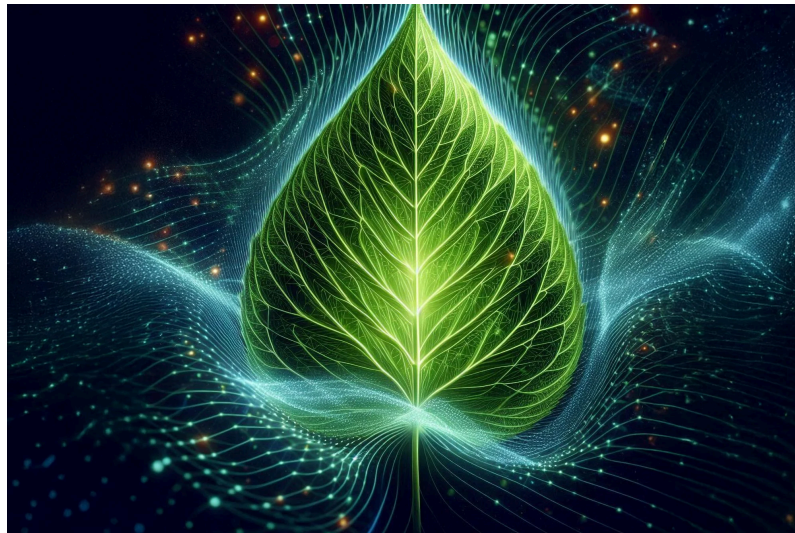


How Quantum Mechanics Powers the Near-Perfect Efficiency of Photosynthesis

Plants harness quantum physics to capture solar energy with near-perfect efficiency.

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Plants harness quantum physics to capture solar energy with near-perfect efficiency. Scientists are now exploring how to apply this to next-gen renewable energy tech. Credit: SciTechDaily.com

Plants harness quantum physics to capture solar energy with near-perfect efficiency. Scientists are now exploring how to apply this to next-gen renewable energy tech.

Photosynthesis, the process plants use to convert sunlight into energy, relies on an incredibly efficient energy transfer system. Before light can be transformed into chemical energy, it must first be captured and transported – a process that happens almost instantly and with minimal energy loss.

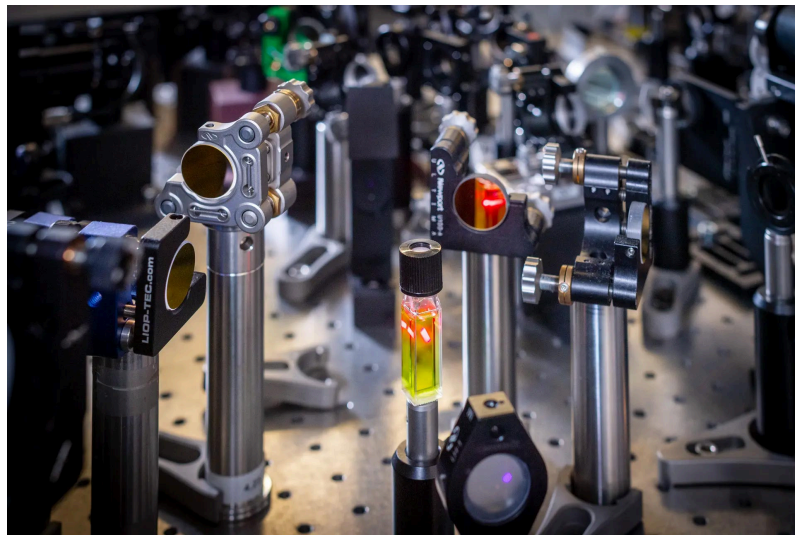
A new study from the Chair of Dynamic Spectroscopy at the Technical University of Munich (TUM) reveals that quantum mechanical effects play a crucial role in this energy transfer. Through precise measurements and simulations, a research team led by Erika Keil and Professor Jürgen Hauer uncovered how these quantum effects contribute to the efficiency of photosynthesis.

Nature's Quantum Secret for Storing Solar Energy

Harnessing solar energy efficiently and storing it as chemical energy has long been a challenge for engineers. However,

nature solved this problem billions of years ago. A new study reveals that quantum mechanics isn't just a concept for physicists — it also plays a crucial role in biological processes.

Green plants and other photosynthetic organisms use quantum mechanics to capture and transfer sunlight with remarkable efficiency. As Professor Jürgen Hauer explains, “When light is absorbed in a leaf, for example, the electronic excitation energy is distributed over several states of each excited chlorophyll molecule; this is called a superposition of excited states. It is the first stage of an almost loss-free energy transfer within and between the molecules and makes the efficient onward transport of solar energy possible. Quantum mechanics is therefore central to understanding the first steps of energy transfer and charge separation.”



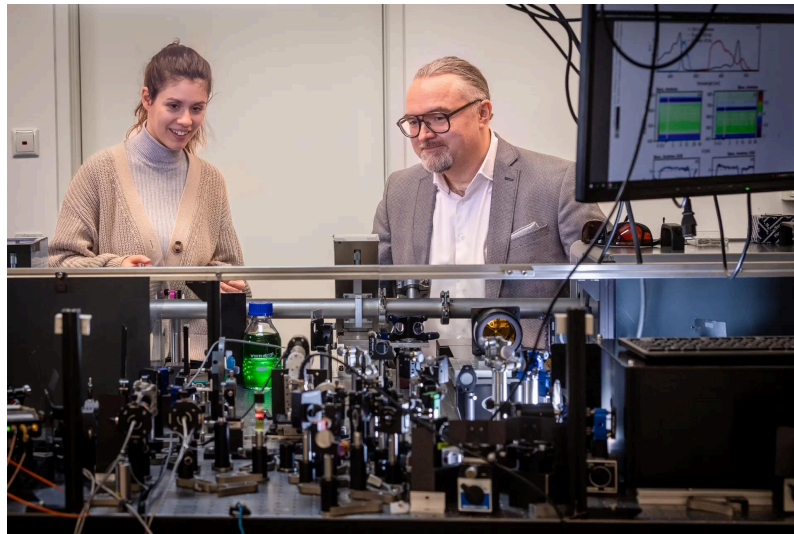
Examination of a sample with plant chlorophyll obtained from frozen spinach.
Credit: Andreas Heddergott / TUM

Unlocking the Mysteries of Chlorophyll's Energy Transfer

This process, which cannot be understood satisfactorily by classical physics alone, occurs constantly in green plants and other photosynthetic organisms, such as photosynthetic bacteria. However, the exact mechanisms have still not been fully elucidated. Hauer and first author Erika Keil see their study as an important new basis in the effort to clarify how chlorophyll, the pigment in leaf green, works.

Applying these findings in the design of artificial photosynthesis units could help to utilize solar energy with

unprecedented efficiency for electricity generation or photochemistry.



First author Erika Keil and Prof. Jürgen Hauer in the lab. Credit: Andreas Heddergott / TUM

The Role of Quantum Coupling in Energy Transport

For the study, the researchers examined two specific sections of the spectrum in which chlorophyll absorbs light: the low-energy Q region (yellow to red spectral range) and the high-energy B region (blue to green). The Q region consists of two different electronic states that are quantum mechanically coupled. This coupling leads to loss-free energy transport in the molecule. The system then relaxes through “cooling,” i.e. by releasing energy in the form of heat. The study shows that quantum mechanical

effects can have a decisive influence on biologically relevant processes.

Reference: “Reassessing the role and lifetime of Q_x in the energy transfer dynamics of chlorophyll a” by Erika Keil, Ajeet Kumar, Lena Bäuml, Sebastian Reiter, Erling Thyraug, Simone Moser, Christopher D. P. Duffy, Regina de Vivie-Riedle and Jürgen Hauer, 27 November 2024, *Chemical Science*.

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