

Pushing the limits on renewable energy technology through hybrid organic/inorganic nanomaterials.

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Organic Chromophores



Fig 1: Organic chromophores

Inorganic Chromophores

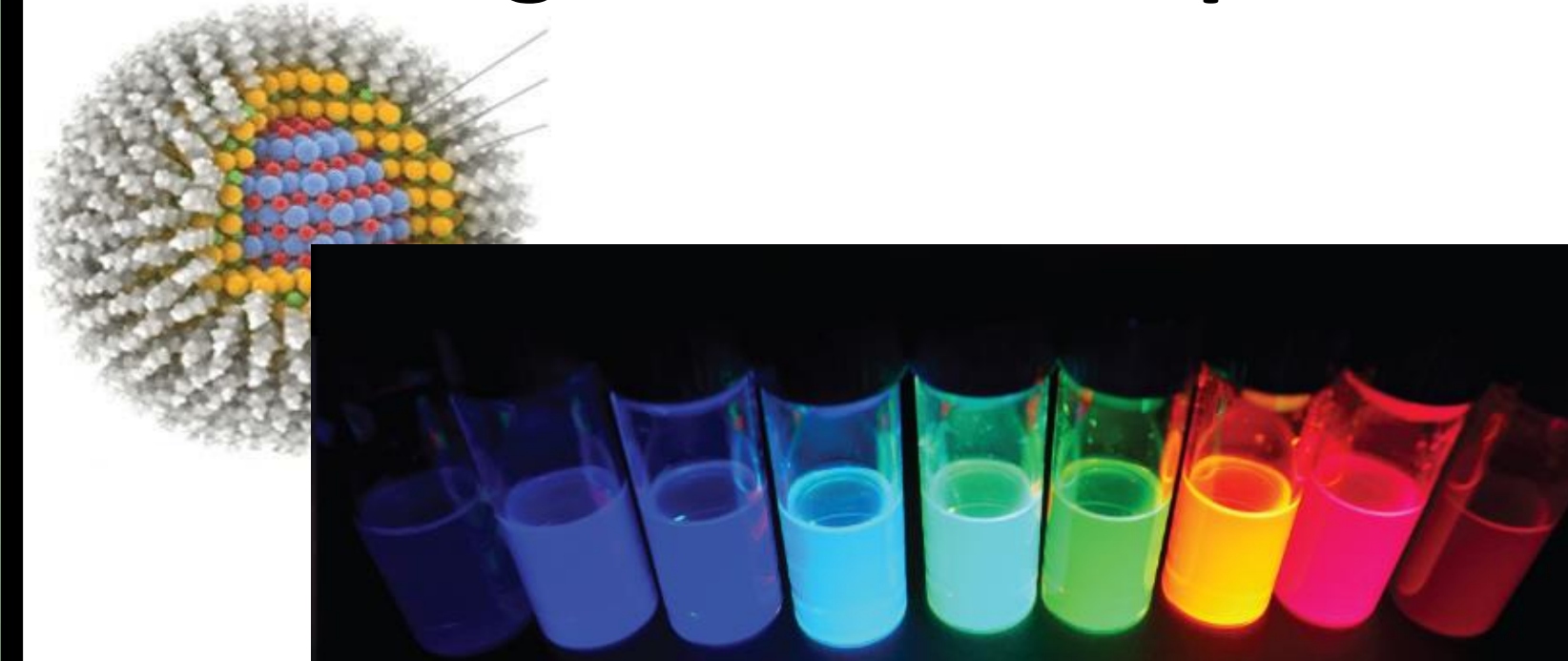


Fig 2: CsPbX (X= Cl, Br and I) nanocrystals

Hybrid Chromophores

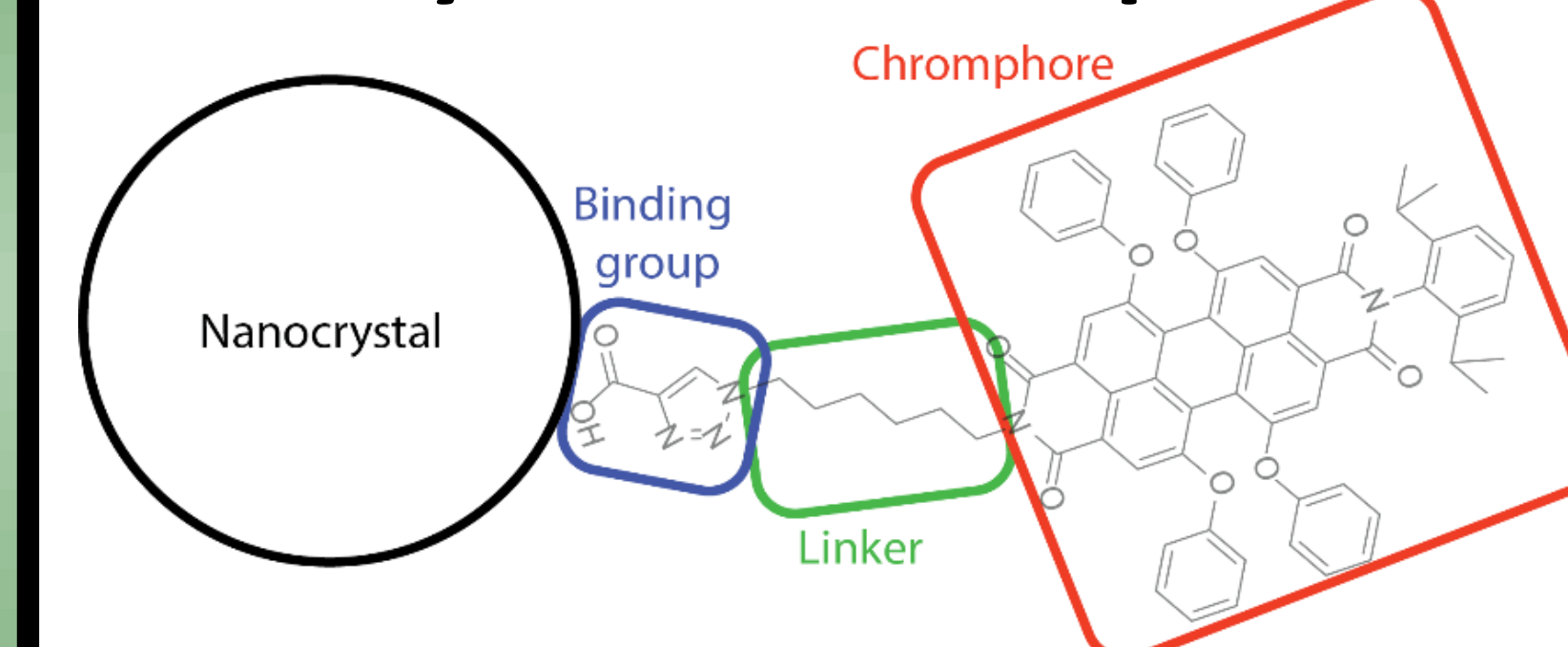


Fig 3: Proposed hybrid materials

Introduction

The field of hybrid nanomaterials is in its infancy, but their biphasic nature and properties beyond the sum of the individual components (Fig 1. and 2.) is causing a rapid expansion in the field. By replacing the ligands on a nanocrystal that offer colloidal stability with ones that add additional optoelectronic properties (Fig 3.) we can create a new generation of hybrid nanomaterial systems for a variety of optoelectronic applications, such as photovoltaics, photocatalysis and lasers.

Reduced reabsorption in solar concentrators

Luminescent solar concentrators (LSCs) consist of a transparent waveguide doped with luminescent chromophores (Fig 4.).

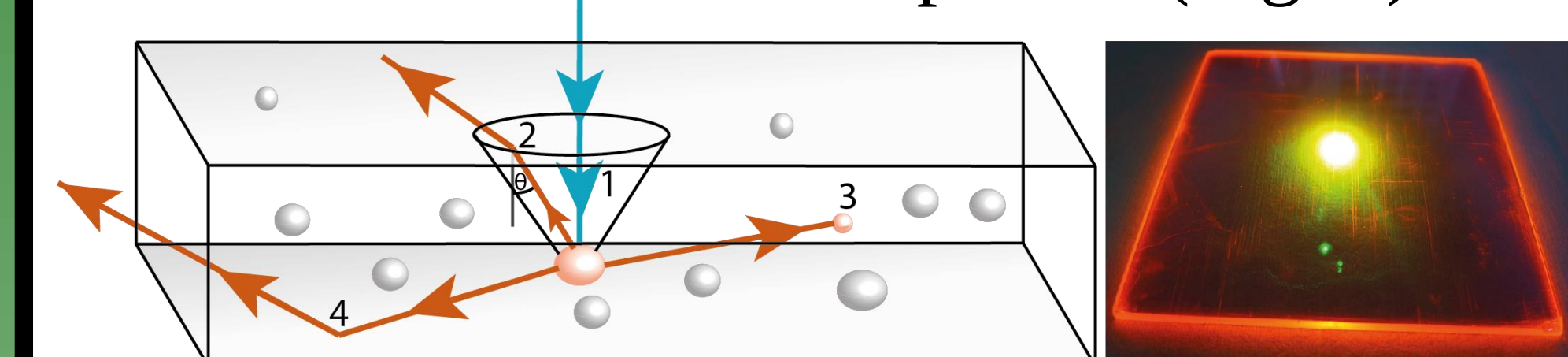


Fig 4: LSC showing operation and edge emission

LSC commercialisation has been limited by reabsorption due to overlap between absorption and emission spectra (Fig 5.).

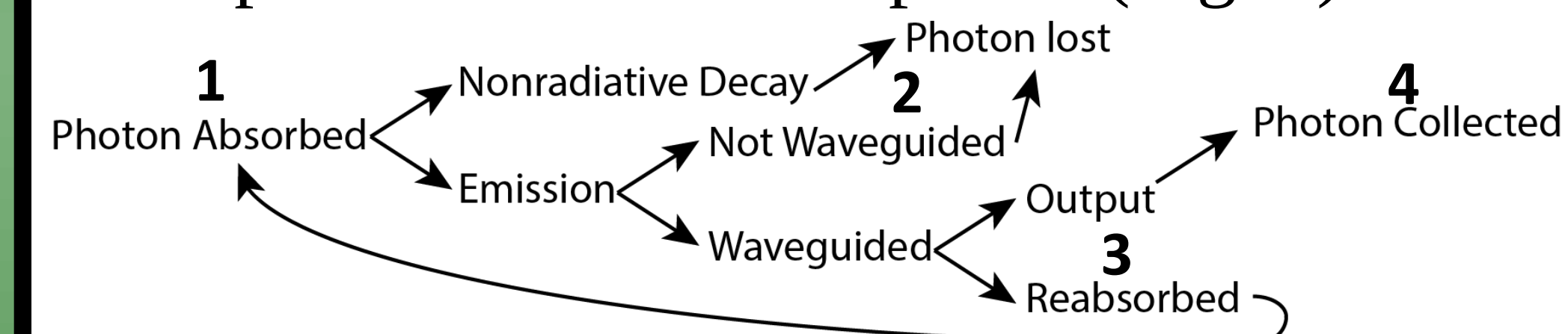


Fig 5: Flow diagram of photon processes

Reabsorption can be reduced by separating the absorbing and emitting chromophores (Fig 6).

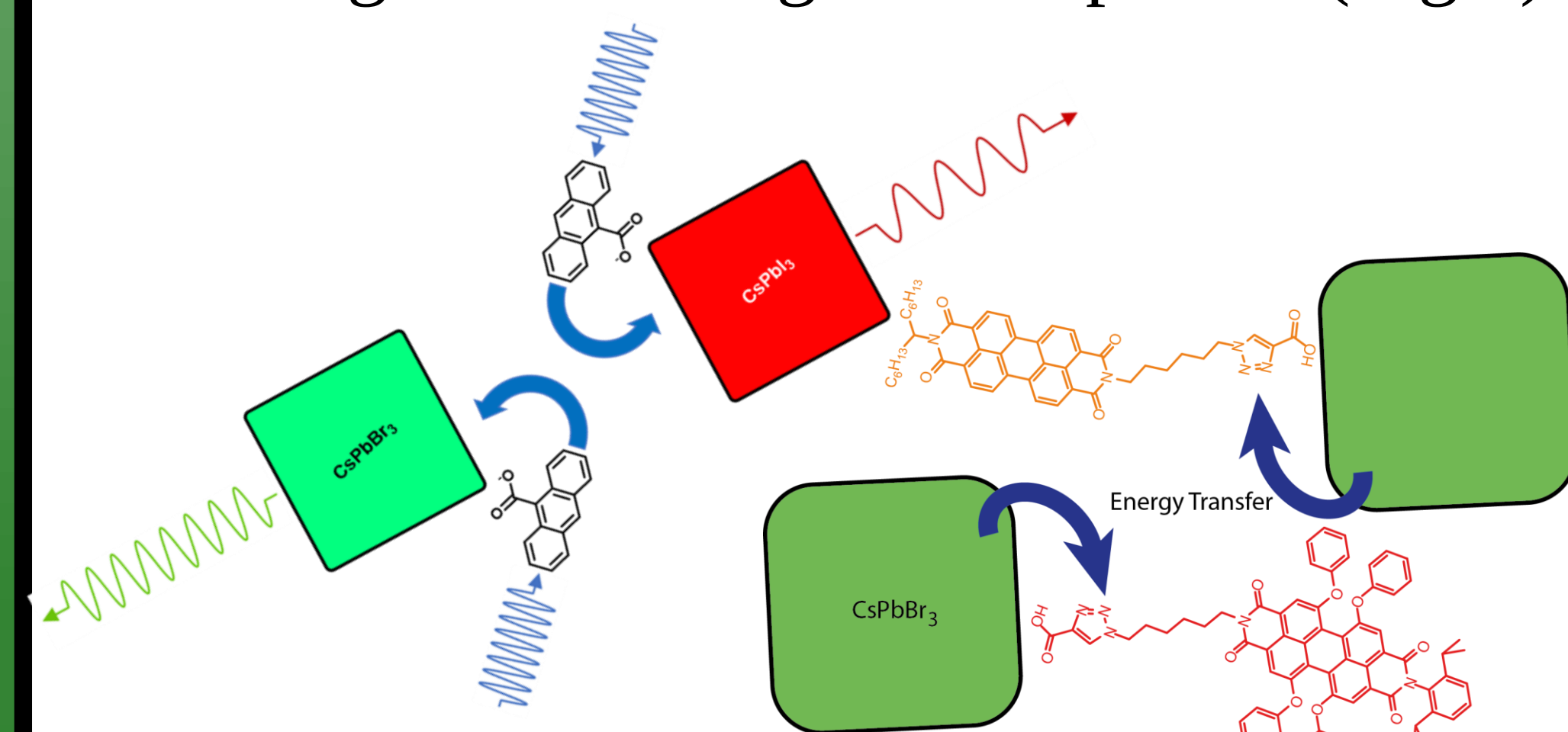


Fig 6: Reabsorption reducing hybrid materials

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Upconversion for water splitting

The photocatalysis of water requires two photons with a wavelength shorter than ≈ 500 nm (Fig 7.). Upconversion (UC) via Triplet-triplet annihilation (TTA) is a process where two absorbed low-energy photons can result in the emission of one high-energy photon (Fig 8.). As such, the lower-energy part of the solar spectrum can be converted to higher-energy, photons.

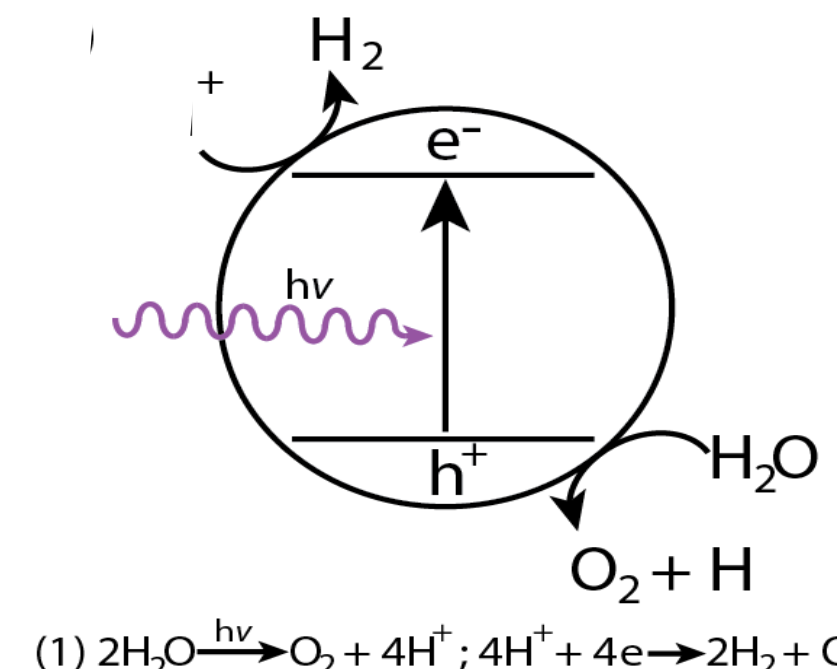


Fig 7: Photocatalysis of water

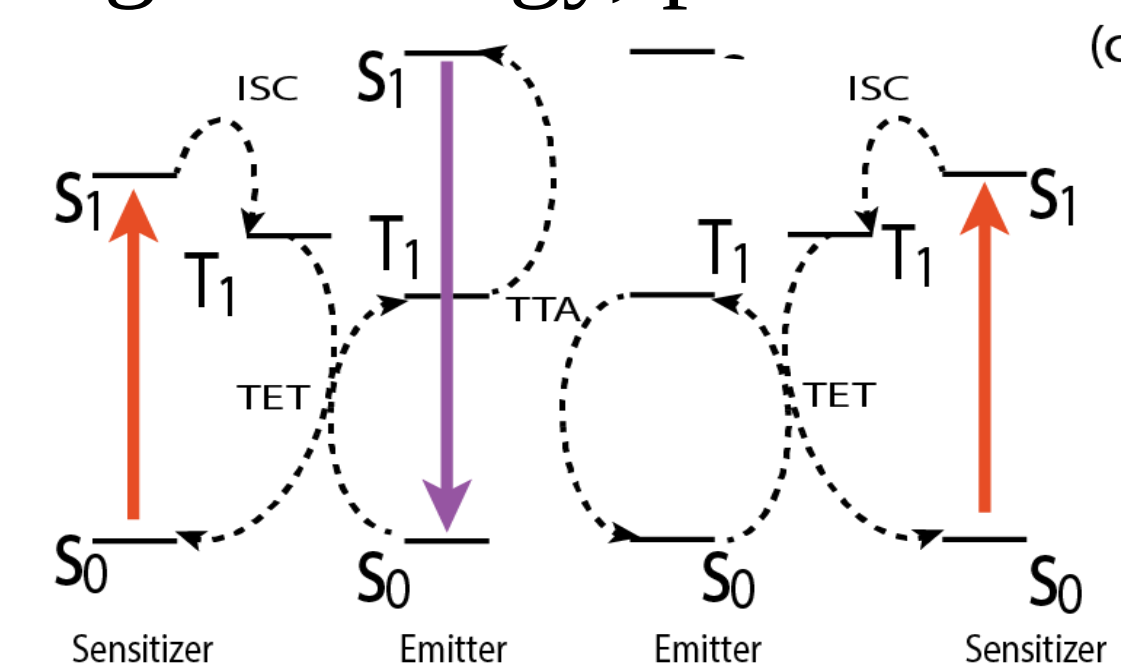


Fig 8: Upconversion via TTA

Nanocrystal/sensitizer hybrids can result in highly efficient UC under solar light intensities (Fig 9. and 10.).

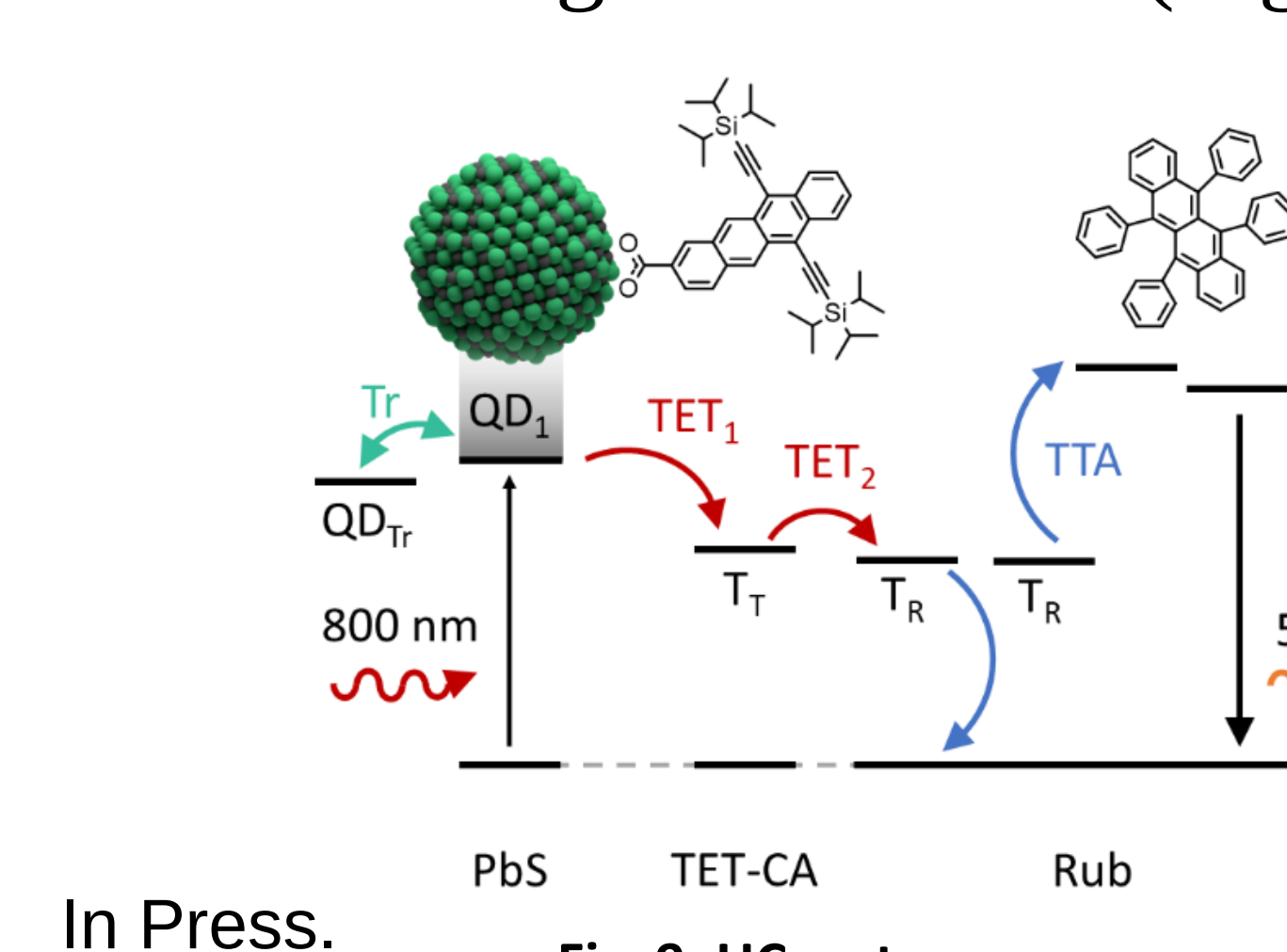


Fig 9: UC system

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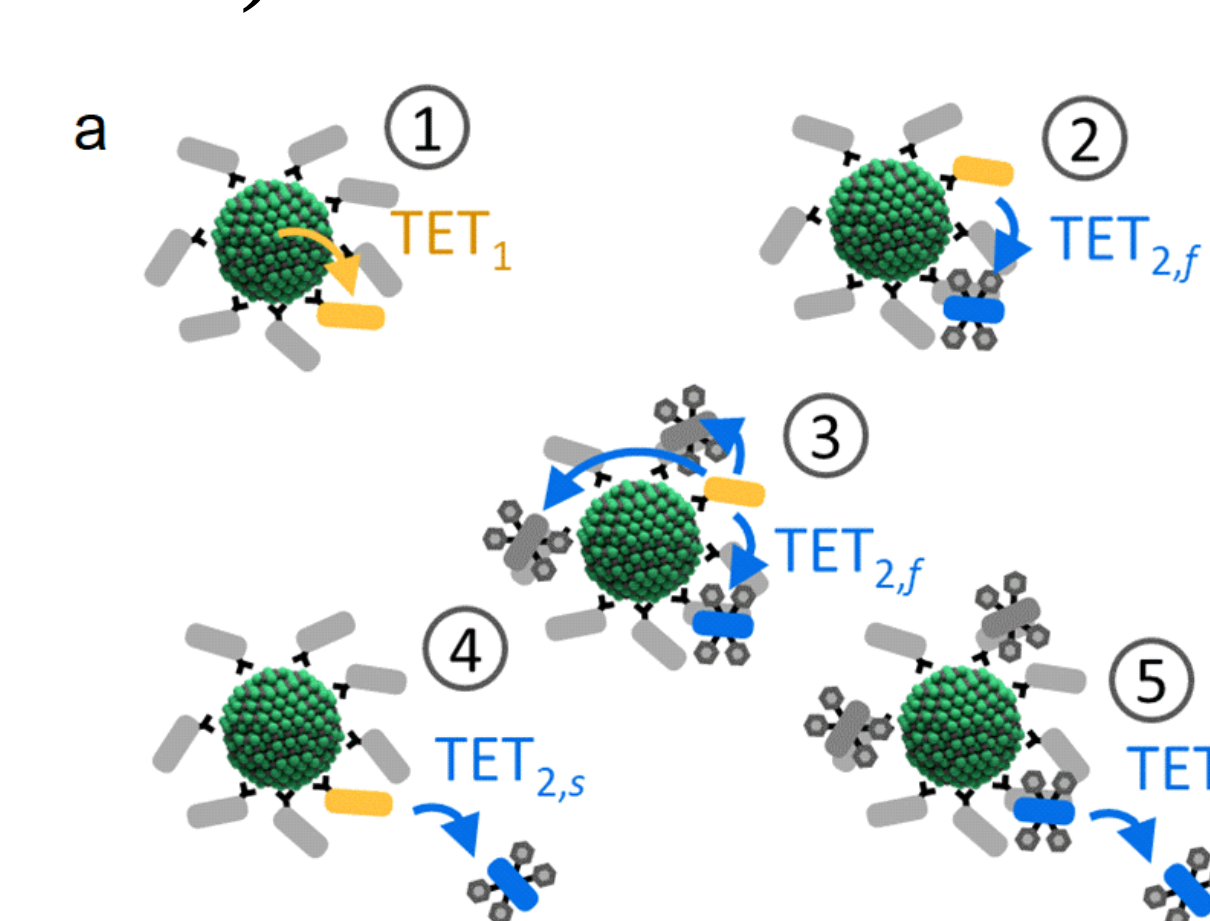


Fig 10: Diagram of UC process

Low-threshold lasers

Lasing occurs when a molecule's emission is dominated by stimulated emission rather than by spontaneous emission. This requires more molecules to be in the excited state compared to the ground state. As such, lasing is excitation dependent. By creating molecular scaffolds (Fig 11 and 12.) that funnel excitations into a single unit, we can reduce the excitation threshold required for lasers (Fig 13.).

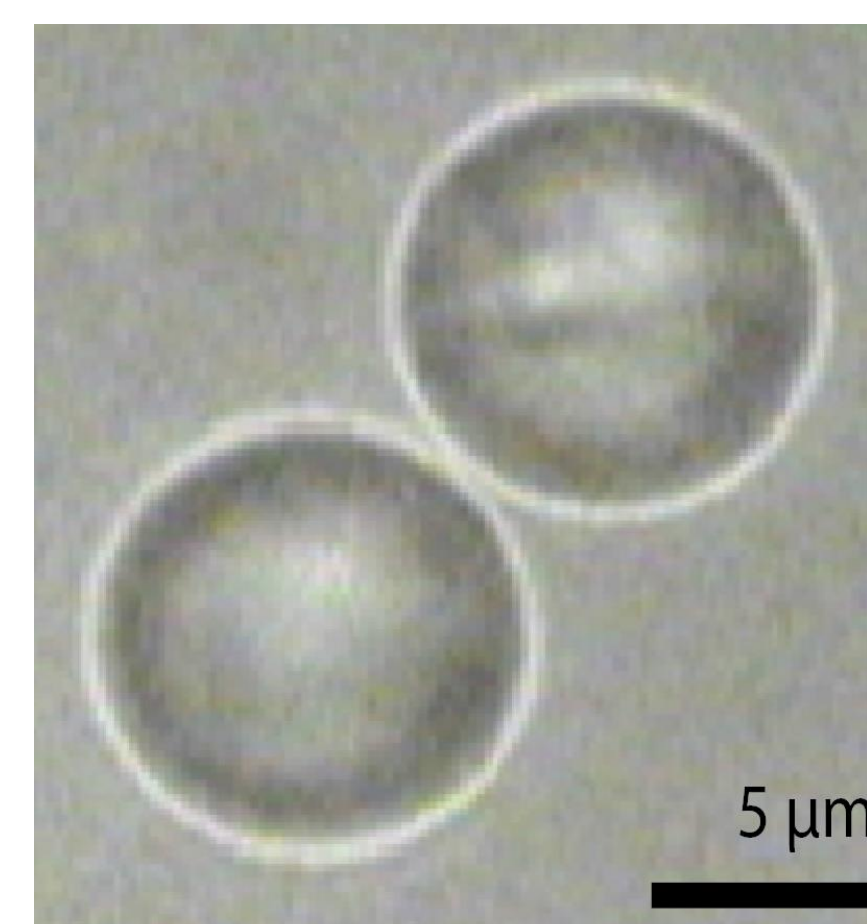
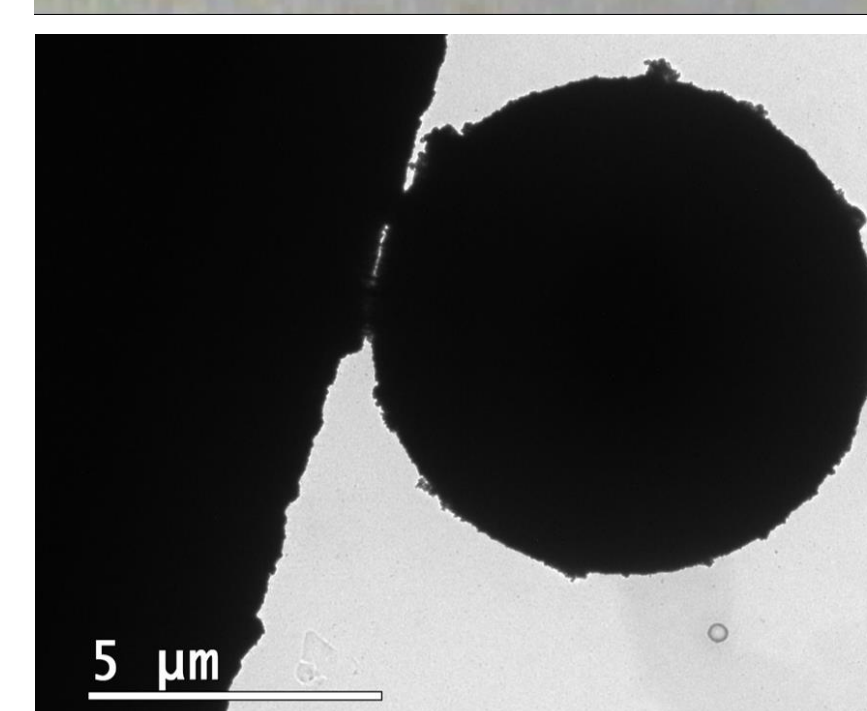
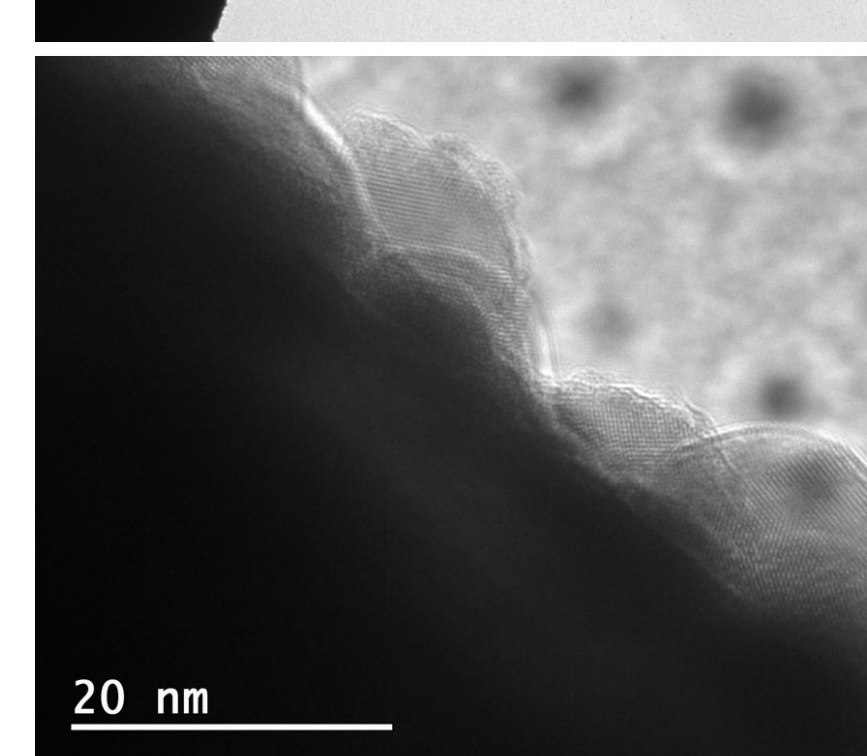


Fig 11: SiO₂ Microsphere lasers

J. Phys. Chem. Lett., 11 (17), 7009-7014, 2020.

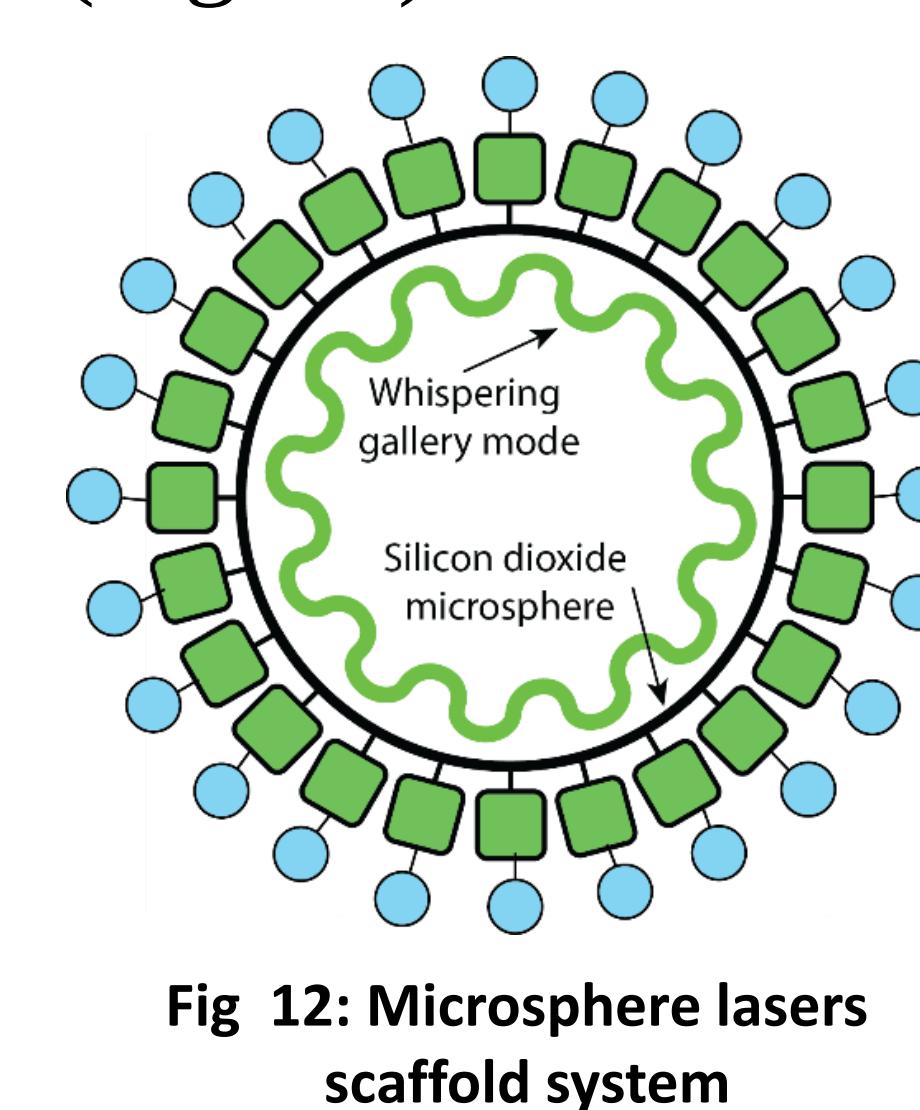


Fig 12: Microsphere lasers scaffold system

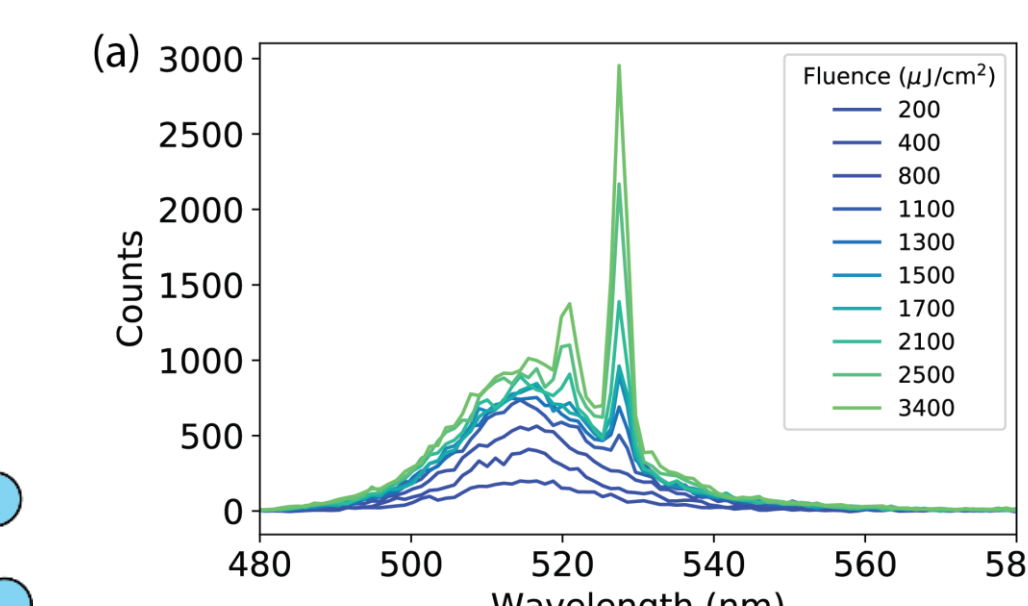
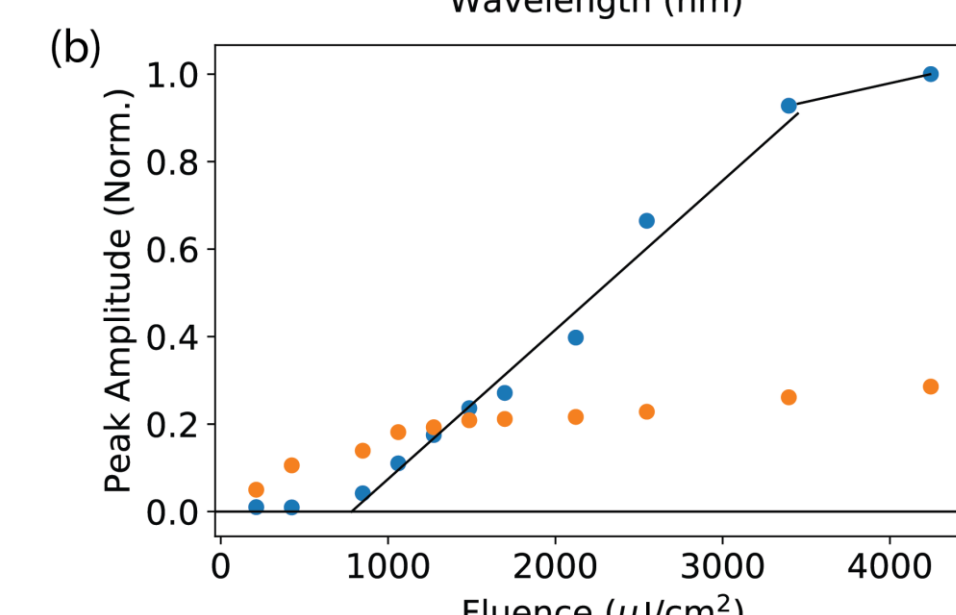


Fig 13: Laser fluence dependence

Singlet fission for solar cells

Solar cells suffer from energetic losses due to photons having too little or too much energy (Fig 14.). Singlet fission is an excitation multiplication process in organic molecules, where the initially photogenerated singlet exciton breaks up to form two triplets (Fig 15.).

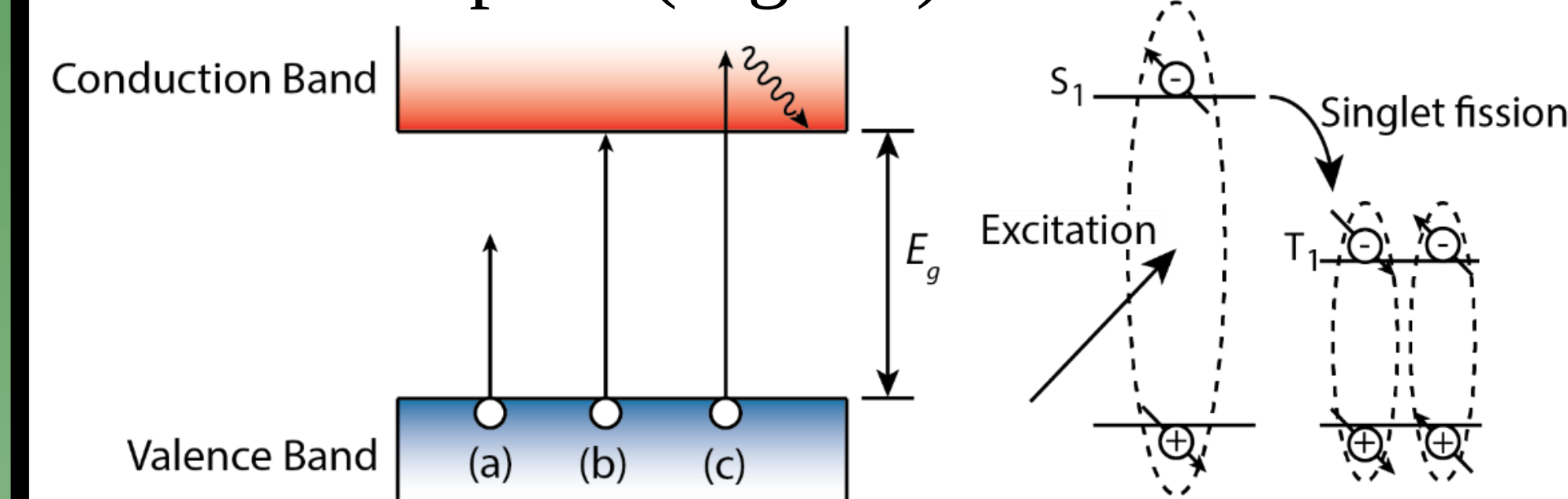


Fig 14: Solar cell bandgap-photon interactions

Fig 15: Singlet fission

These triplets can be transferred to a nanocrystal in hybrid nanomaterials and emitted as photons (Fig 16.).

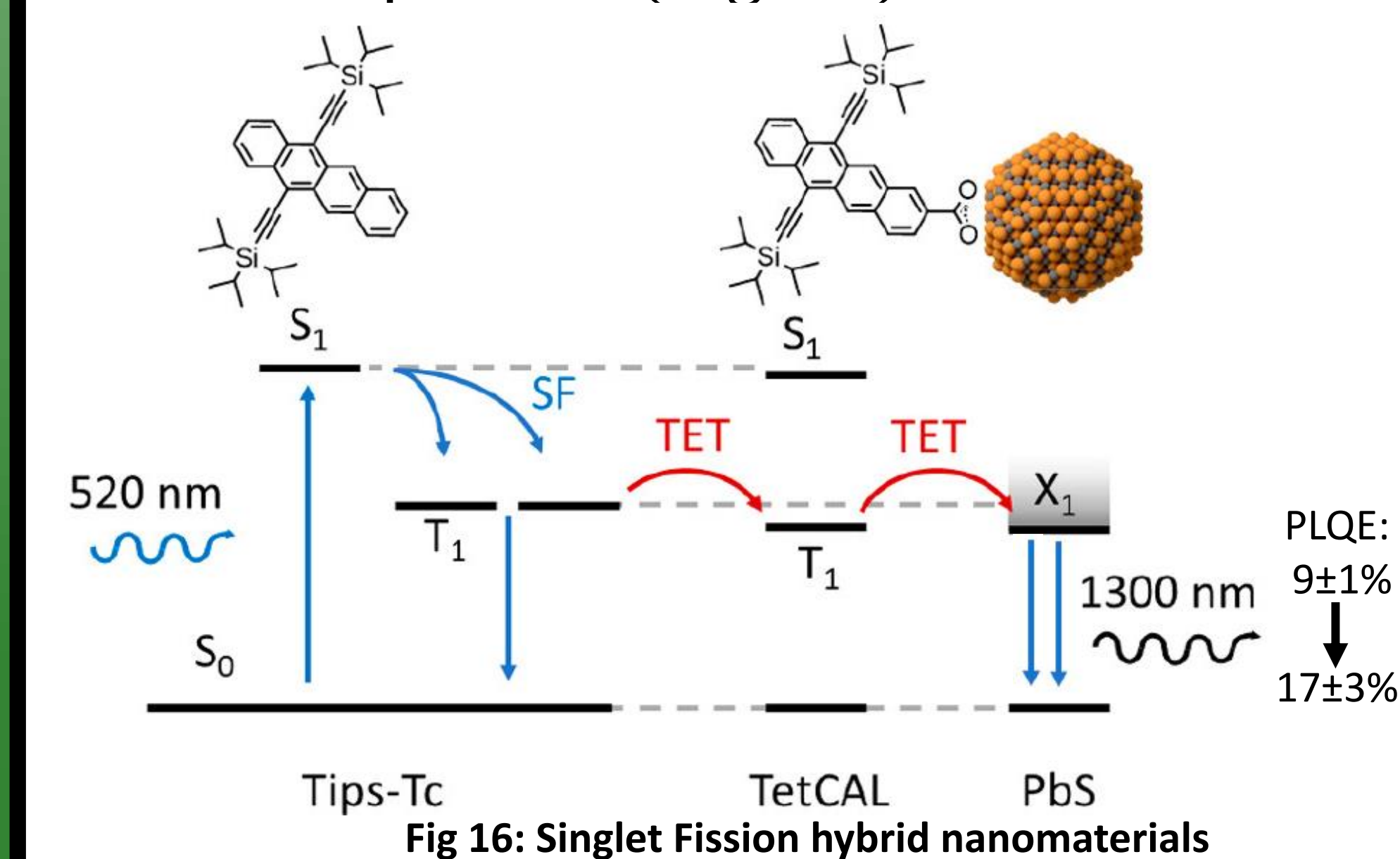
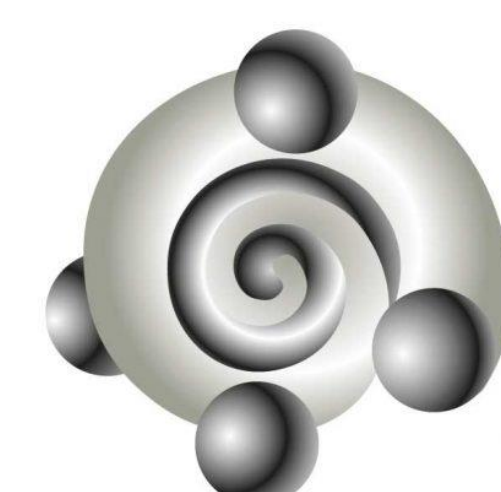


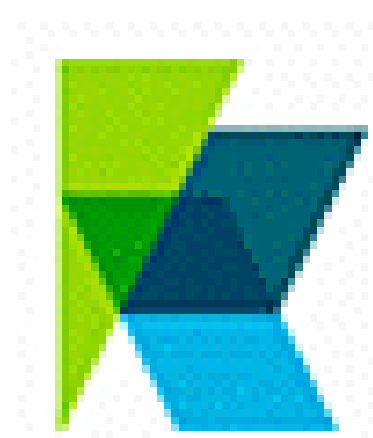
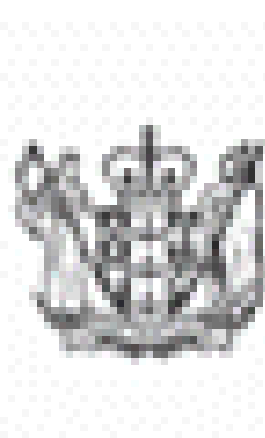
Fig 16: Singlet Fission hybrid nanomaterials

J. Phys. Chem. Lett. 9, 6, 1454-1460 2018.

J. Am. Chem. Soc., 141, 32, 12907-12915, 2019.



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