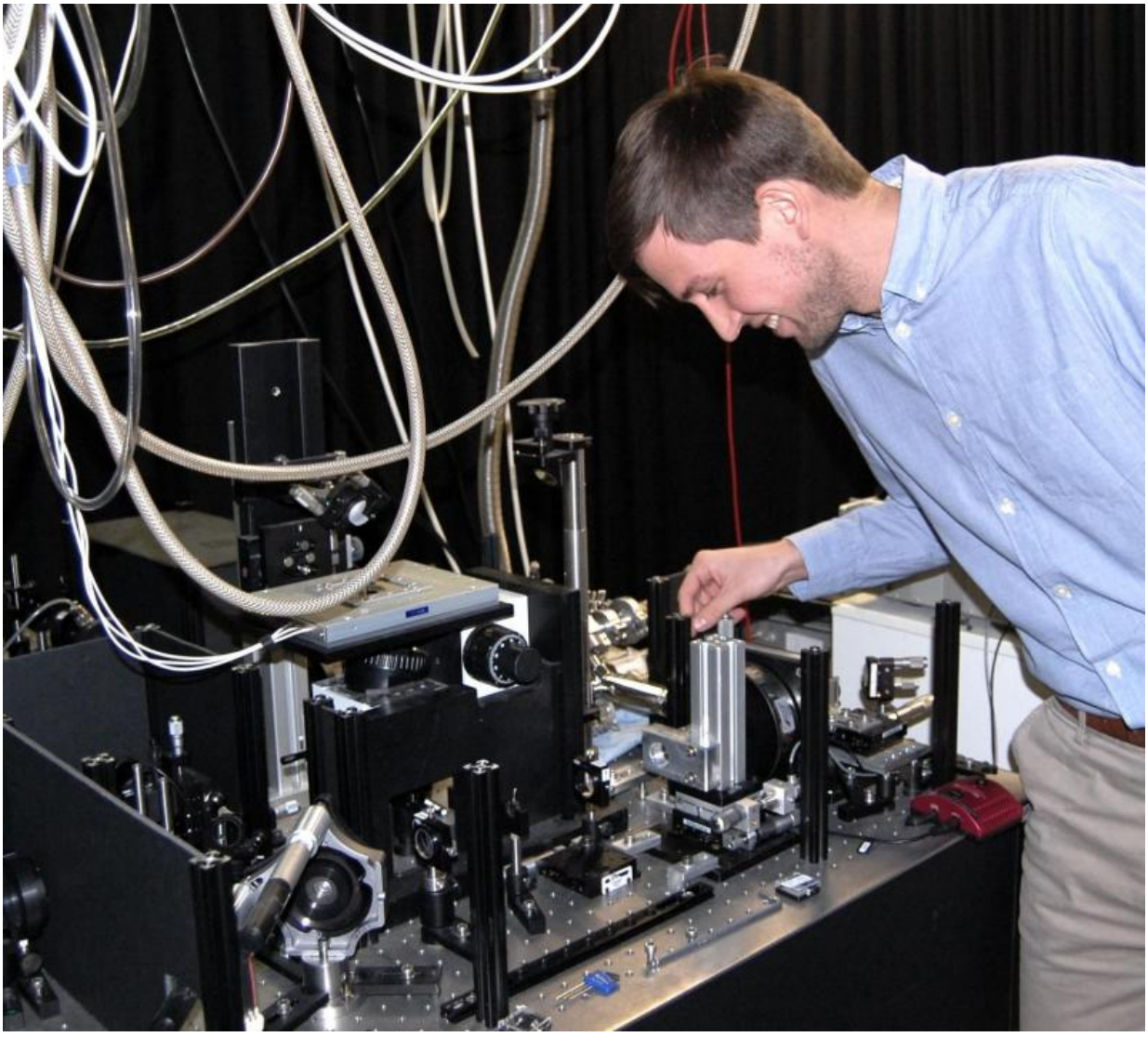

Johannes Maier (M.Sc.) made significant contributions to the research findings presented in Scientific Reports while carrying out his doctoral research in

physics. He is a member of the Bayreuth Graduate School of Mathematical and Natural Sciences (BayNAT). Credit: C. Wissler

Scientists in Bayreuth examine the deliberate switching of individual photochromic molecules. Their findings are opening up new research possibilities for visualizing the structures of complex molecules and even entire biological systems.

Basic Research Focusing on Photochromic Molecules

Basic research has been addressing photochromic molecules for quite some time. Photochromic molecules can be controlled in such a way that they toggle back and forth between two different states similar to an electronic device being switched to the on-position and off-position. They are controlled using light. The wavelength of the light hitting the molecule determines which of two possible structures the molecule assumes. Scientists have known for some time how to make the switch between two states visible – namely, by linking the photochromic molecule with strongly fluorescent molecules. These partner molecules – the so-called "fluorophores" – only fully light up when the photochromic molecule is in the on-position.

Against this background, photochromic molecules are of great interest, not least for super-resolution optical microscopy. For in order to be able to make structures that are smaller than 200 nanometres visible with an optical microscope, researchers need individual molecules that are capable of toggling back and forth between a visible on-position and an off-position. These molecules can then be installed like probes in the structures under investigation that are to be made visible. It is to the best advantage if switching between the two states does not occur at random, but can rather be deliberately controlled in the laboratory. Thus, in the

first instance, photochromic molecules seem to represent ideal tools for advancing research in super-resolution imaging. Light-induced switching between two clearly defined, visible states could thereby be exploited at the level of individual molecules, and thus at the smallest possible scale.

Spontaneous blinking or deliberate light-induced switching?

There is, however, one major obstacle to this application. The fluorophores linked to a photochromic molecule which display its change of state have the property of lighting up at random, regardless of the photochromic molecule's state. This phenomenon is referred to in the literature as "stochastic blinking". However, as long as it is completely unclear whether the fluorophores are lighting up at random in this way or due to structural changes in the photochromic molecule, one cannot deliberately turn this molecule on and off. In that case, there would be no benefit for super-resolution optical microscopy compared to the dyes that are normally used.

This is exactly the point at which the research group led by Prof. Dr. Jürgen Köhler and Prof. Dr. Mukundan Thelakkat at the University of Bayreuth has succeeded in taking a significant step forward. The research group carefully investigated both the stochastic blinking of the fluorophores and how they light up due to structural changes in the photochromic molecule. In so doing, the scientists were able to determine that illumination was caused by a "switch" – namely a beam of light on the photochromic molecule – with a probability of 70 - 90%. In a few exceptional cases, the probability can even be as high as 95%. Prof. Köhler is pleased: "This research success was only possible because experimental physicists and polymer chemists work together closely on Bayreuth's campus. This enabled us to jointly develop and synthesize new molecular compounds and test their photophysical

properties in a relatively short amount of time."

The findings that have now been published in *Scientific Reports* were made by the researchers in Bayreuth while investigating a molecular compound of this kind. The compound is a triad of molecules. Its centre contains a photochromic molecule: a molecule of the dithienylcyclopentene (DCP) type, to be precise. Its chemical name is "1,2-bis(2-methyl-5-phenyl-3-thienyl)-perfluorocyclopentene". Hanging on this molecule like a pair of arms are two strongly fluorescent perylene bisimide (PBI) units.

Towards new imaging systems

Not only can individual photochromic molecules now be switched on and off using light, the visible effects thus achieved can also very likely now be identified as such for the first time. This opens up a host of new possible applications in research. "For example, the new triads can provide valuable assistance when it comes to visualizing the structures of complex molecules or even biological systems," explained Prof. Köhler. "The award of the 2014 Nobel Prize in Chemistry to Eric Betzig, William E. Moerner, and Stefan Hell has once again illustrated the international importance of this research area in which physics and chemists cooperate," said the Bayreuth physicist.

More information: Johannes Maier et al. Deliberate Switching of Single Photochromic Triads, *Scientific Reports* (2017). DOI: 10.1038/srep41739

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