Solid-state organic/nanocrystal films for infrared↔visible photon conversion via excitonics

The ability to efficiently interconvert low-intensity light between the visible and infrared would be an enabling technology—particularly for applications such as 3rd-generation photovoltaics, biological imaging, and cost-effective cameras in the short-wave infrared (SWIR; λ:1–3µm). Here, we present a novel approach using multi-excitonic interactions in nanostructured materials that could enhance existing silicon-based detectors. Specifically, we show that two excitonic materials—organic semi-conductors and colloidal nanocrystals—can be combined to create passive thin-film devices that achieve broadband, non-coherent down- or up-conversion between the SWIR and the visible.

To achieve upconversion, we synthetically tune the bandgap of PbS nanocrystals to absorb SWIR photons (λ>1 µm), and funnel these excitations to an organic semiconductor (rubrene). Here, their energy is combined to create visible light. We achieve an upconversion efficiency of 1.2±0.2% with λ=808 nm excitation at 12 W/cm². Further, we show that there is no fundamental barrier to efficient performance at a thousandth of this excitation intensity (less than natural sunlight!)

Our hybrid approach to achieve non-coherent upconversion may prove broadly applicable in solar and SWIR-detection applications, where effective molecular phosphors are lacking—indeed, quantum dots are ideal SWIR sensitizers, as their excitons are functionally spin-mixed at room temperature, and both their optical gap and ionization energy can be tuned via colloidal synthesis.