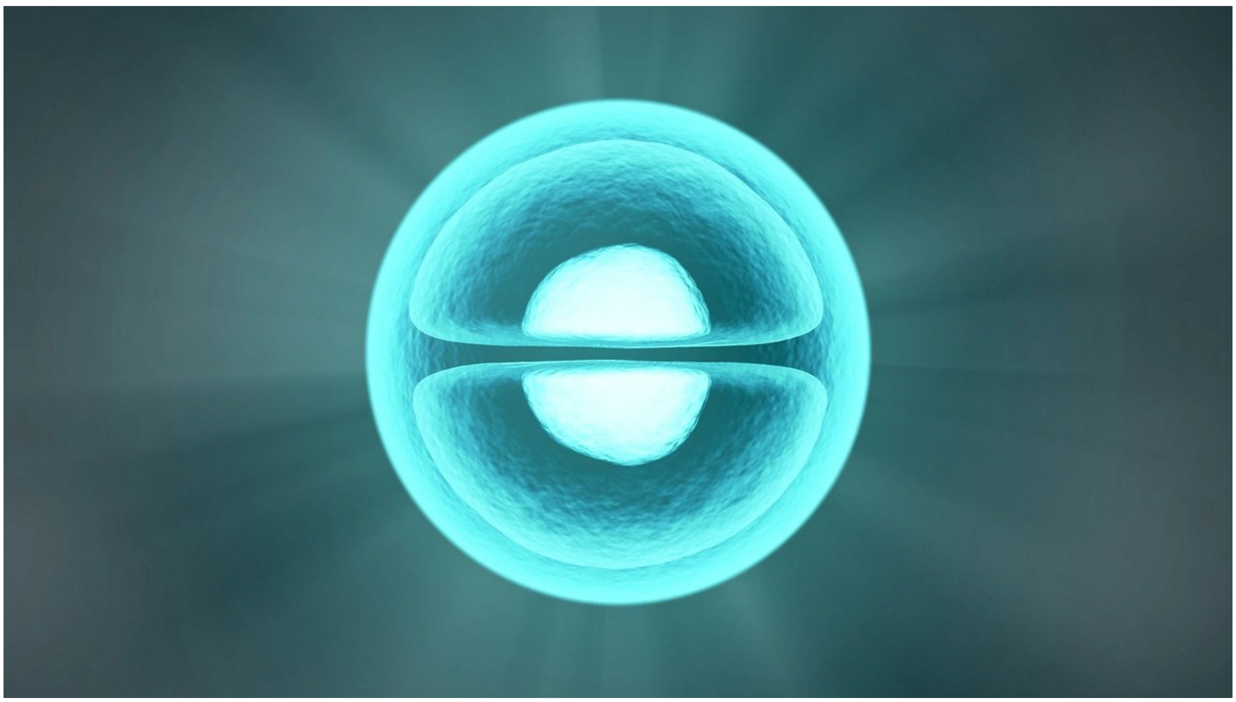
New imaging technology captures movement of quantum particles with unprecedented resolution

February 19 2019



Credit: CC0 Public Domain

Excitons—electrically neutral quasiparticles—have extraordinary properties. They exist only in semiconducting and insulating materials and can be easily accessed in two-dimensional (2D) materials just a few atoms thick, such as carbon and molybdenite. When these 2D materials are combined, they exhibit quantum properties that neither material possesses on its own.

A new Tel Aviv University study explores the generation and propagation of excitons in 2D materials within an unprecedented small time frame and at an extraordinarily high spatial resolution. The research was led by Prof. Haim Suchowski and Dr. Michael Mrejen of TAU's Raymond & Beverly Sackler Faculty of Exact Sciences and published in *Science Advances* on February 1.

Quantum mechanics is a fundamental theory in physics that describes nature at the smallest scales of energy. "Our new imaging technology captures the movement of excitons in a short time frame and at nanometer scale," Dr. Mrejen says. "This tool can be extremely useful for peeking into a material's response at the very first moments light has affected it."

"Such materials can be used to significantly slow down light to manipulate it or even store it, which are highly sought-after capabilities for communications and for photonics-based quantum computers," Prof. Suchowski explains. "From the instrument capability point of view, this tour de force opens up new opportunities to visualize and manipulate the ultrafast response of many other material systems in other spectrum regimes, such as the mid-infrared range in which many molecules are found to vibrate."

The scientists developed a unique spatiotemporal imaging technique at the femtosecond-nanometric scale and observed exciton-polariton dynamics in tungsten diselenide, a semiconductor material, at room temperature.

The exciton-polariton is a quantum creature spawned by the coupling of light and matter. Due to the specific material studied, the speed of propagation measured was about 1% of the speed of light. At this time scale, light manages to travel only several hundred nanometers.

"We knew we had a unique characterization tool and that these 2D materials were good candidates to explore interesting behavior at the ultrafast-ultrasmall intersection," Dr. Mrejen says. "I should add that the material, tungsten diselenide, is extremely interesting from an applications point of view. It sustains such light-matter coupled states in very confined dimensions, down to single atom thickness, at room temperature and in the visible spectral range."

The researchers are now exploring ways of controlling the velocity of semiconductor waves by, for example, combining multiple 2D materials in stacks.

More information: M. Mrejen et al, Transient exciton-polariton dynamics in WSe2 by ultrafast near-field imaging, *Science Advances* (2019). DOI: 10.1126/sciadv.aat9618

Provided by Tel Aviv University