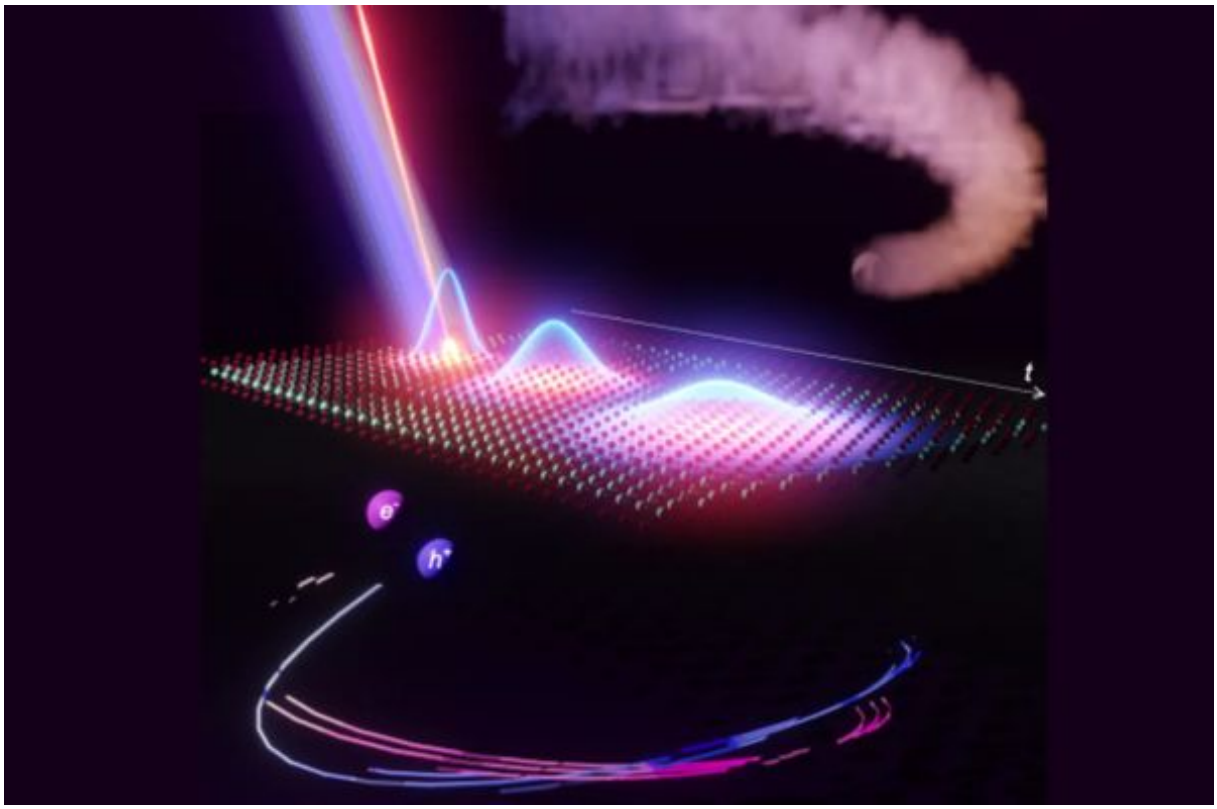

Spatiotemporal Microscopy as a powerful tool for studying transport phenomena

A review recently published in ?**Advanced Electronic Materials**' by researchers from ICN2, ICFO and Vrije University discusses spatiotemporal microscopy as a promising and versatile technique for observing and controlling transport phenomena. It presents the advantages of this technique over conventional ones, showcasing recent discoveries in particle and heat transport, describes its experimental implementations, and offers insights into potential future applications.

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Understanding transport phenomena -processes originating from the spontaneous or force-induced movement of mass, charge, or heat- is fundamental for research on materials and their adaptation to specific applications. The study and control of transport phenomena enables scientists to observe complex processes occurring in matter and potentially learn

how to steer and exploit them.

Some conventional techniques used to study charge or heat transport require physical contacts (to apply stimuli and/or read out responses), which can lead to unwanted effects. Additionally, they do not always facilitate distinguishing between different species of particles or carriers. In contrast, optical techniques do not require electronic contacts and allow researchers to focus on specific species of interest, thanks to wavelength selectivity. Among these techniques, **spatiotemporal microscopy (SPTM)** is emerging as a particularly promising method to **study transport phenomena by visualizing the spatial diffusion or translation of the species under observation as a function of time**.

Dr. Guillermo Brinatti-Vazquez and **Giulia Lo Gerfo Morganti** from the **Institute of Photonic Sciences** (ICFO, Spain), in collaboration with researchers from the Catalan Institute of Nanoscience and Nanotechnology (ICN2, Spain) and Vrije University of Amsterdam (VU, The Netherlands), are the first authors of a review on spatiotemporal microscopy recently published in Advanced Electronic Materials. The essay discusses **its experimental implementations and some applications**, giving examples of interesting physical phenomena discovered thanks to this technique.

Intended as an overview of the topic, the paper describes the principles of time-resolved optical measurements and the advantage of observing both the time and the spatial evolution of the studied system. The cases of transport governed by particles or quasi-particles and of electronic or phononic heat are considered.

Different experimental implementations of SPTM -namely, time-correlated microscopy, widefield imaging, point scanning, and grating-based techniques-are discussed, highlighting scenarios where one may be preferable over the others. After providing a brief summary of transport theory, the authors proceed to present recent discoveries related to particle transport made possible by spatiotemporal studies, both in the case of particle and of heat transport. Indeed, this technique offers **remarkable advantages in terms of time scale, down to femtoseconds, and length scales, down to nanometres**.

Finally, an outlook on **emerging and future applications or extensions** of this technique is provided. The authors suggest that photocurrent based SPMT will play a crucial role in connecting transport dynamics with device functionality and performance. Broad-band and multidimensional SPTM are also promising, as they would allow the separation of transport contributions of different species. Further developments are required to enable the use of this technique to resolve nanometric structures near interfaces or in other situations in which diffraction phenomena can hinder its performance. Another exciting direction of evolution is the replacement of optical beams by electron beams, which would lead to a very high spatial resolution.

The review aims to be a reference introduction to spatiotemporal microscopy for the study of transport phenomena in different contexts and to provide guidelines for scientists interested in including SPTM in their research i¿½toolboxi?

ICFO

Bibliographic reference

Guillermo D. Brinatti Vazquez, Giulia Lo Gerfo Morganti, Alexander Block, Niek F. van Hulst, Matz Liebel, Klaas-Jan Tielrooij, **Spatiotemporal Microscopy: Shining Light on Transport Phenomena.** Advanced Electronic Materials, 2023. DOI: https://doi.org/10.1002/aelm.202300584