Development of light harvesting structures for photovoltaics

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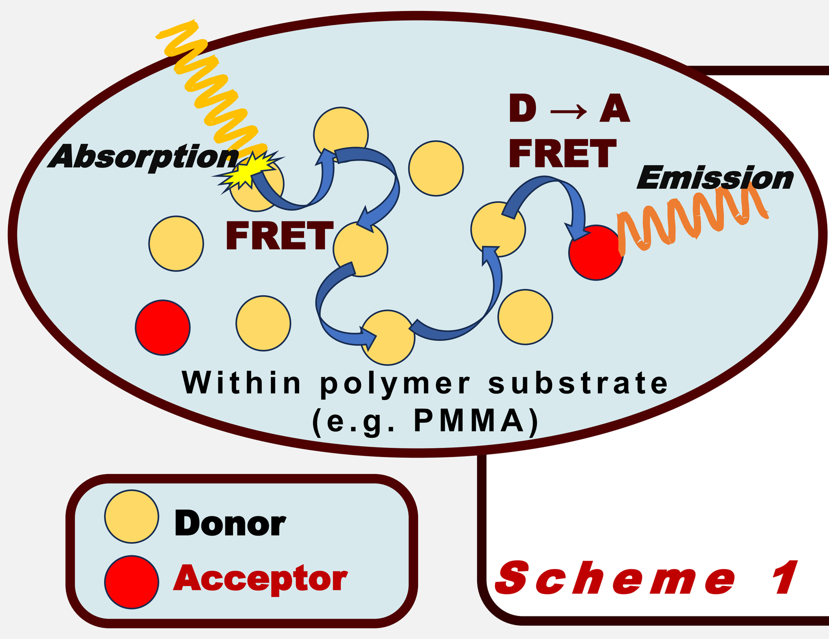
Introduction and theory

- **Förster resonance energy transfer** (FRET) can promote luminescence downshifting and **spectral management**.
- By arranging a many-to-1 donor : acceptor dye ratio, light may be spectrally managed as a **light harvesting structure**.
- **Luminescent dyes** may be freely dispersed, or structured via covalent bonding *(scheme 1 & 2)*.
- Use **steady-state** emission, **time resolved** (TR) fluorescence decays and **fluorescence lifetime microscopy** (FLIM), to **quantify energy-transfer efficiency** (ETE).

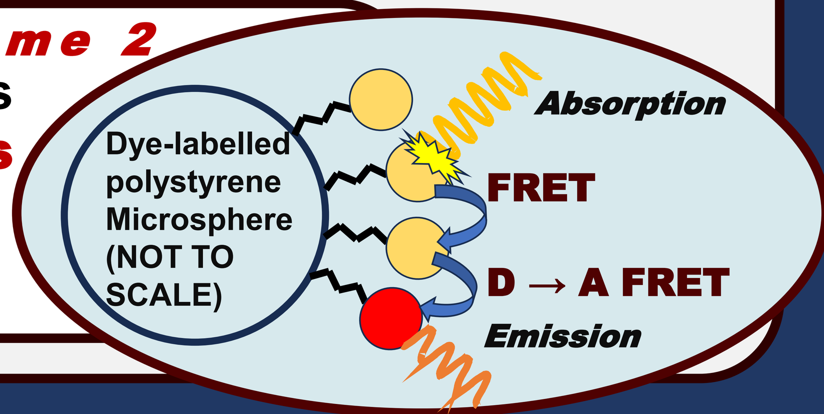


Many : 1 donor : acceptor spectral conversion can occur for 3D **homogeneous distributions** in polymer thin films

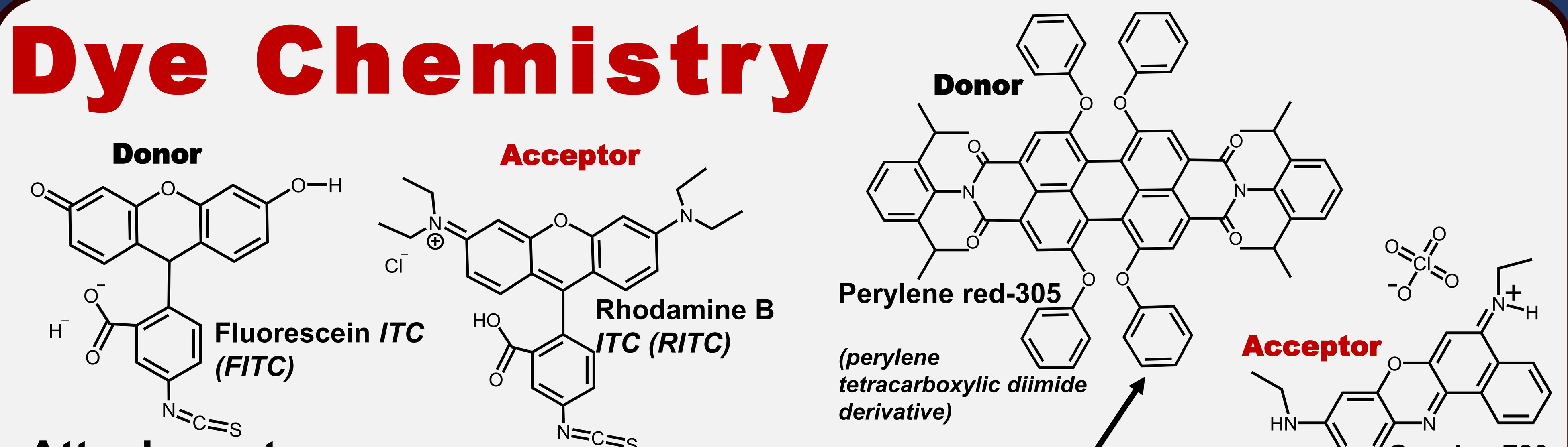
Scheme 1

Scheme 2

...or confined to 2D surfaces of **polymer microspheres** via covalent bonding *(See images in **figure 3**)*



Dye Chemistry



Attachment group
Isothiocyanate (amine-reactive)

Steric groups
Prevent aggregation

Dye-polymer thin films

- Spincoat with PMMA in toluene.

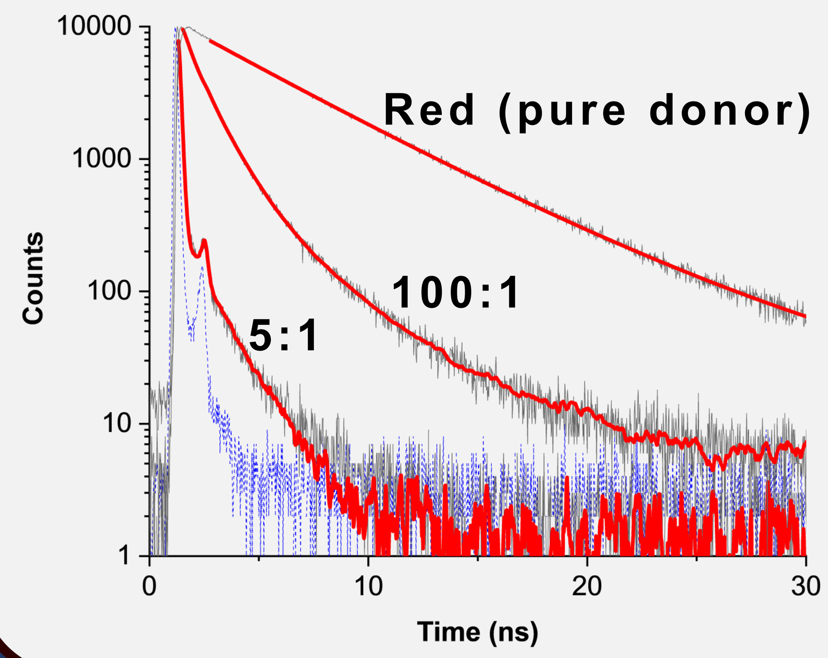


Figure 1: *Spincoated thin-film, red-305 (donor)*

Figure 2: *Time-resolved fluorescence decays of thin-film red:oxazine samples.*

Dye-microspheres

- Covalent attachment of dyes to polystyrene 1 µm aliphatic-amine microspheres using thiourea linkers
- **Suspend dye-spheres** in PVA and take FLIM images.

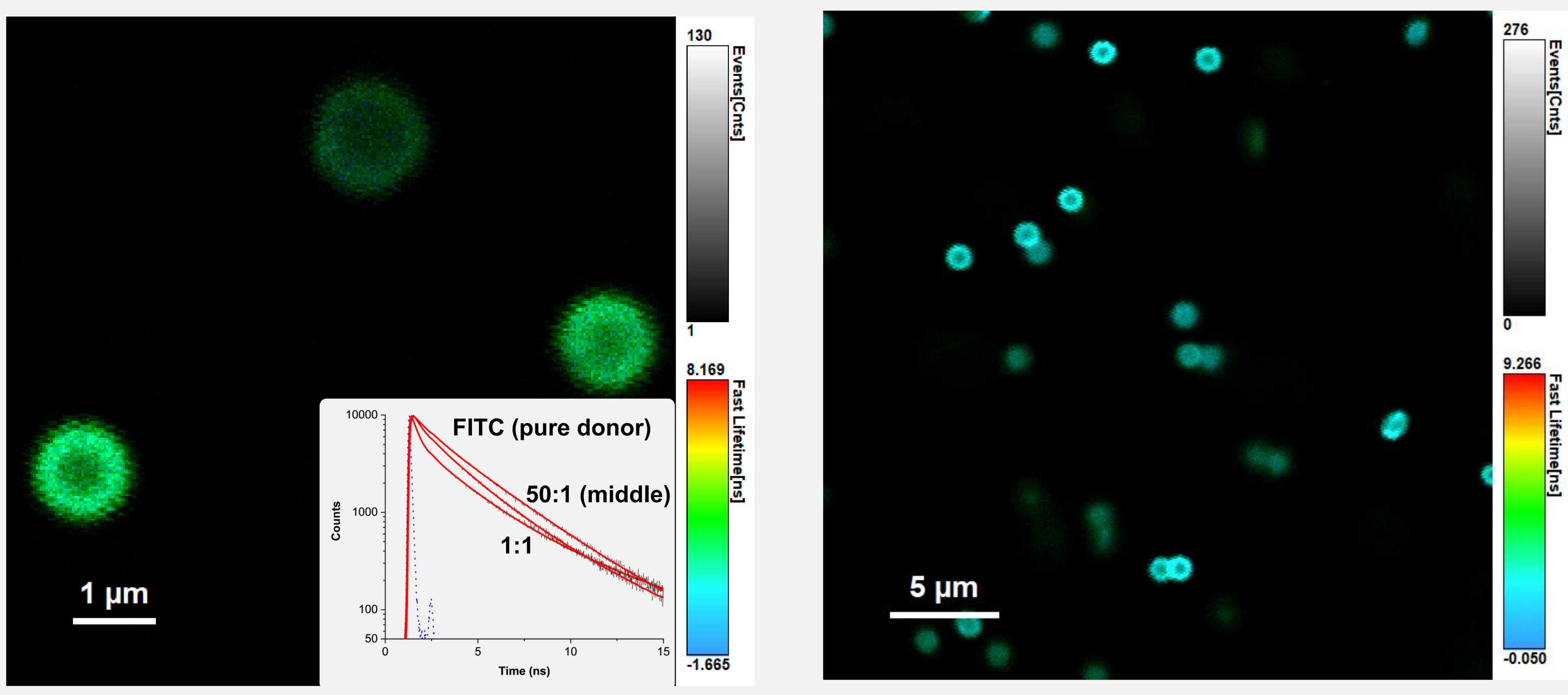
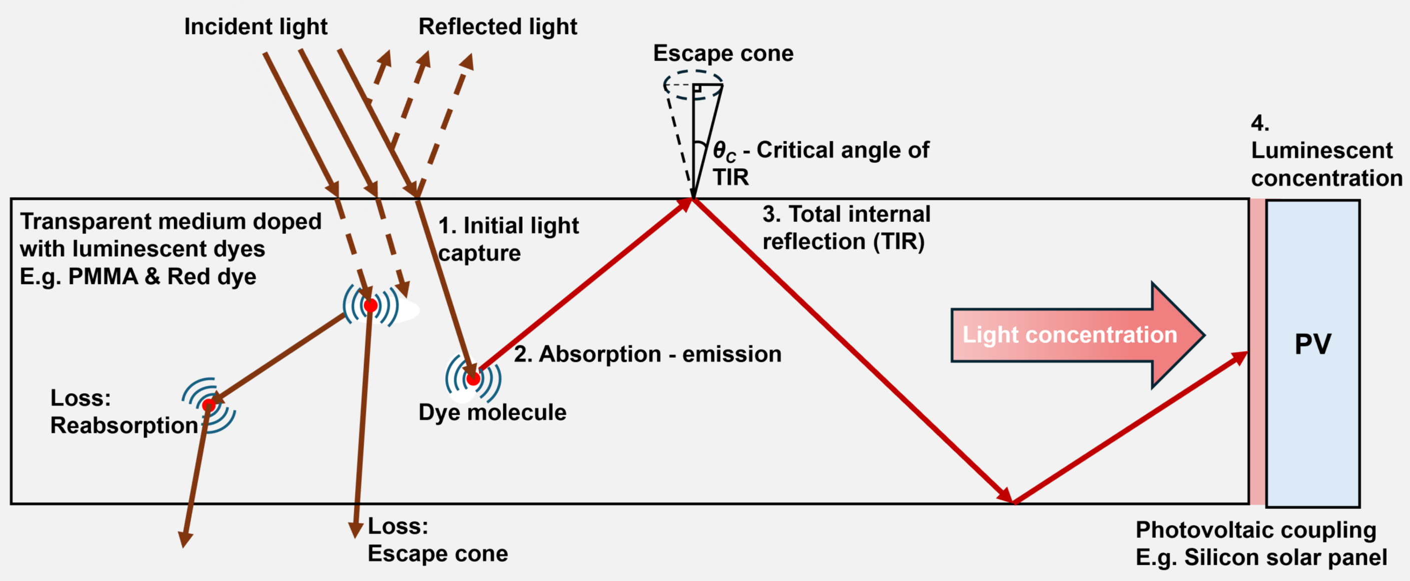


Figure 3: *1:1 (left) and 50:1 (right) FITC:RITC Dye-labelled 1 µm polystyrene microspheres. Imaged using FLIM in an Olympus IX73 stage and PicoQuant Microtime 200 TCSPC hardware. Fluorescence decay data inset in the left figure, including a 1:0 (pure donor) FITC lead decay.*

3D printing concentrators

Scheme 3: *Luminescent solar concentrator (LSC), light is geometrically concentrated from the top to the edges.*



- **3D printing** allows for the expedient testing of dyes, multi-dye-ratios, and light harvesting structures.

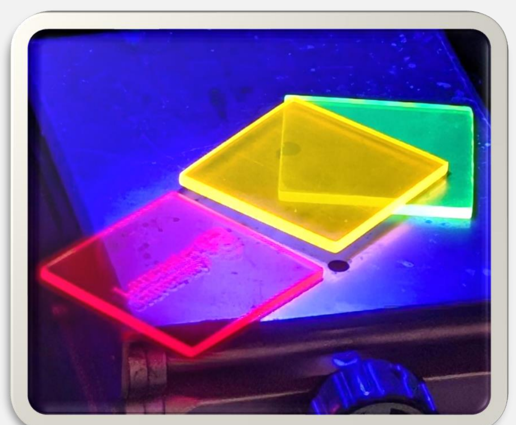


Figure 4: *3D printed LSCs under blue light LED illumination, Red-305, Orange-240 and Coumarin-153.*

Results and Further work

- Dye-labelled polystyrene microspheres reach ETE nearing **60%** for **2:1** D:A ratios. Dyes in thin films achieve **78% as high as 100:1**. Thin-film dyes may use higher efficiency perylene-based dyes and are prepared in non-aqueous environments, mitigating aggregation. *Ask the author for further detail.*
- Future work hopes to covalently attach **novel perylene attachment dyes** onto aminated **silica microspheres**, which may tolerate higher concentrations and appropriate solvent systems.
- Further spectroscopic characterisation including **time-resolved emission spectra** (TRES) and TR-**anisotropy** are in development.

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