Department of Physics
Condensed Matter Physics
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UNIVERSITY OF OXFORD

CONDENSED MATTER SPECIAL SEMINAR

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"Device-based probes of exciton transport in organic semiconductors"

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Organic semiconductors are conjugated molecular materials whose facile thin film processing and tunable optoelectronic properties have made them of interest for applications in light-emission, detection, and solar photoconversion. In addition, devices made from organic semiconductors can be integrated with a broad range of substrates allowing them to be mechanically flexible, enabling novel form and functionality. In contrast to conventional inorganic semiconductors, the excited state in these materials is a tightly-bound electron-hole pair termed an exciton. In organic semiconductor devices, exciton migration and recombination strongly dictate device design and performance. In an organic photovoltaic cell (OPV), excitons must be efficiently transported to a dissociating heterojunction in order to realize efficient photocurrent generation. In the simplest OPVs, performance is limited by an unfavorable trade-off between a short exciton diffusion length (LD) and the optical absorption length. Consequently, state-of-the-art devices rely on a morphology-optimized mixture of the active materials to reduce the distance an exciton must migrate. Frequently, fluorescence quenching methods are used to experimentally probe LD for potential active materials. Unfortunately, many promising active materials are non-luminescent, or rely on the formation of non-radiative spin-triplet excited states. These systems are not amenable to fluorescence-based methods and hence, values of LD are less frequently reported. While photocurrent spectroscopy can be used to probe optically dark states, such methods often require assumptions to be made about unknown charge carrier recombination losses.

In the talk, a straightforward, device-based measurement technique is demonstrated that is capable of yielding the intrinsic material LD despite the presence of unknown recombination losses. The method is first applied to extract LD for luminescent materials to demonstrate agreement with conventional fluorescence-based measurements. A series of dark small molecule and polymer semiconductors are also considered. With confidence in the ability to extract LD for dark states, we characterize several systems exhibiting singlet fission, where in some cases both singlets and dark triplets may contribute to photoconversion. The broad usefulness of the method is further demonstrated by also extracting LD for a thin film of CdSe quantum dots. Finally, we find that knowledge of the materials-relevant LD permits a deeper understanding of device performance, here applied to reveal an exciton relaxation bottleneck in OPVs containing the archetypical electron acceptor C60.

Host: Dr Moritz Riede
Audrey Wood Room, Clarendon Laboratory