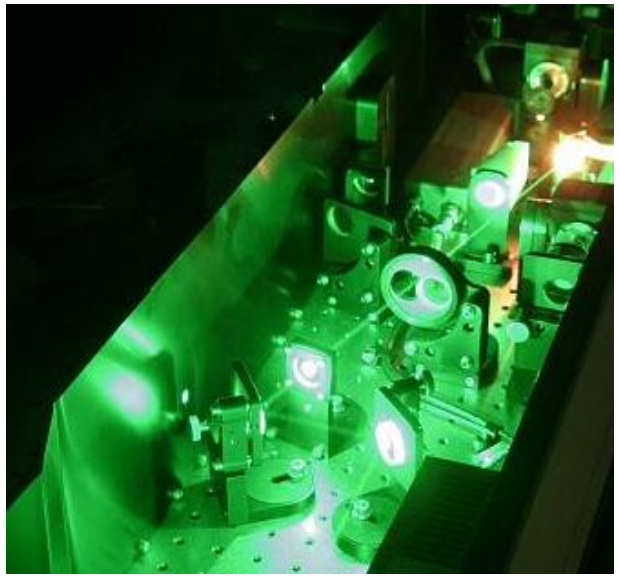
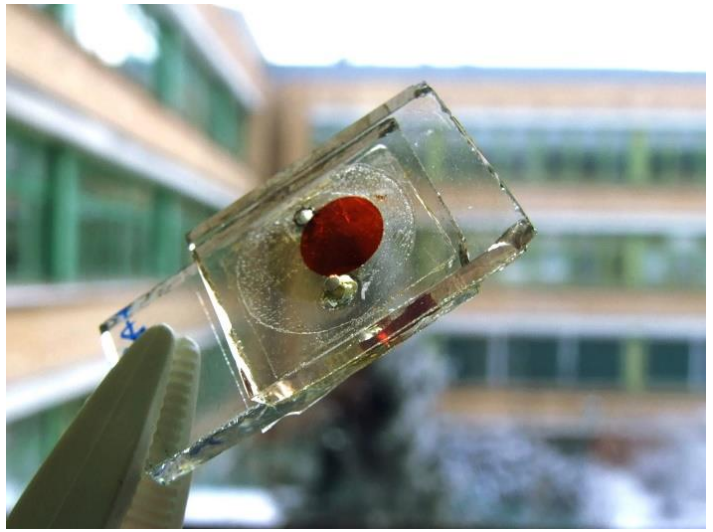
Studies of some sunlight energy conversion systems using time-resolved techniques



Marcin Ziółek

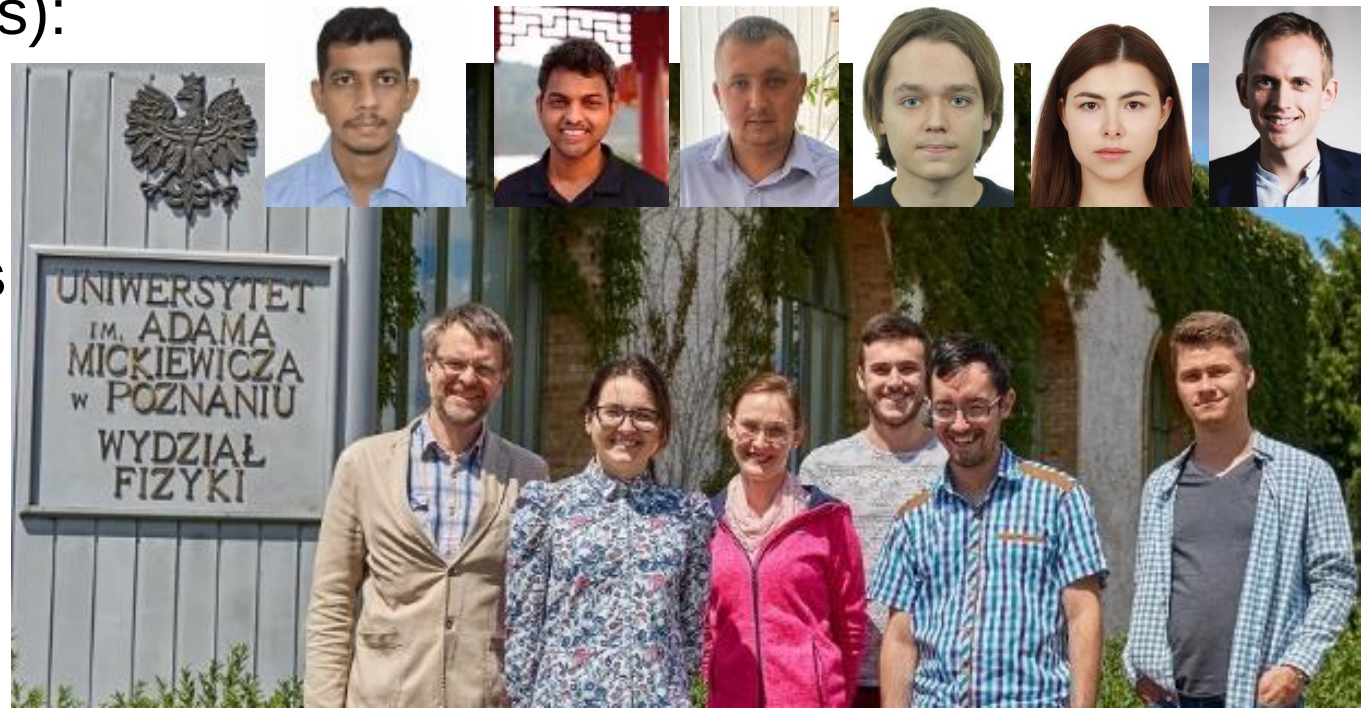
Quantum Electronics Division
Faculty of Physics and Astronomy,
Adam Mickiewicz University,
Poznań, Poland



Our group (2014-2024):

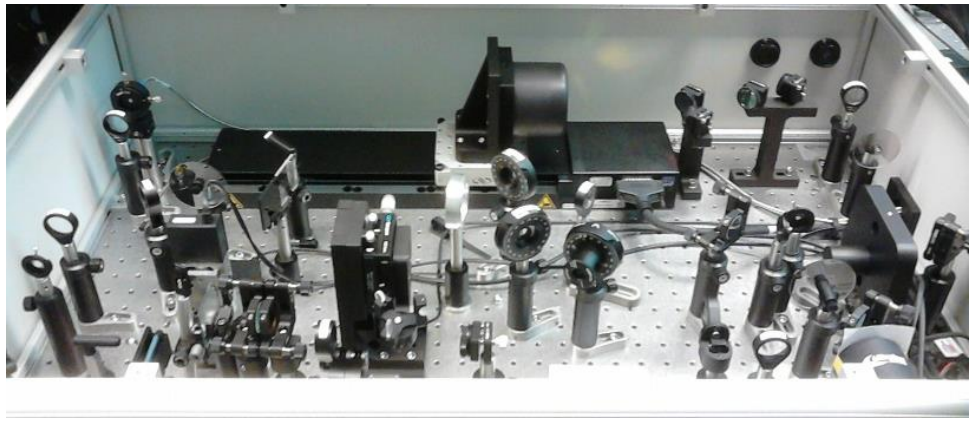
www.solencon.home.amu.edu.pl

Topics (present and past group members):

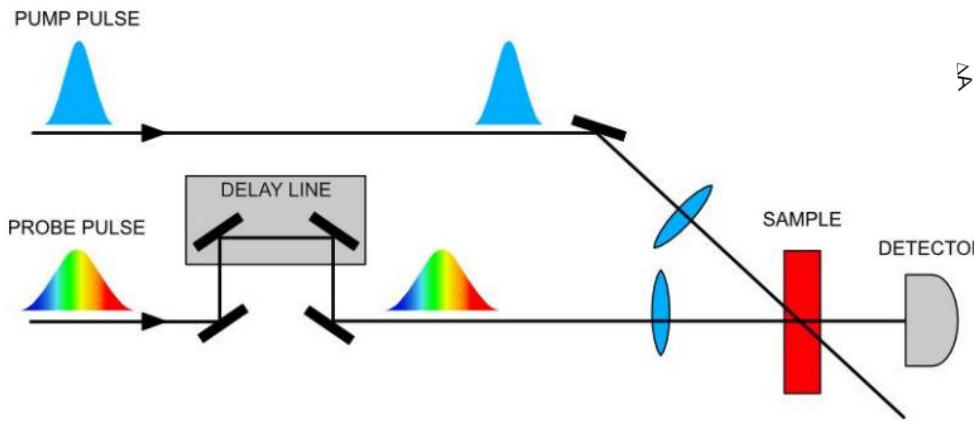


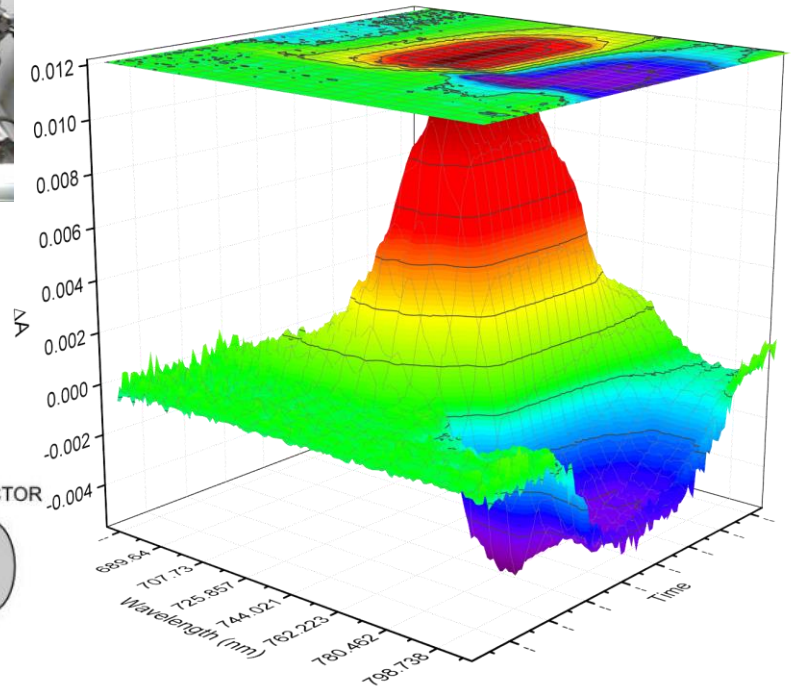
- Dye-sensitized solar cells (DSSC):
  Chinmai Mysorekar, Mateusz Gierszewski, Adam Glinka, Jan Sobuś
- Perovskite solar cells:
  Sanjay Sahare, Mykhailo Solovan, Jacek Baranowski, Katarzyna Pydzińska-Białek, Viktoriia Drushliak, Brian Quere
- Water-splitting systems with Ru compunds:
  Iwona Grądzka-Kurzaj, Mateusz Gierszewski

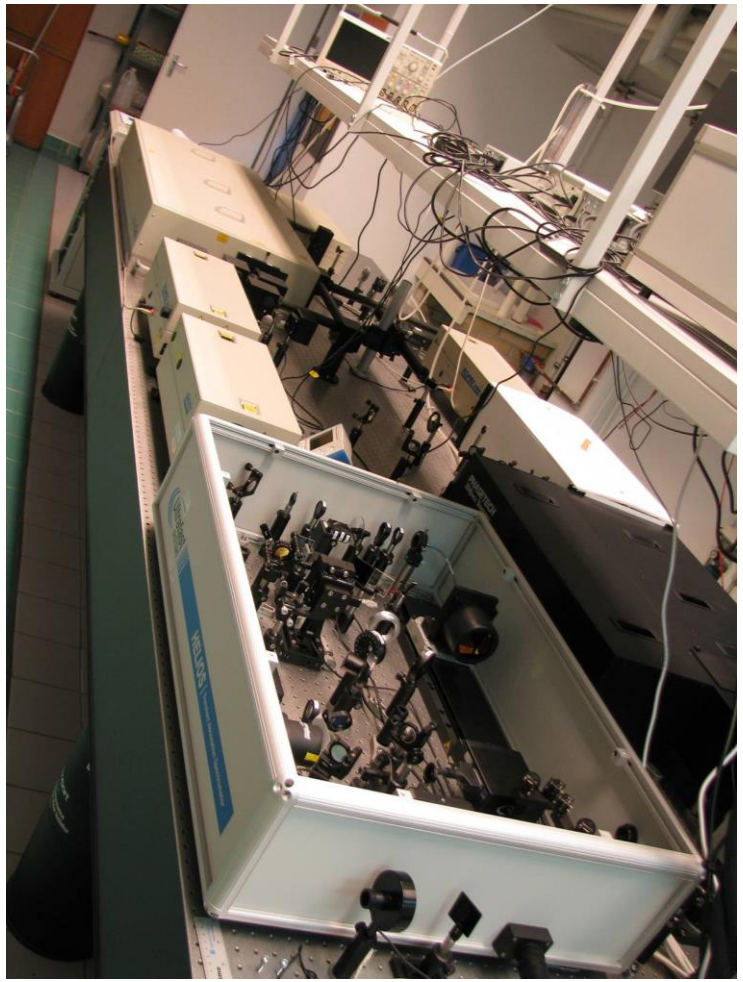
Femtosecond transient absorption (TA)



We need laser pulses to measure very short charge transport times in solar cells.



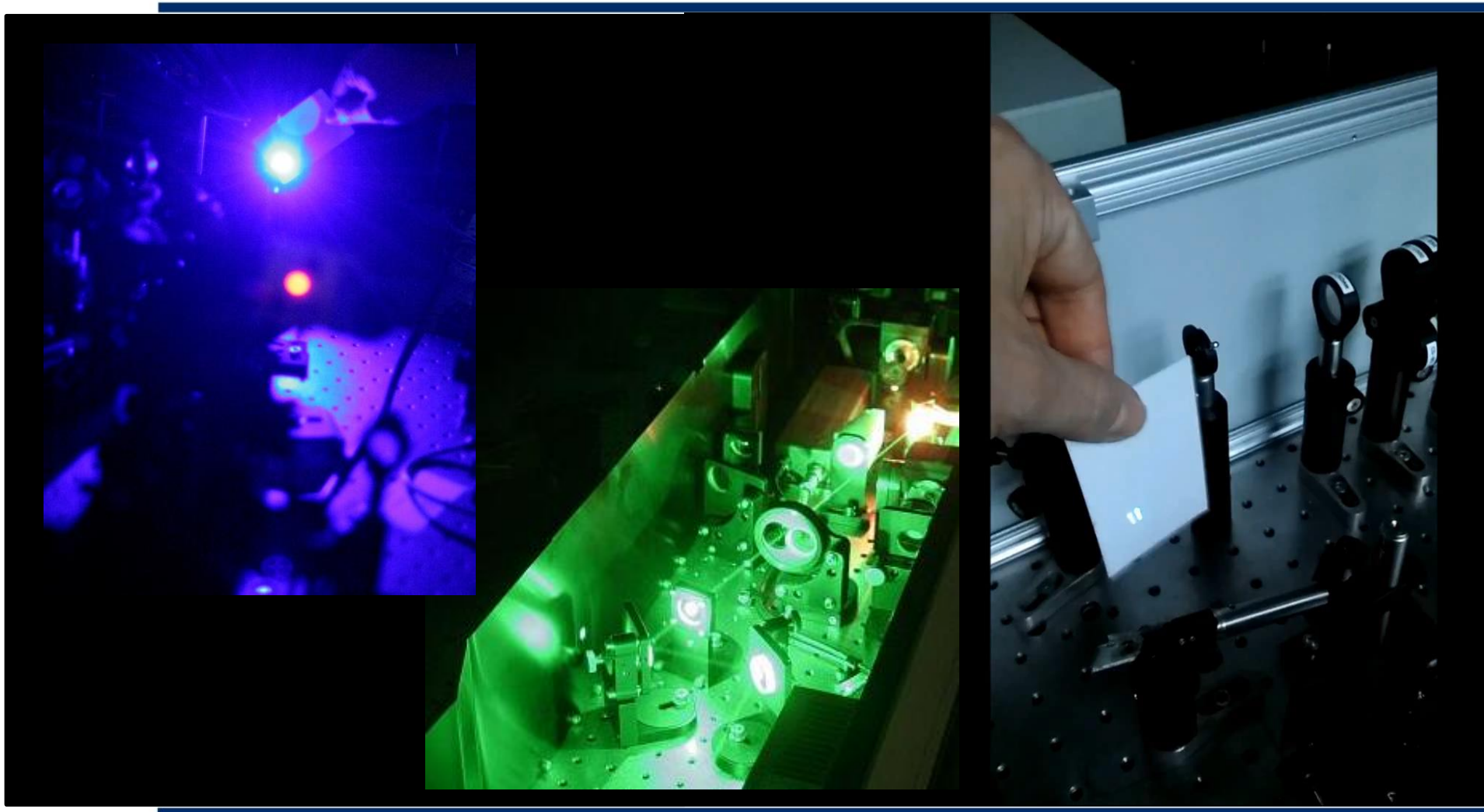




Femtosecond pulses

Pulse duration: ~100 fs

10 fs (10^{-14} s) is as much shorter than 1 minute, as 1 minute is shorter than the Universe age.



Other stationary and time-resolved techniques

Current-voltage measurements (PV characteristics)

Incident Photon to Current Efficiency (IPCE) spectra

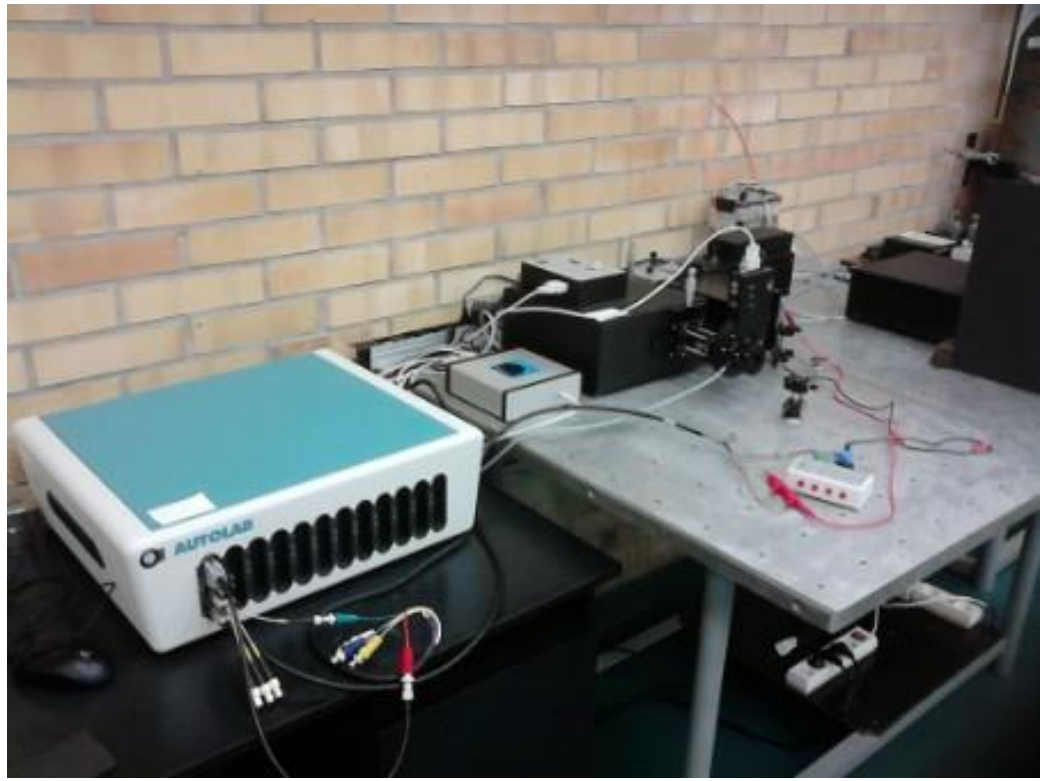
Stationary absorption of solid samples (also with integrating sphere)

Picosecond time-resolved fluorescence (TCSPC) (~10 ps resolution)

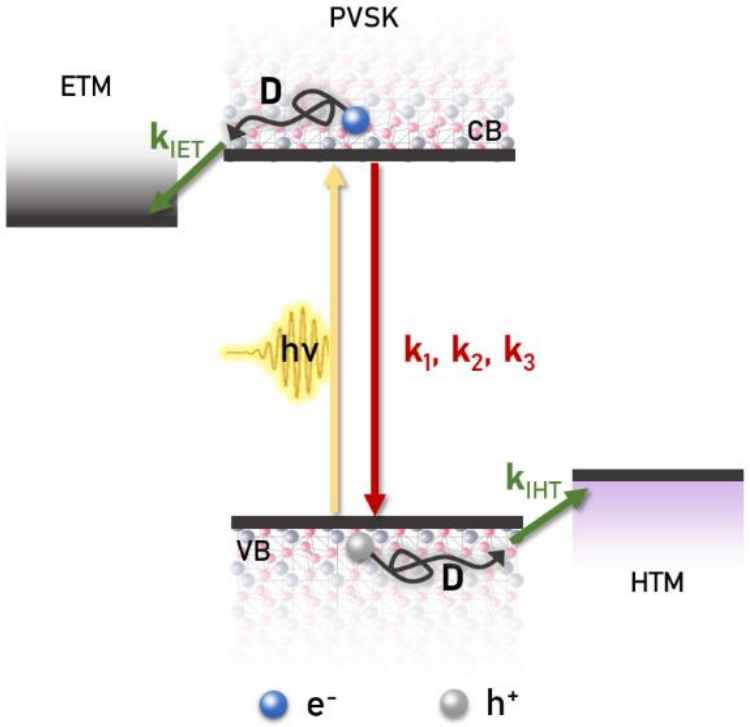
Nanosecond flash photolysis (~10 ns resolution)

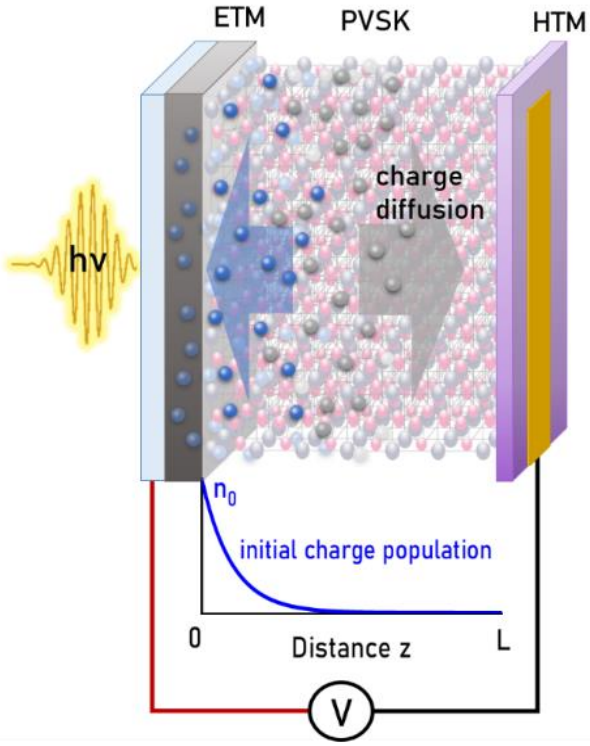
Electrochemical Impedance Spectroscopy (sub-ms resolution)

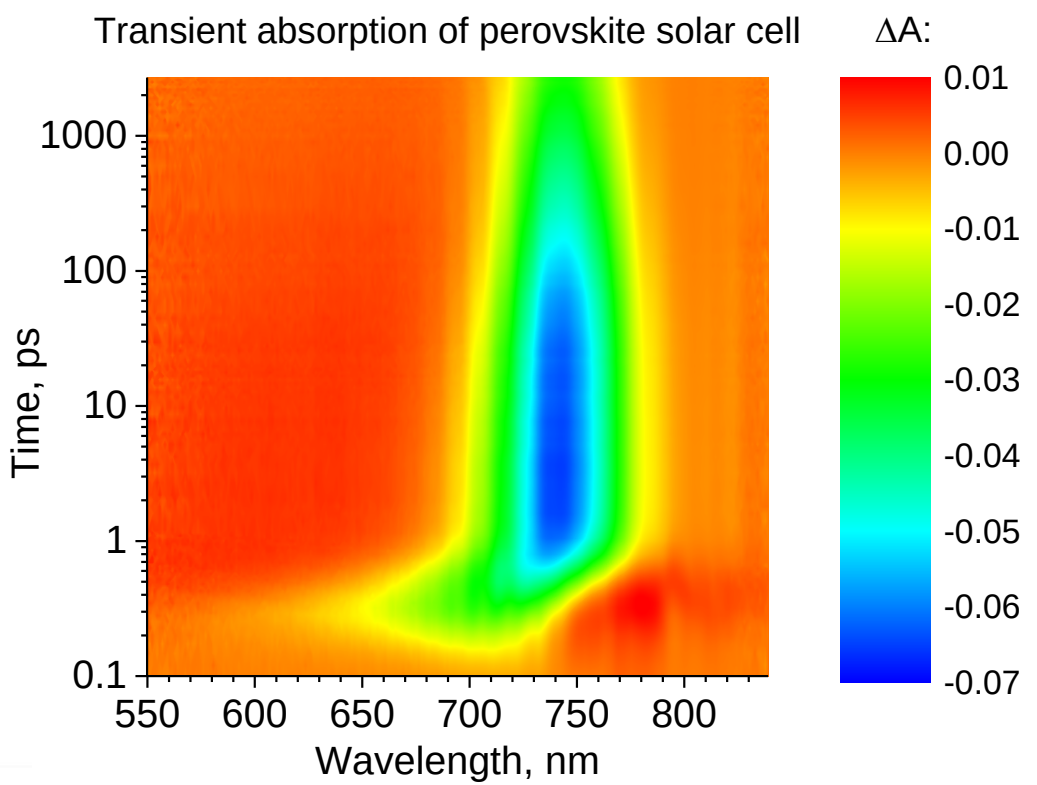
Femtosecond up – conversion (new)



Charge dynamics in perovskite solar cells

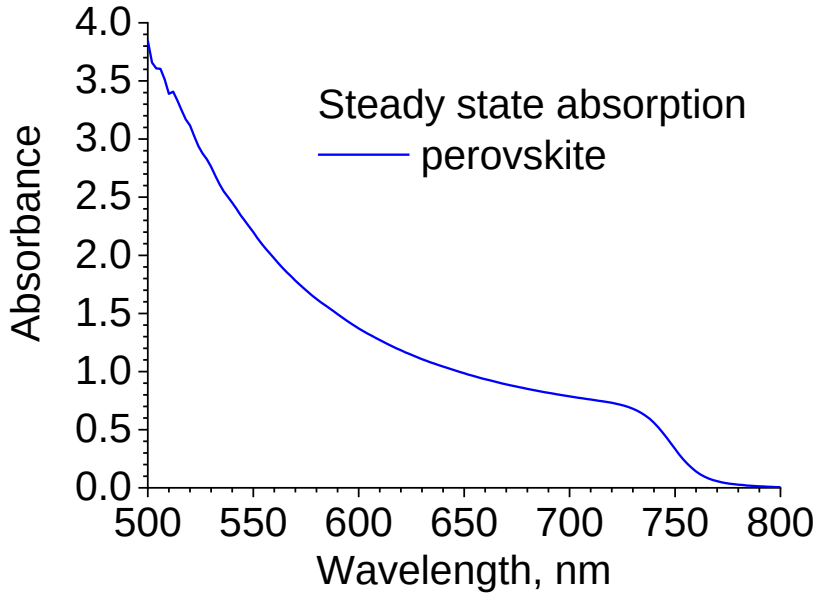




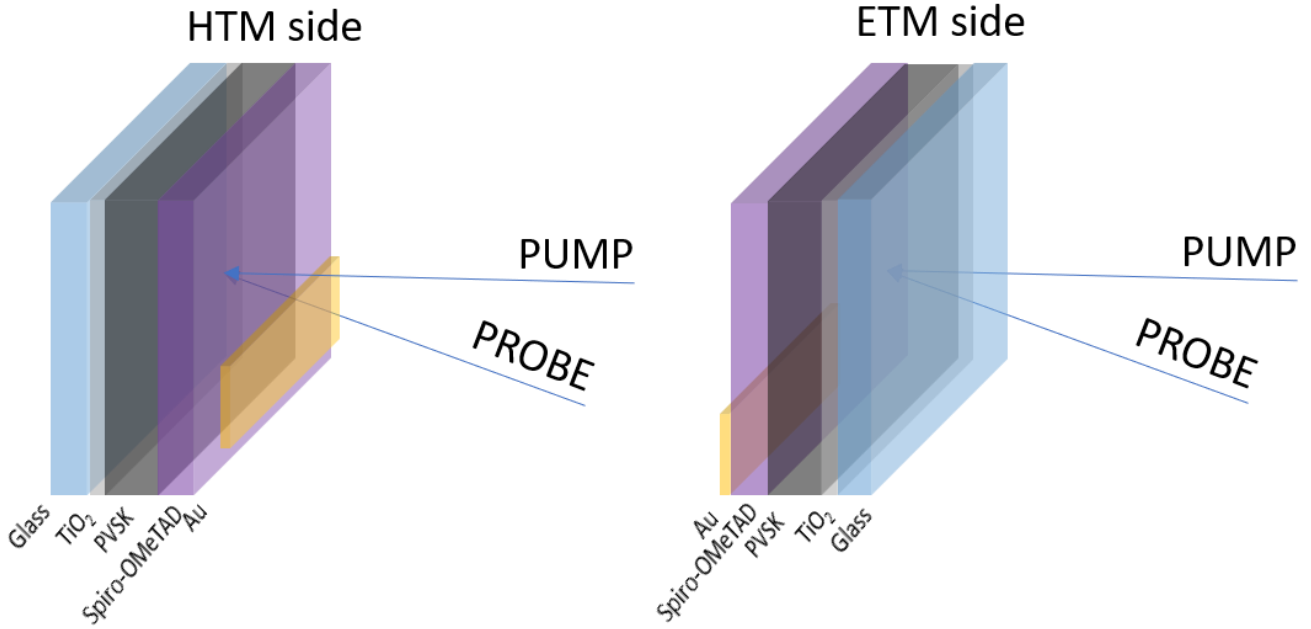


Charge cooling dynamics, exciton dissociation, charge population decay due to charge recombination and interfacial charge transfers observed in the bleach band.

Probing two interfaces with transient absorption

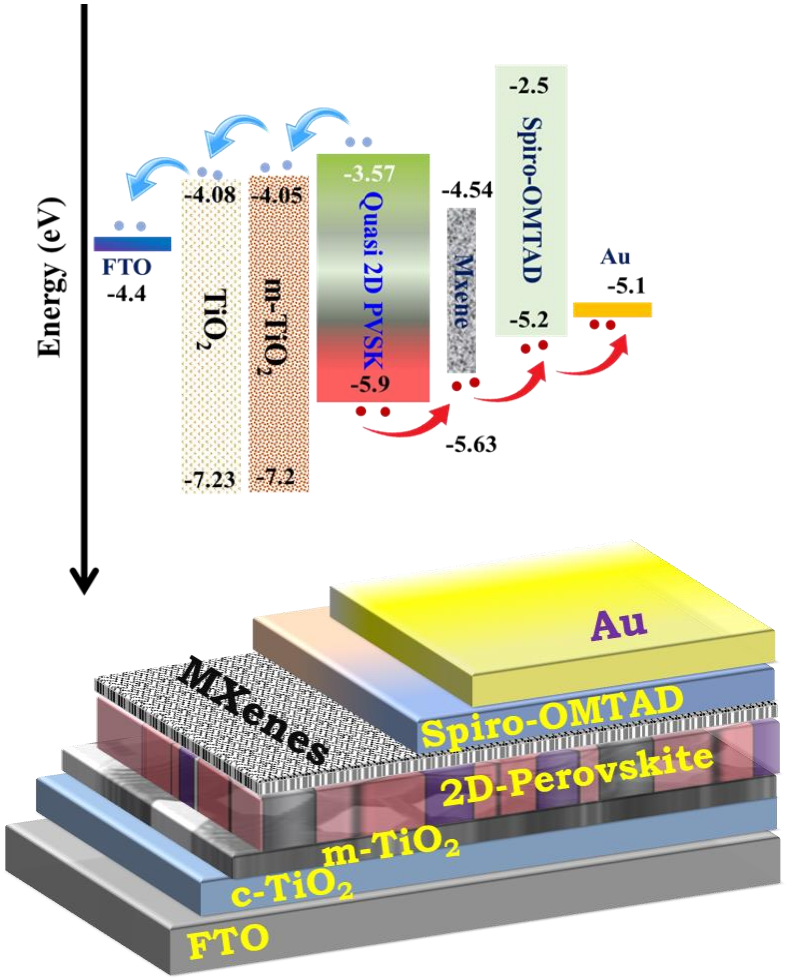


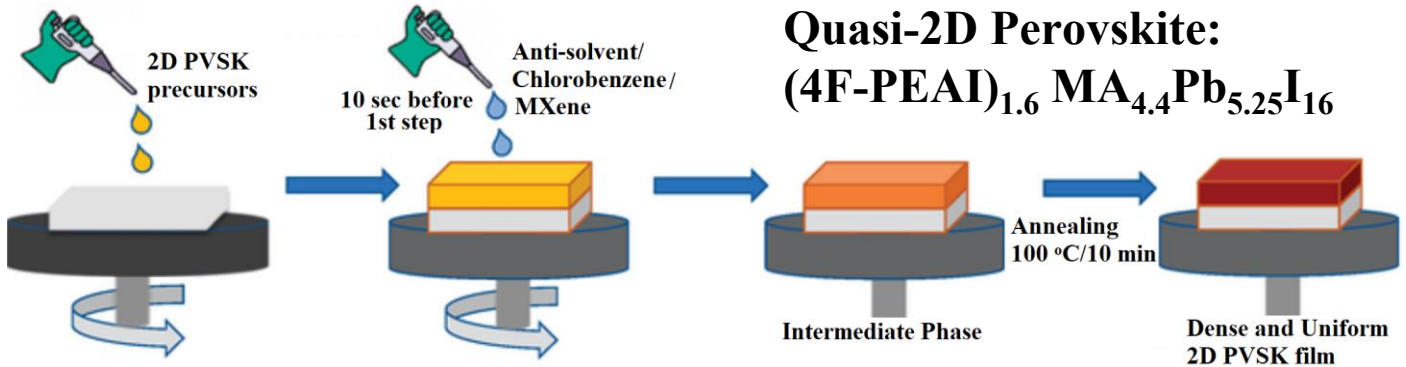
In the typical samples more than 80% of light is absorbed within the first 100 nm of perovskite layer for the excitation wavelength below 500 nm.



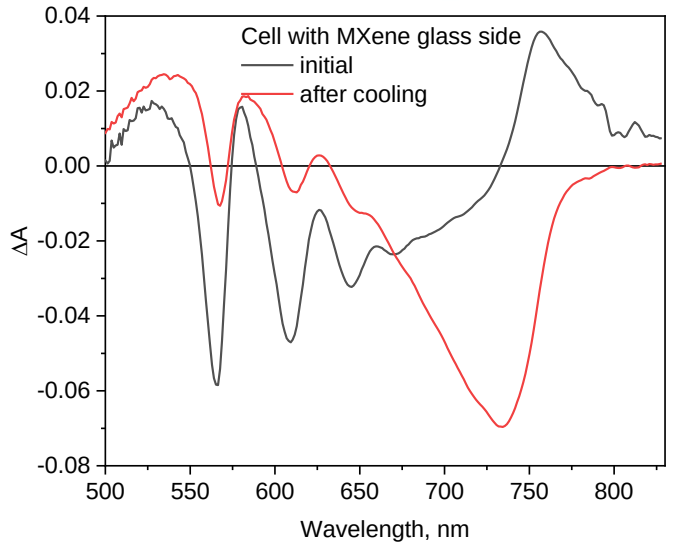
Transient absorption can be used as very unique interface selective steady-state probing!

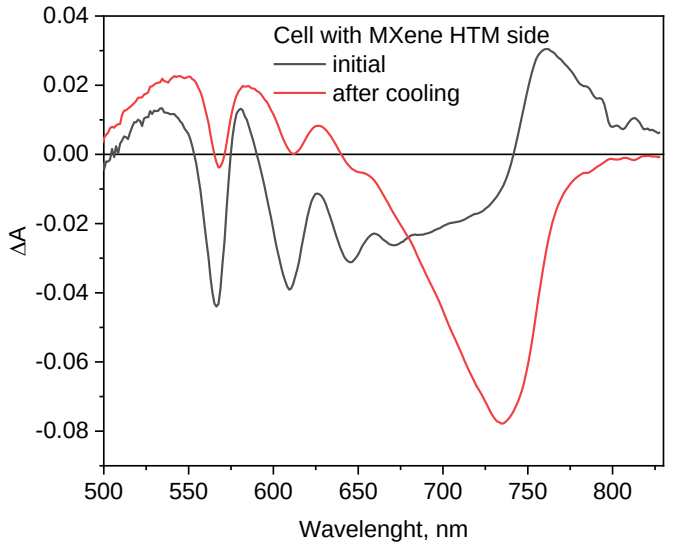
Distribution of low dimensional phases in 2D perovskites





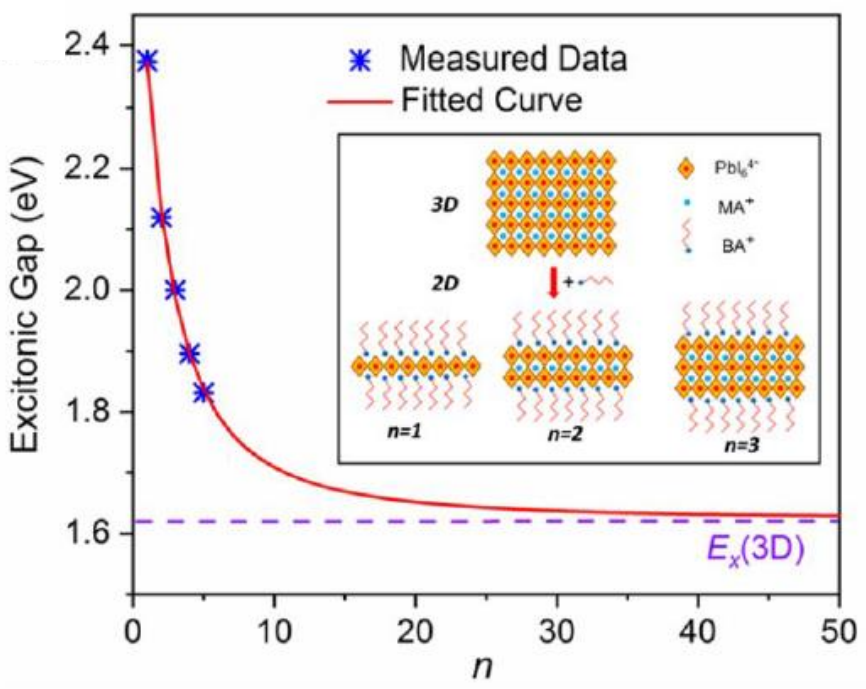
Quasi-2D Perovskite:
$(4F\text{-}PEAI)_{1.6}\ MA_{4.4}Pb_{5.25}I_{16}$





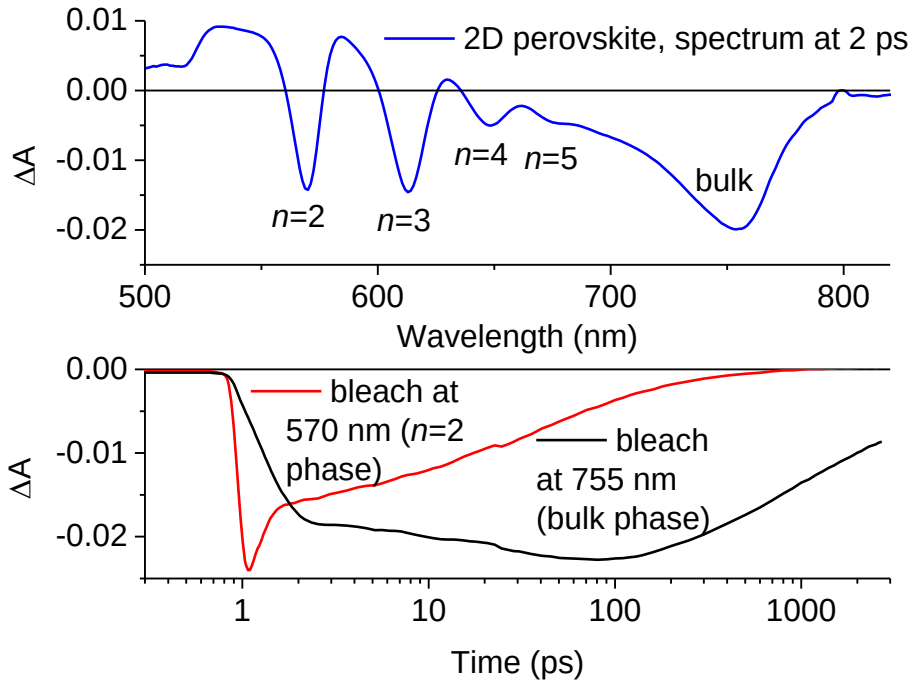
S. Sahare et al., J. Mater. Chem. C, **12** (2024) 8357-8367

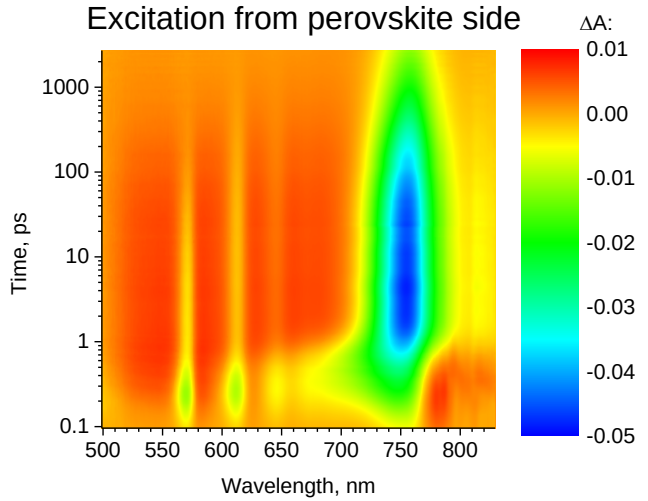
Distribution of low dimensional phases in 2D perovskites

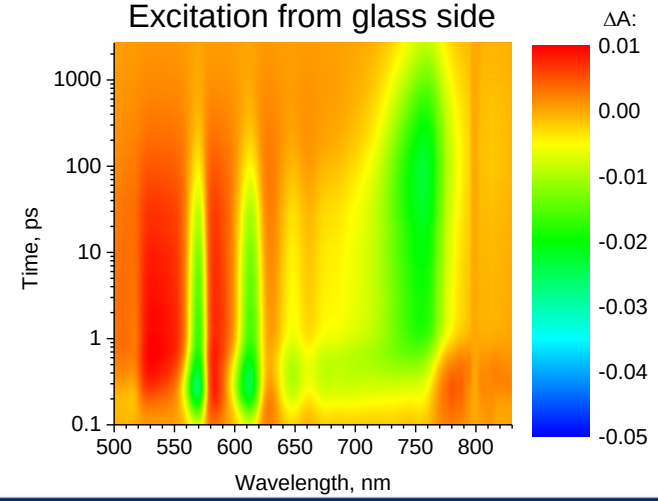


ACS Appl. Mater. Interfaces 12 (2020) 25980

Two-dimensional (2D) Ruddlesden-Popper perovskites

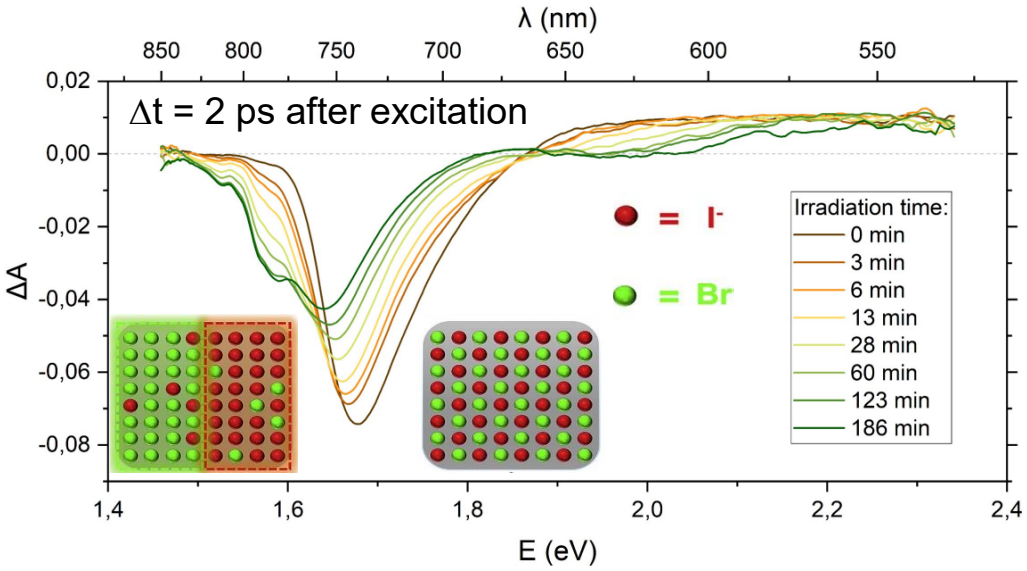




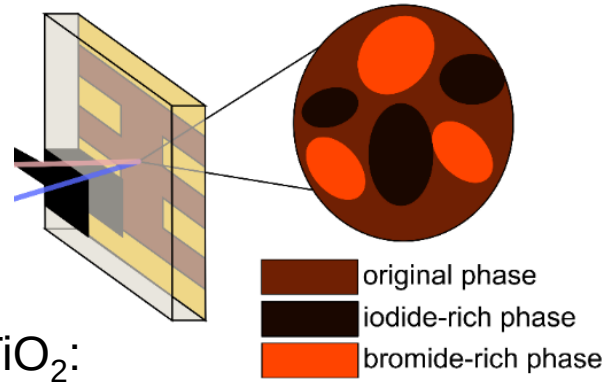


S. Sahayaraj et al.,
J. Mater. Chem. A, **9** (2021) 9175

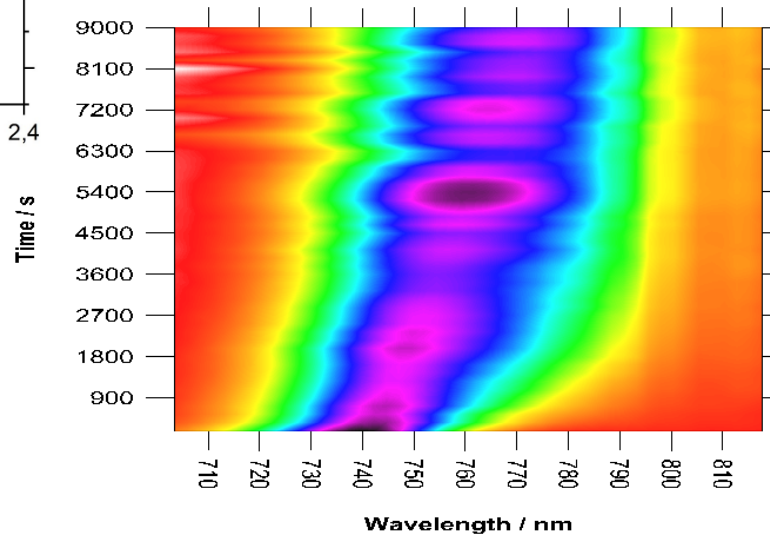
Changes due to ion segregation in mixed halide perovskites



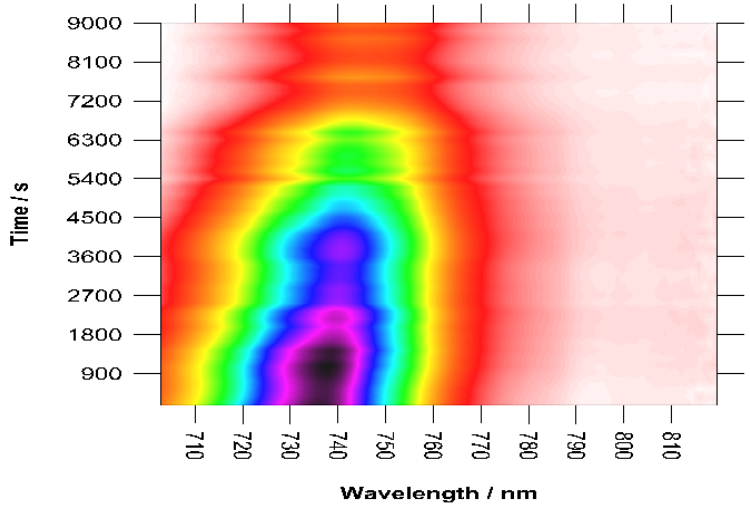
Triple cation mixed halide perovskite:
$FA_{0.76}MA_{0.19}Cs_{0.05}Pb(I_{0.81}Br_{0.19})_3$



With mesoporous TiO_2:

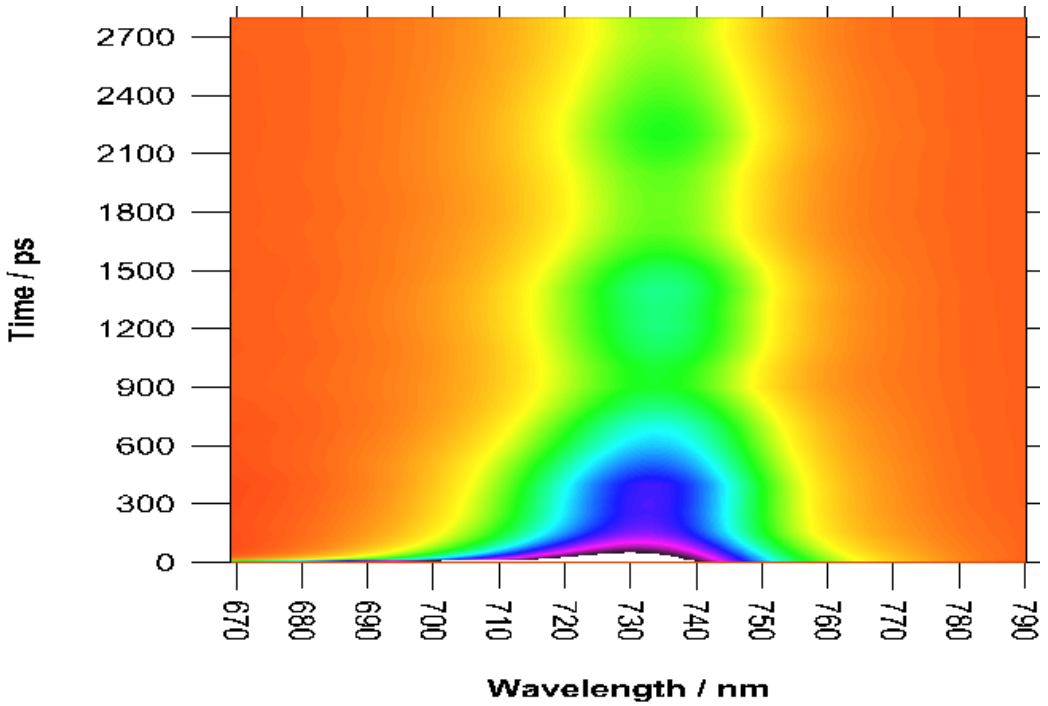


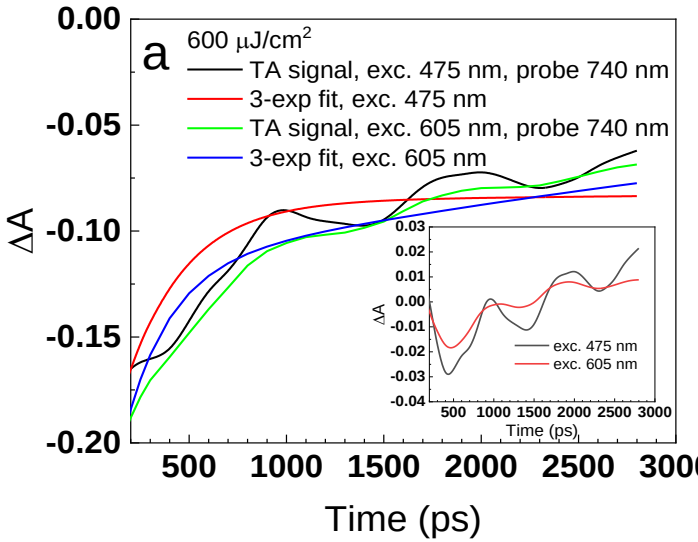
No TiO_2:



J. Baranowski et al., submitted

Observation of coherent acoustic phonons

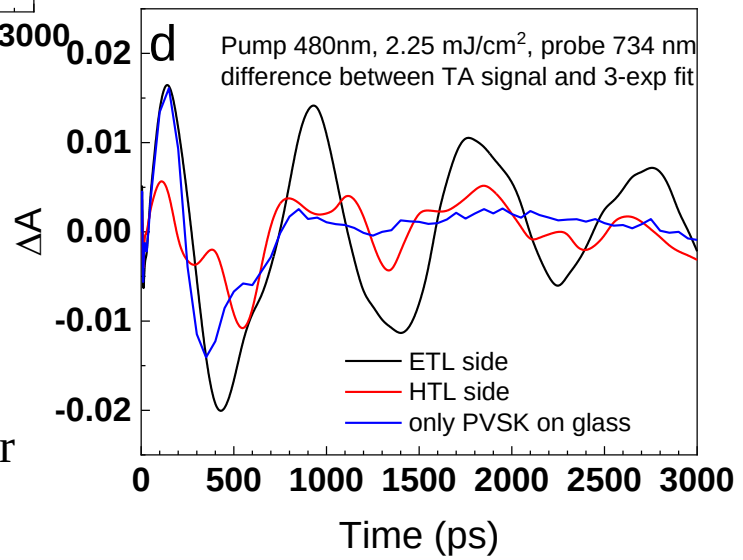




the speed of sound:

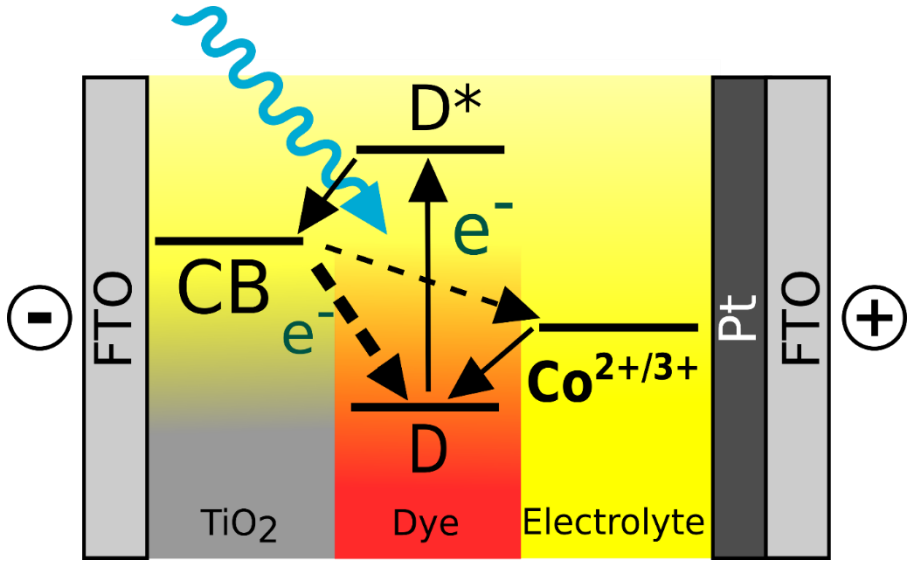
$$v = \frac{4d}{T}$$

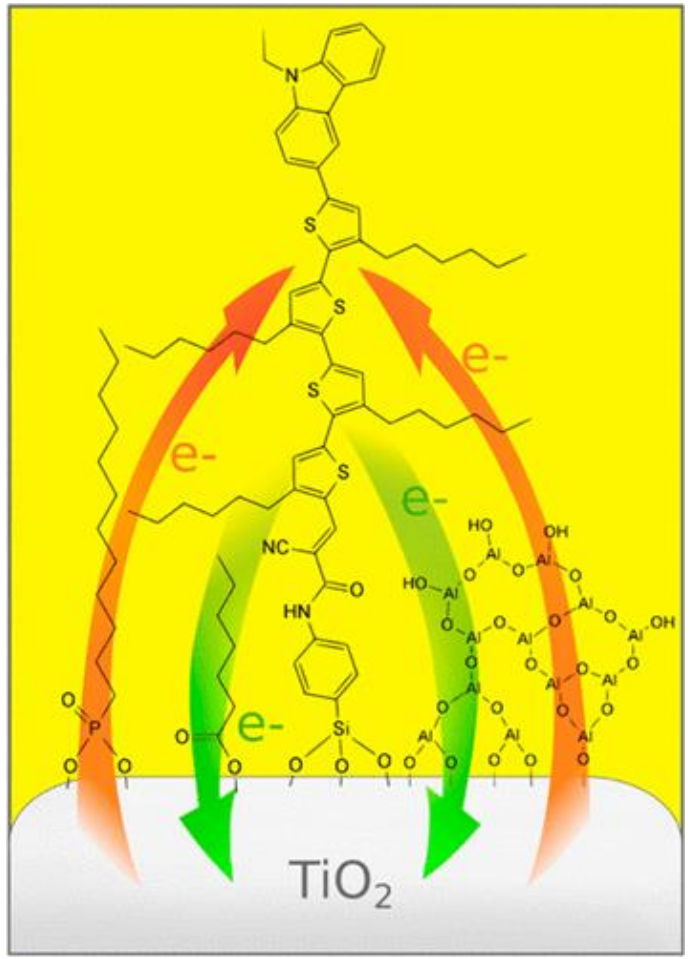
d: thickness of the perovskite layer
T: the period of oscillations



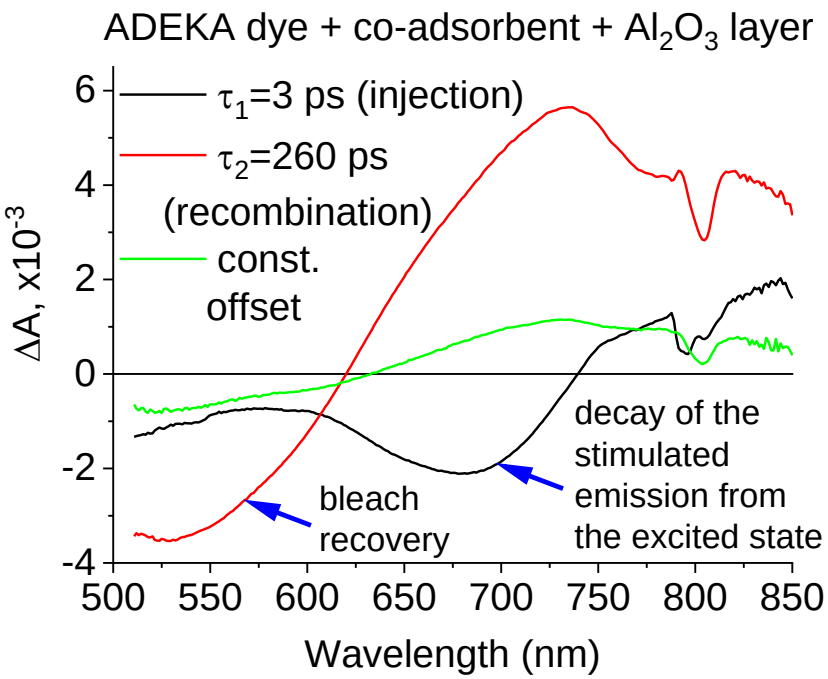
J. Baranowski et al., submitted

Charge separation processes in dye sensitized solar cells

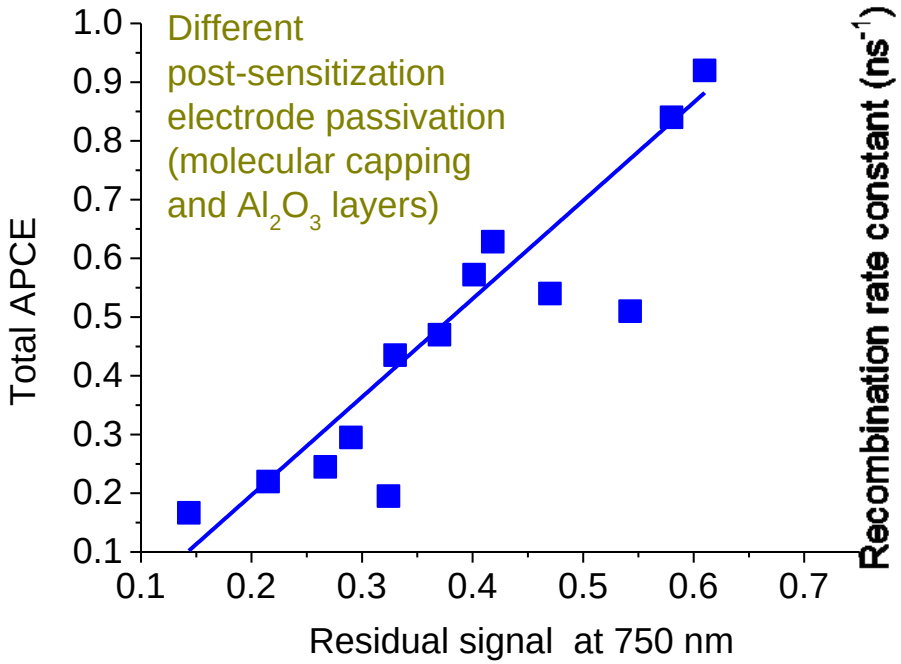


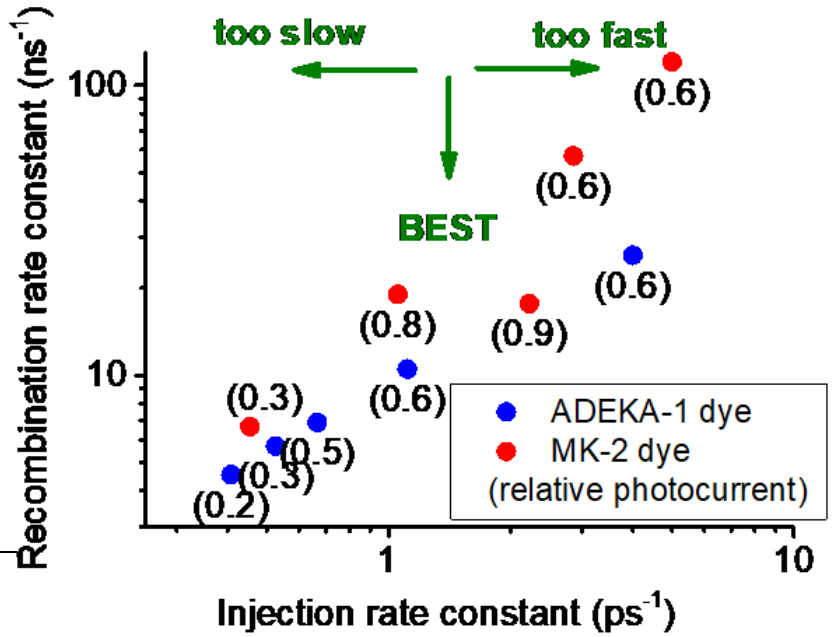


Determination of charge injection and recombination in transient absorption:



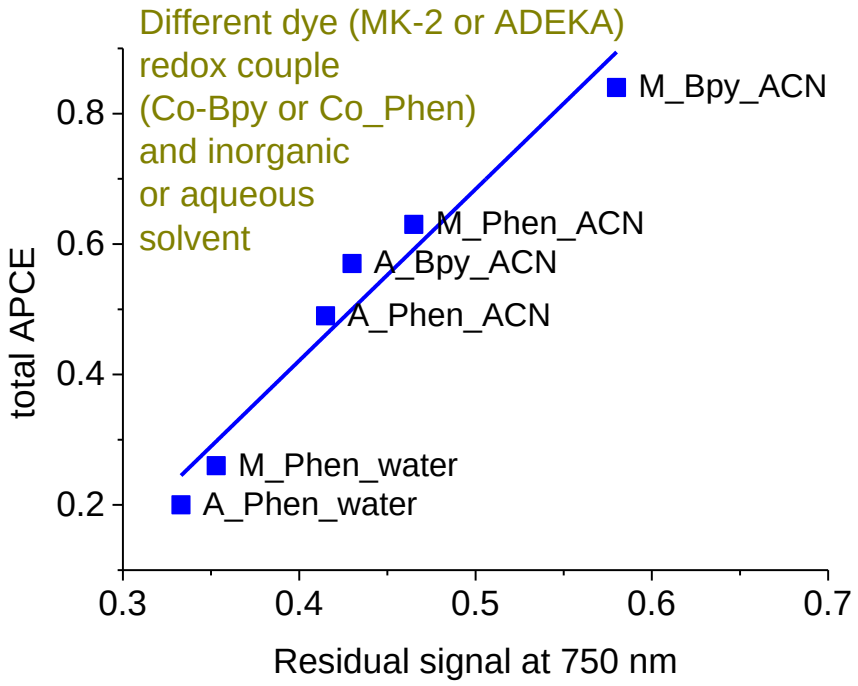
Correlations of ultrafast charge dynamics with DSSC photovoltaic parameters (e.g. photocurrent)





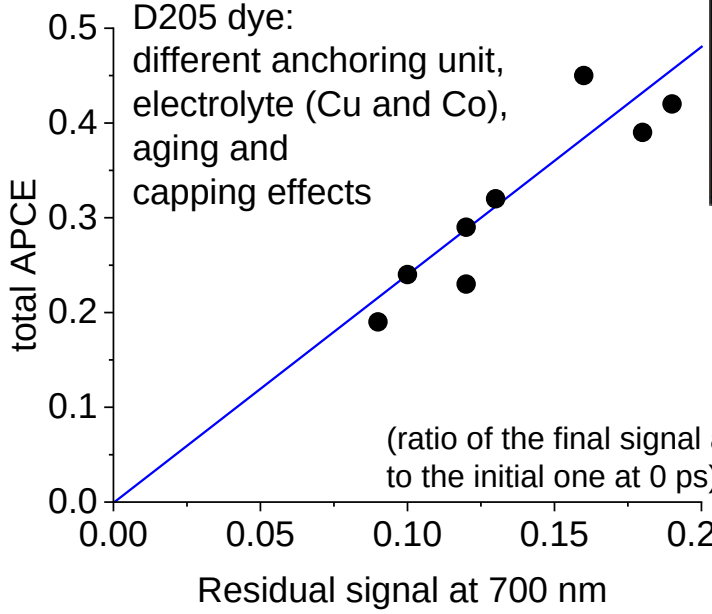
M. Gierszewski et al., ACS Appl. Mater. Interfaces, **9** (2017) 17102-17114

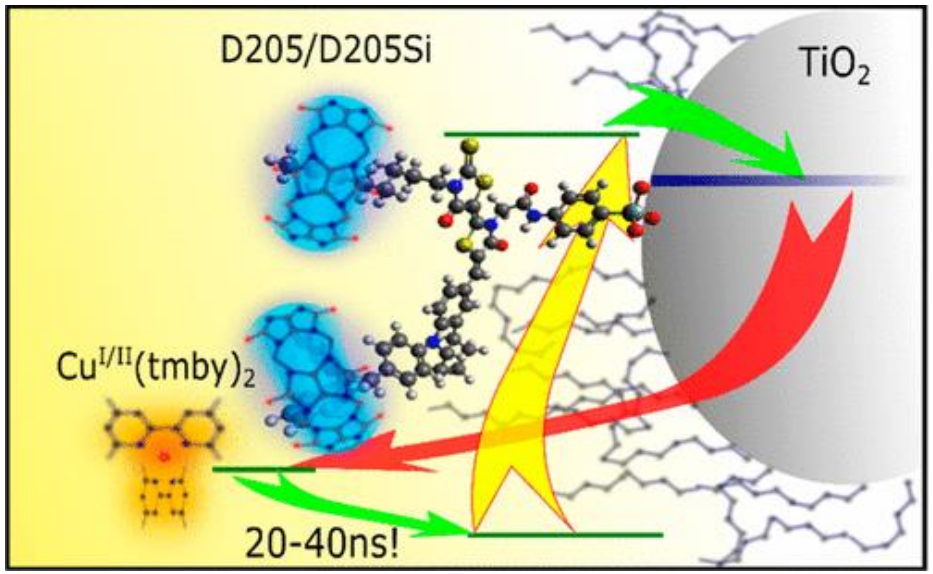
DSSC studies: different anchoring unit, electrolyte and molecular capping



A. Glinka et al., J. Phys. Chem. C,

122 (2018) 8147-8158





A. Glinka et al., J. Phys. Chem. C,

124 (2020) 2895–2906

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