Visualizing energy transport in nanostructured semiconductors.

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Nanostructured semiconductors are playing an increasingly dominant role in next-generation photovoltaic (PV) technologies. Unlike conventional bulk crystalline semiconductors (e.g. silicon), nanostructured semiconductors benefit from dramatically reduced process temperatures, enabling the use of light-weight substrates, roll-to-roll fabrication, and flexible integration. At the same time though, the low process temperatures increases the complexity of the material, with small imperfections introduced during the processing leading to disorder that affects the energy transport characteristics.

Traditional techniques to characterize energy transport rely on bulk measurements. While such techniques work well for the characterization of the spatially homogeneous lattices of crystalline semiconductors, they fail to capture the spatially varying complexity of nanostructured semiconductors. To tackle this issue, Transient Microscopy techniques have emerged in recent years, capable of *directly visualizing the energy transport with sub-nanosecond and few nanometer resolution*. These measurements have revealed important new insights into the spatial dynamics of the optical excited state. This information is crucial for the optimization of next-generation photovoltaic technologies.

Importantly though, previous work by our group and others have shown that energy transport in nanostructured semiconductors is dominated by inhomogeneities in the energy landscape of the material. However, none of the current implementations of transient microscopy can directly address this disorder. *In this project, you will take the crucial step of developing the first Hyperspectral Transient Microscope* – a technique capable of simultaneously measuring transport in space, time, and energy. During this project, you will learn key aspects of microscope design, laser microscopy, measurement automation (using Python), and data analysis. Aside from this broad training in state-of-the-art microscopy, careful attention will be given to strengthening of communication skills. You will be part of a young international team, working on a variety of topics in nanophotonics.

For more information on the work we do and our past work in transient microscopy, please visit our website (www.ferryprinslab.com) or reach out by email (ferry.prins@uam.es).

Key references:

1) *Exciton diffusion in two-dimensional metal-halide perovskites.* M. Seitz, A. J. Magdaleno, N. Alcazar-Cano, M. Melendez, T. J. Lubbers, S. W.Walraven, S. Pakdel, E. Prada, R. Delgado-Buscalioni, F. Prins, **Nature Communications**, 2020, 11, 2035
2) *Efficient interlayer exciton transport in two-dimensional halide perovskites.* A. J. Magdaleno, M. Seitz, M. Frising, A. Herranz de la Cruz, A. I. Fernandez-Dominguez, F. Prins, **Materials Horizons**, 2021, 8, 639
3) *Mapping the Trap-State Landscape in 2D Metal-Halide Perovskites using Transient Photoluminescence Microscopy*, M. Seitz, M. Meléndez, N. Alcázar-Cano, D. N. Congreve, R. Delgado-Buscalioni, F. Prins **Advanced Optical Materials,** 2021, 2001875