Laser-enhanced Atomic Mobility and Nanoparticles Formation in Porous Glass

Luca Marmugi

CNISM and Department of Physical Sciences, Earth and Environment - University of Siena
via Roma 56, 53100 Siena

INO-CNR, UOS Pisa, via G. Moruzzi 1, 56124 Pisa

luca.marmugi@ino.it

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INO - UOS "A. Gozzini" Pisa, March 7th 2014

Introduction

Adsorption, desorption and surface interaction.

➡ Adsorption and desorption influence atom/substrate interaction.

➡ Direct influence on atomic mobility: dynamics and evolution at the nanoscale.

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➡ Adsorption and desorption influence atom/substrate interaction.

➡ Direct influence on atomic mobility: dynamics and evolution at the nanoscale.

➡ Adsorption and desorption can be controlled by light.

[A. Gozzini *et al.*, Il Nuovo Cimento D **15**, 5, 709, 1993]

Photodesorption and applications

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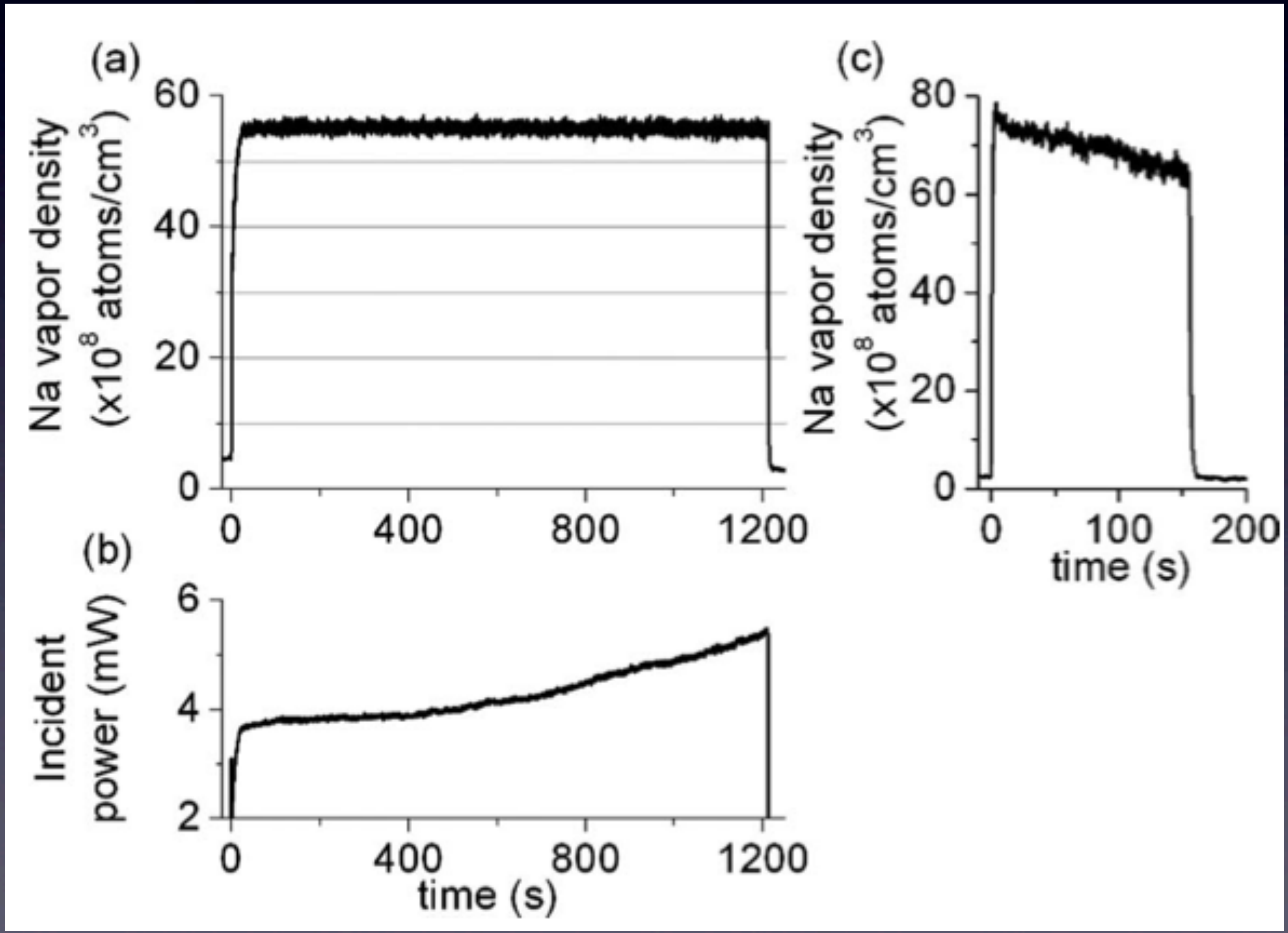
➡ RT vapor density stabilization and modulation: all-optical atomic dispenser.



[A. Bogi *et al.*, Opt. Lett. **34**, 17, 2643, 2009]

Photodesorption and applications

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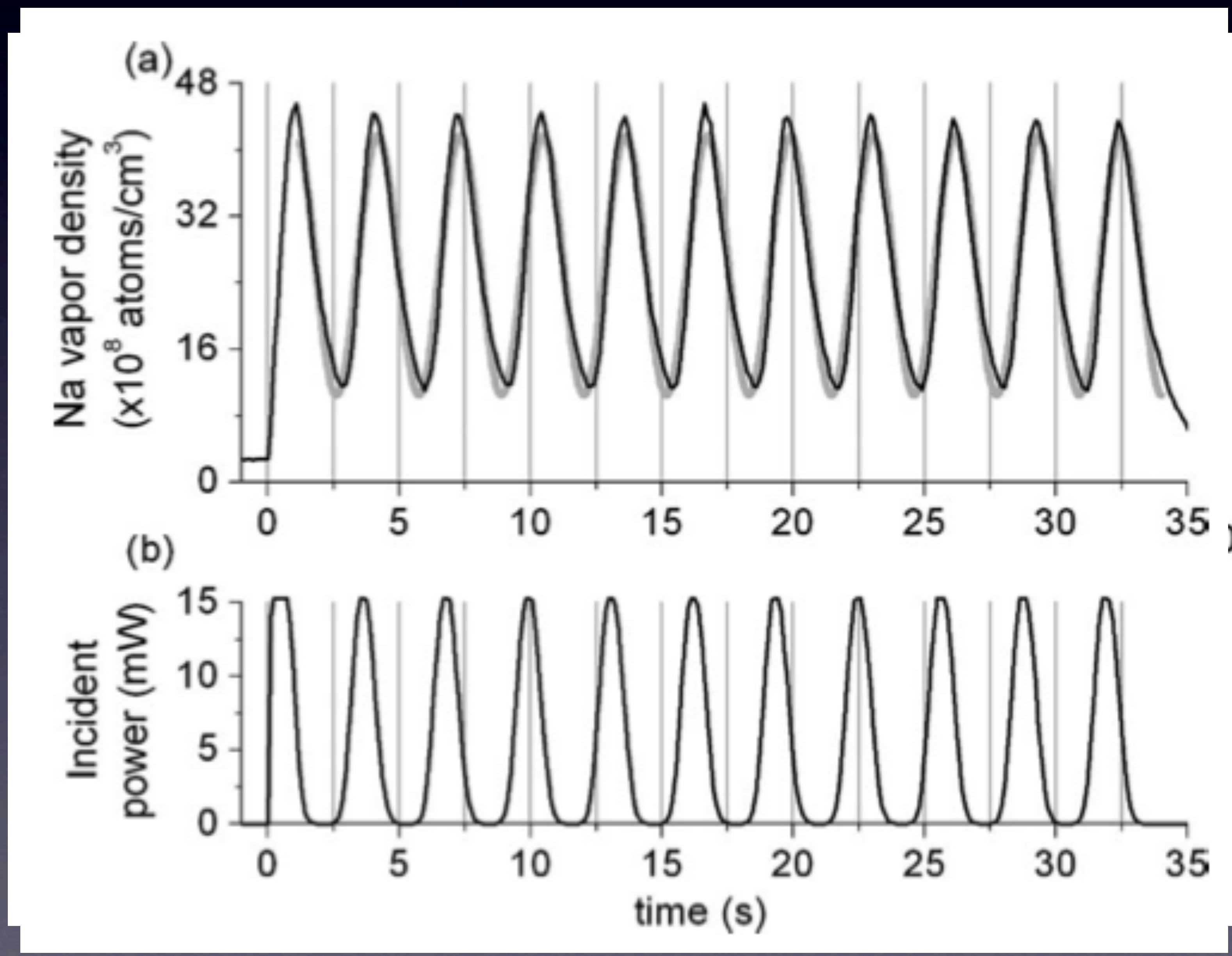

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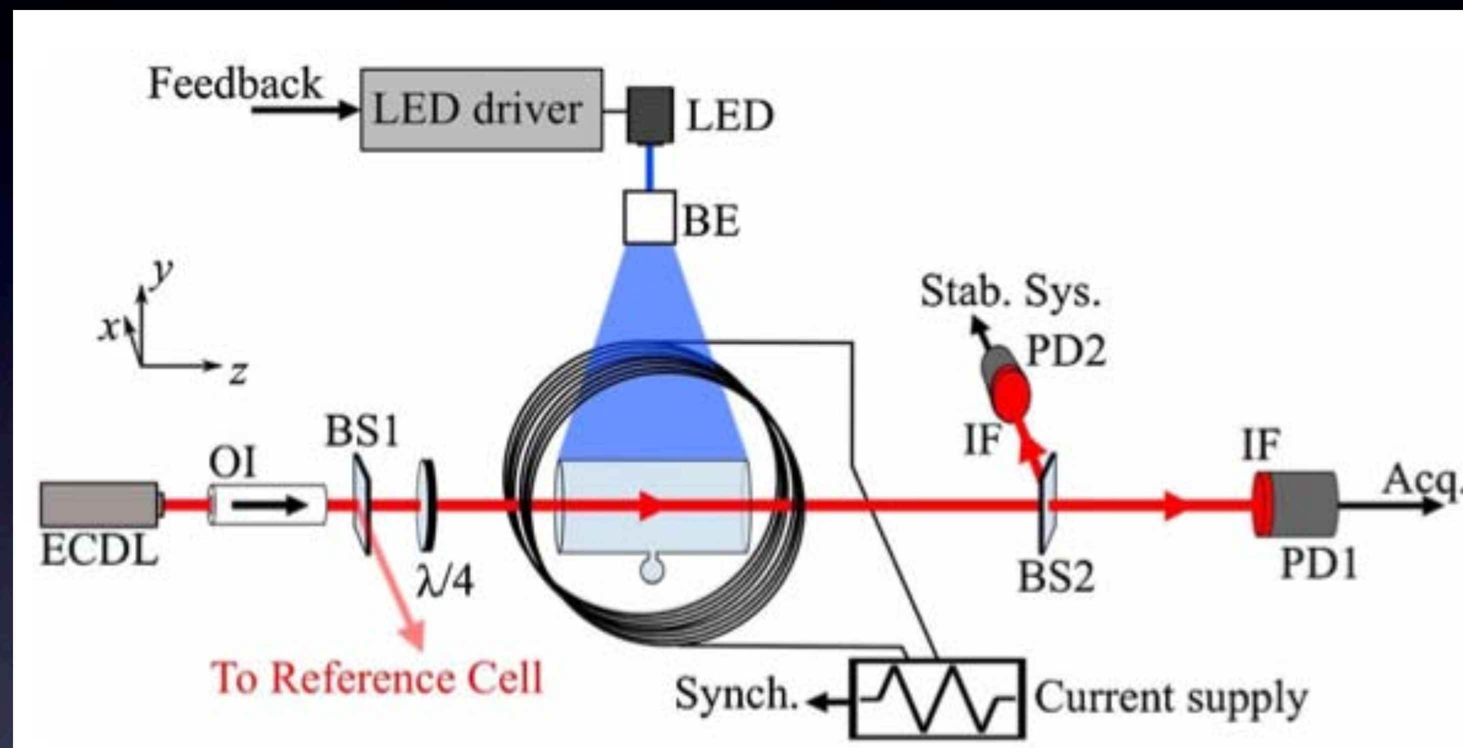
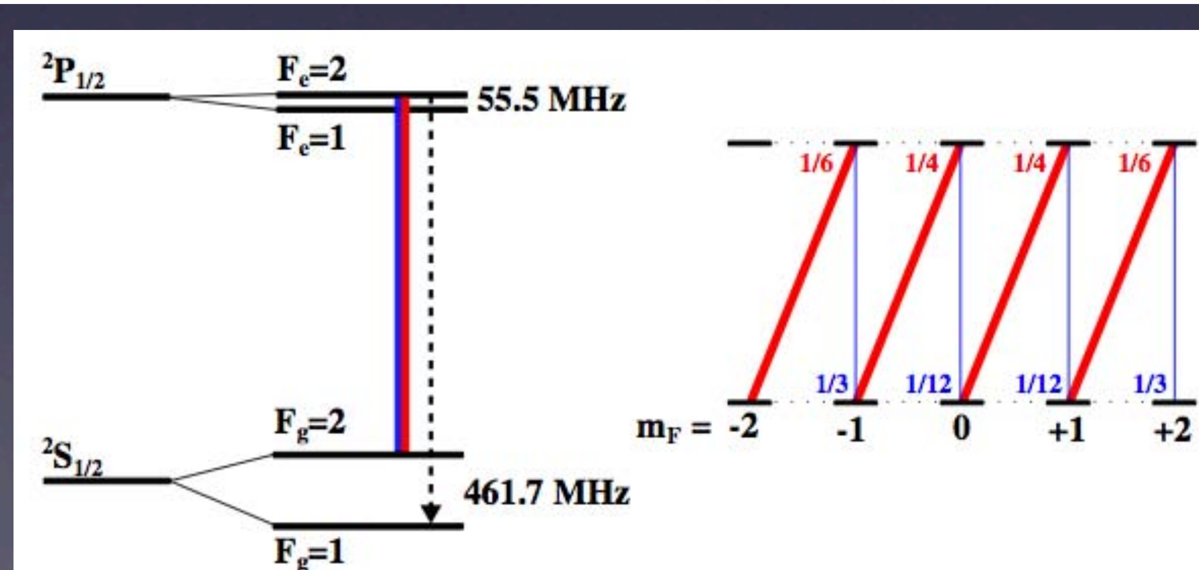
Photodesorption and applications

➡ RT EIT in optically stabilized vapors: costant, improved C and 33 kHz FWHM.





L. Marmugi *et al.*, J. Opt. Soc. Am. B **29**, 10, 2729, 2012

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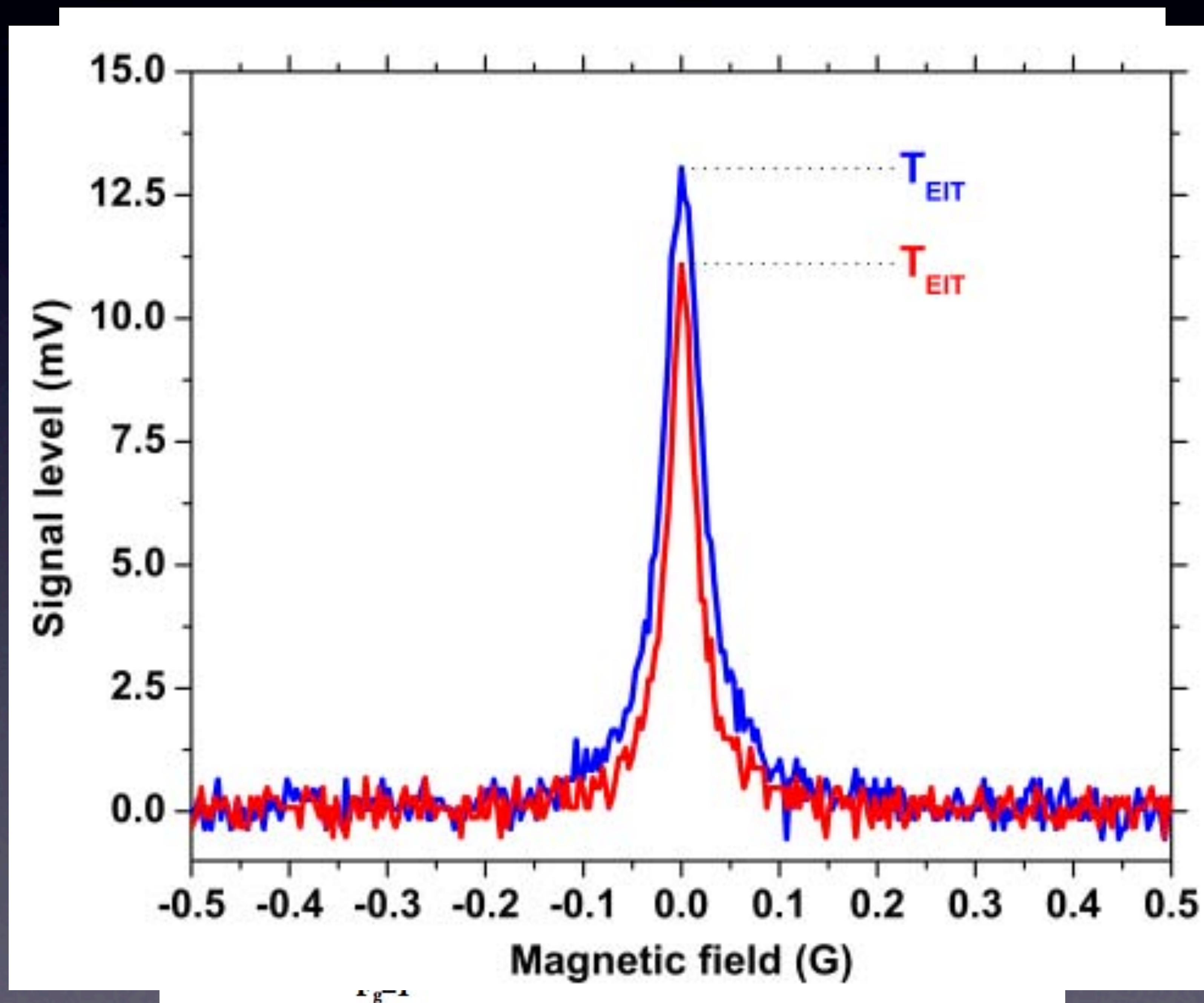

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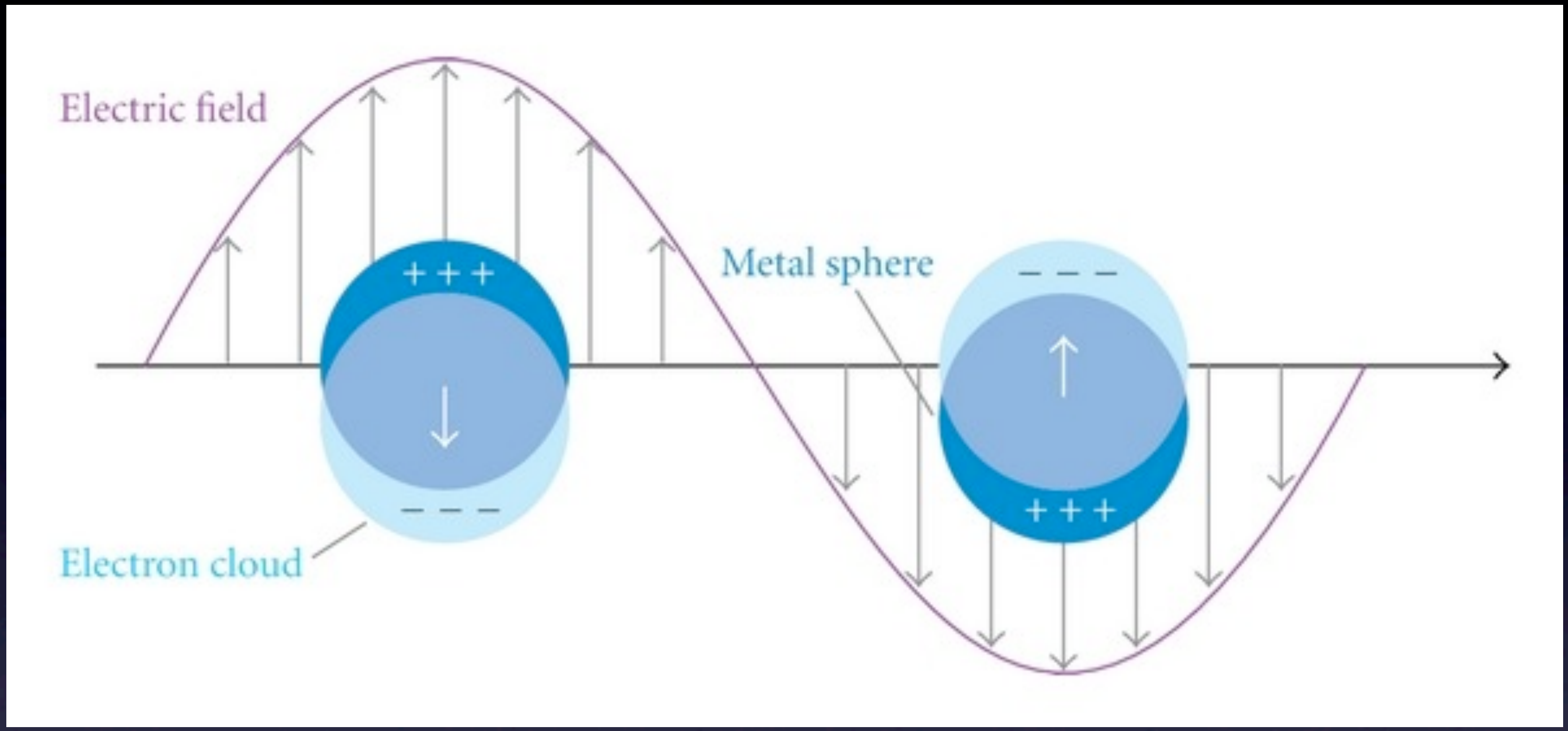
Optical response of metal nanoparticles

Localized Surface Plasmons.



- Interaction between photon EF and CB e^- metal NP.
- Non propagating ➡ Localization.
- **k**=0 ➡ PM with incoming radiation.
- Quasi-static and dipole approximation ➡ 2a < 20 nm

Optical response of metal nanoparticles

Localized Surface Plasmons.

- Int
- No
- **k=**
- Qu

Optical response of metal nanoparticles

Localized Surface Plasmons: Gans approach.

$$\alpha_j(\omega) = \varepsilon_0 \frac{\varepsilon(\omega) - \varepsilon_m}{\varepsilon_m + [\varepsilon(\omega) - \varepsilon_m] L_j} V$$

$$\Downarrow$$

$$\sigma_{ext}^{Gans} = V \frac{\omega}{3c} \varepsilon_m^{3/2} \sum_{j=a,b,c} \frac{\varepsilon_2(\omega)/L_j^2}{\varepsilon_2^2(\omega) + \left[\varepsilon_1(\omega) + \varepsilon_m \frac{1 - L_j}{L_j}\right]^2}$$

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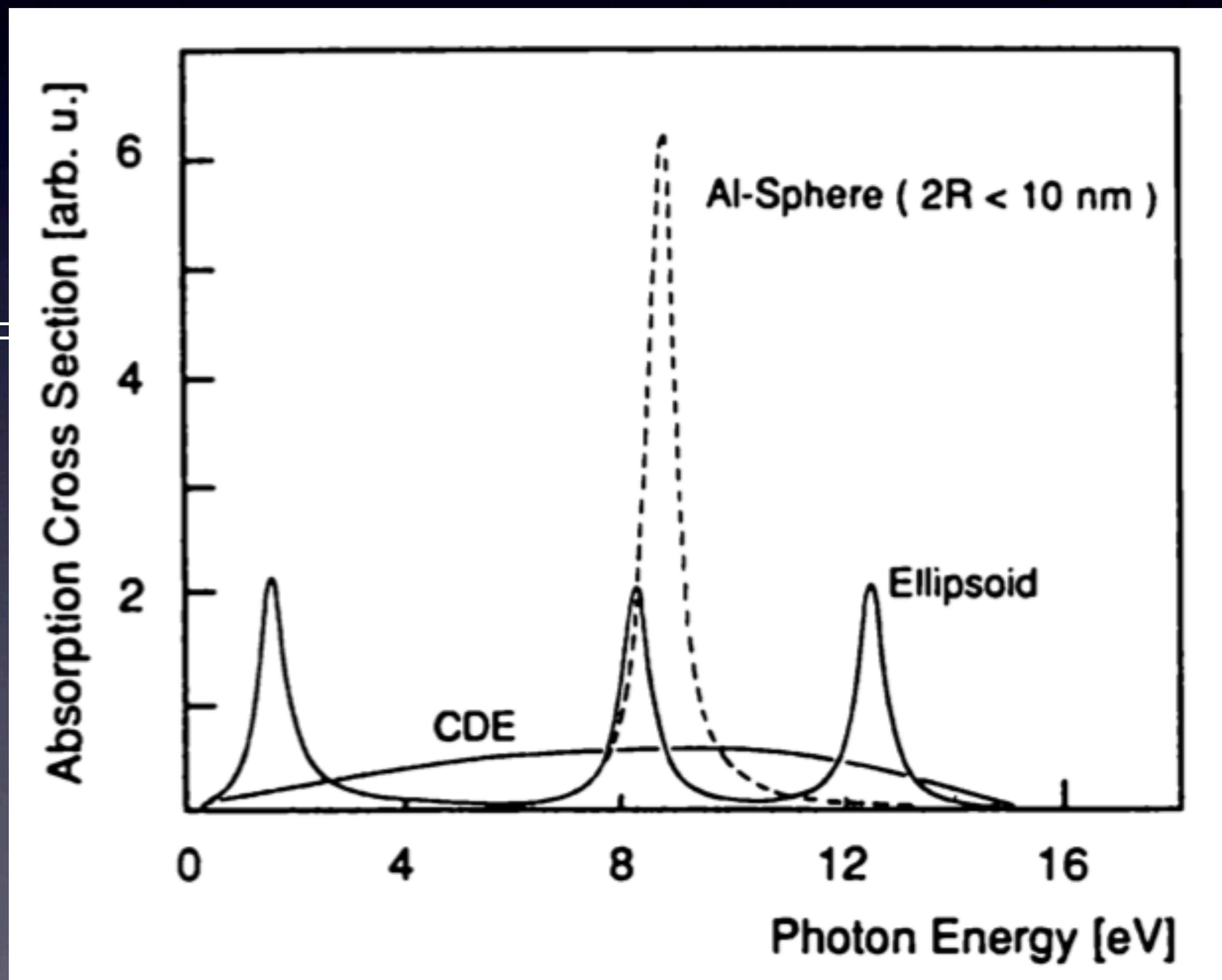
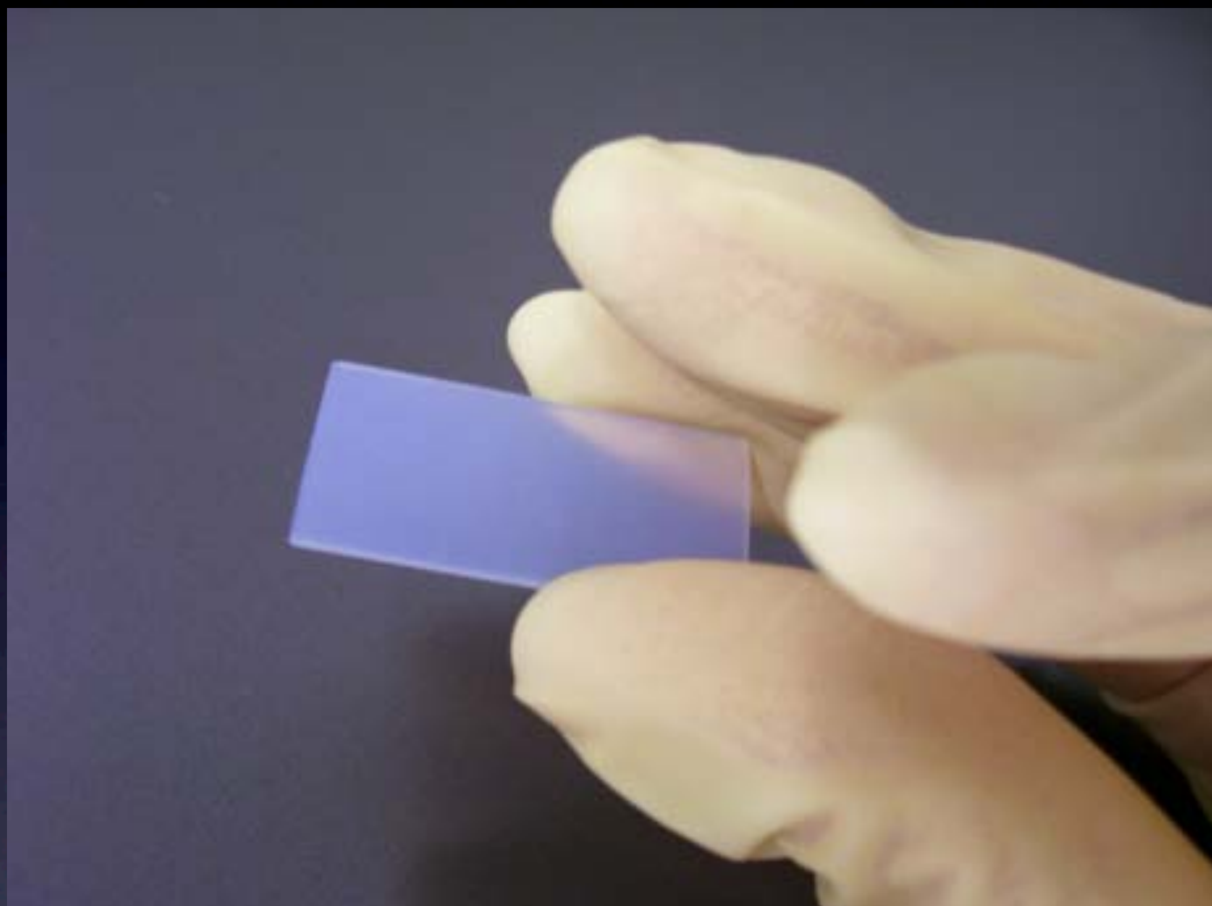
$\sigma_{ext}^{Gans} =$ … $- L_j$ … L_j … $]^2$

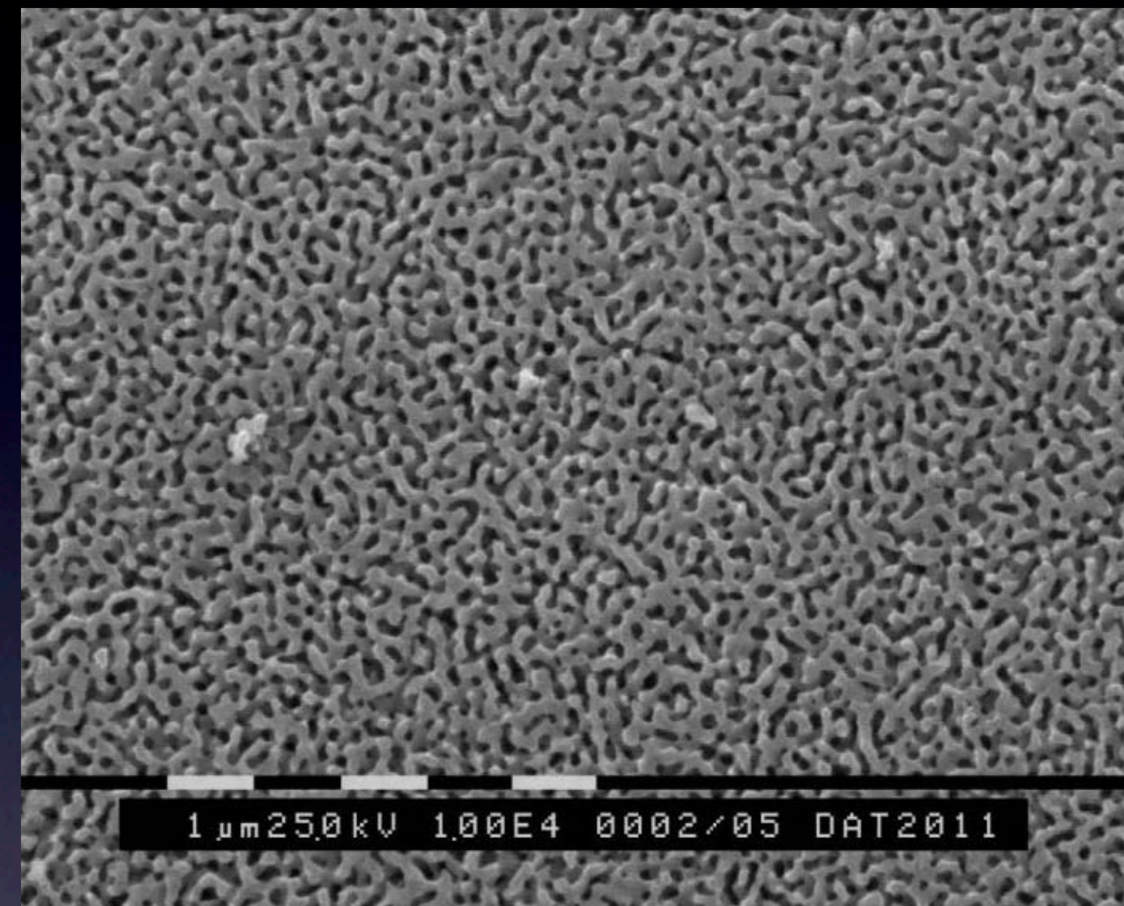


[Bohren, Huffman 1983]

Porous glass

PG: a small flat on a fingertip.





- SiO_2 96%
- B_2O_3 3%
- Traces: Na_2O, Al_2O_3, ZrO_2

Spinodal decomposition:

- domains $\sim t^{1/2}$

- average radius $\sim t$

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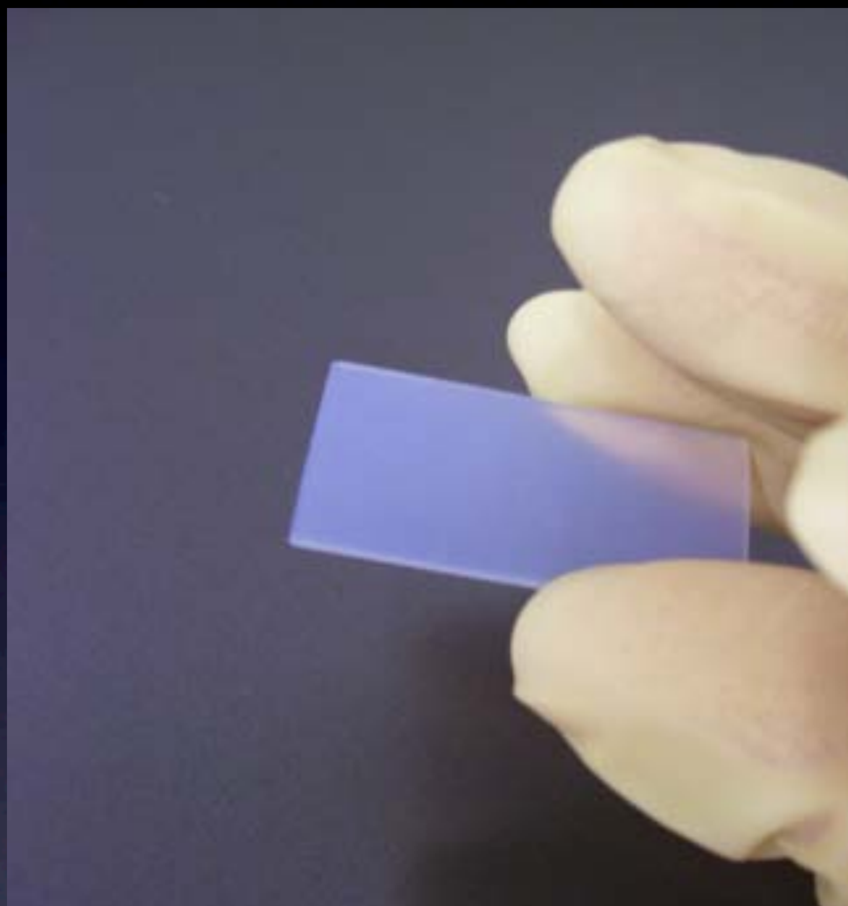

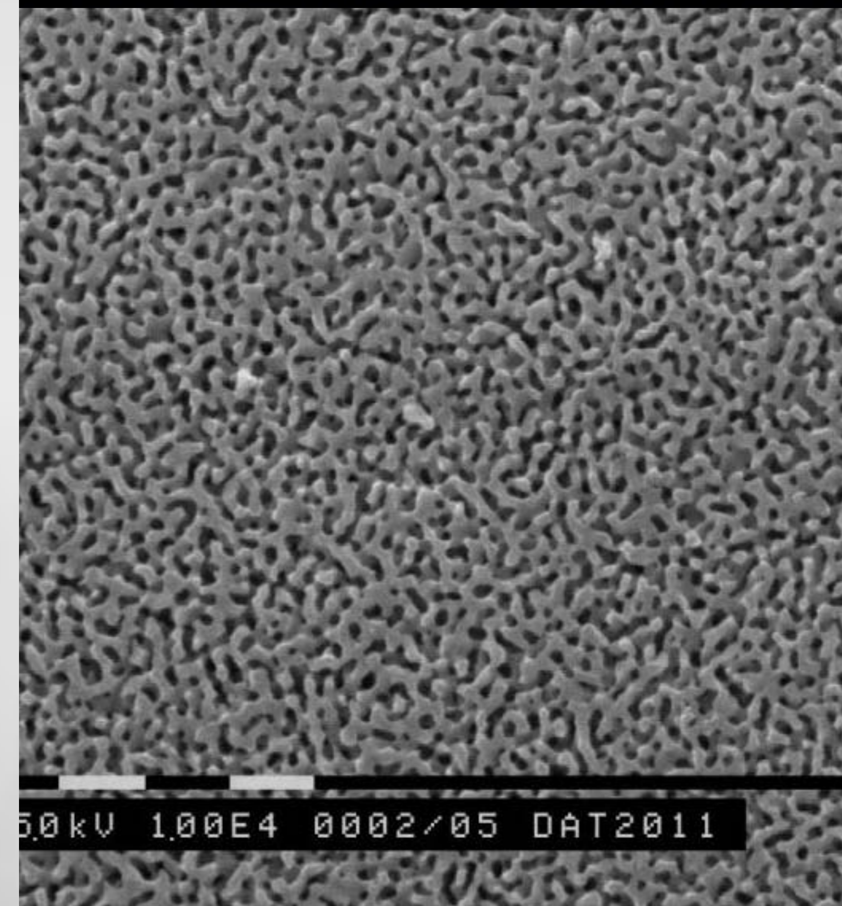

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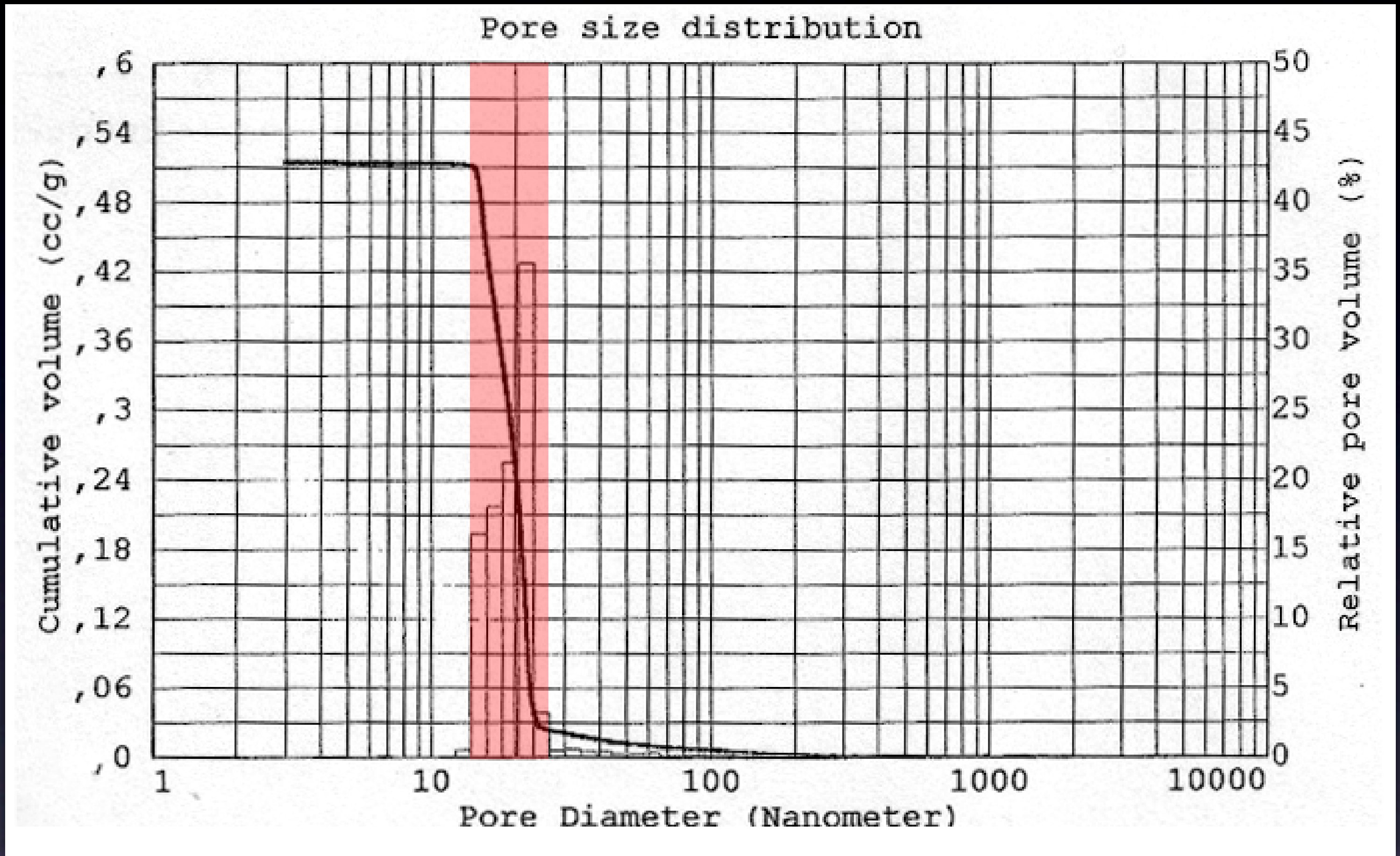

- Average pore diameter: 20 nm.
- Free volume: 0.55.
- Internal surface: 31 m^2.

Light-induced phenomena in PG

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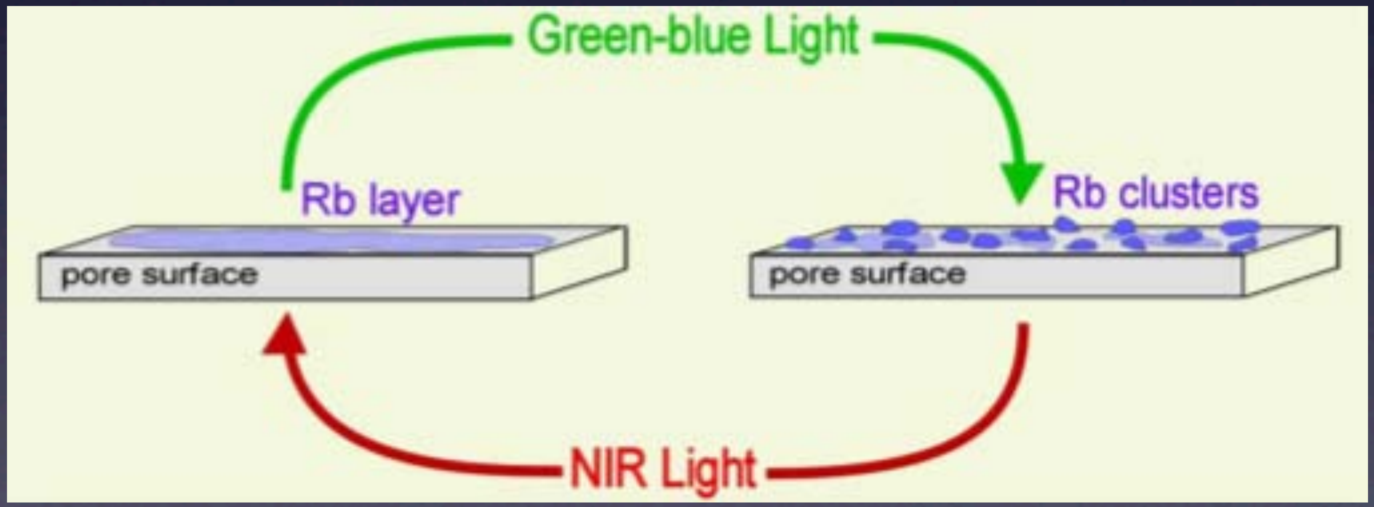

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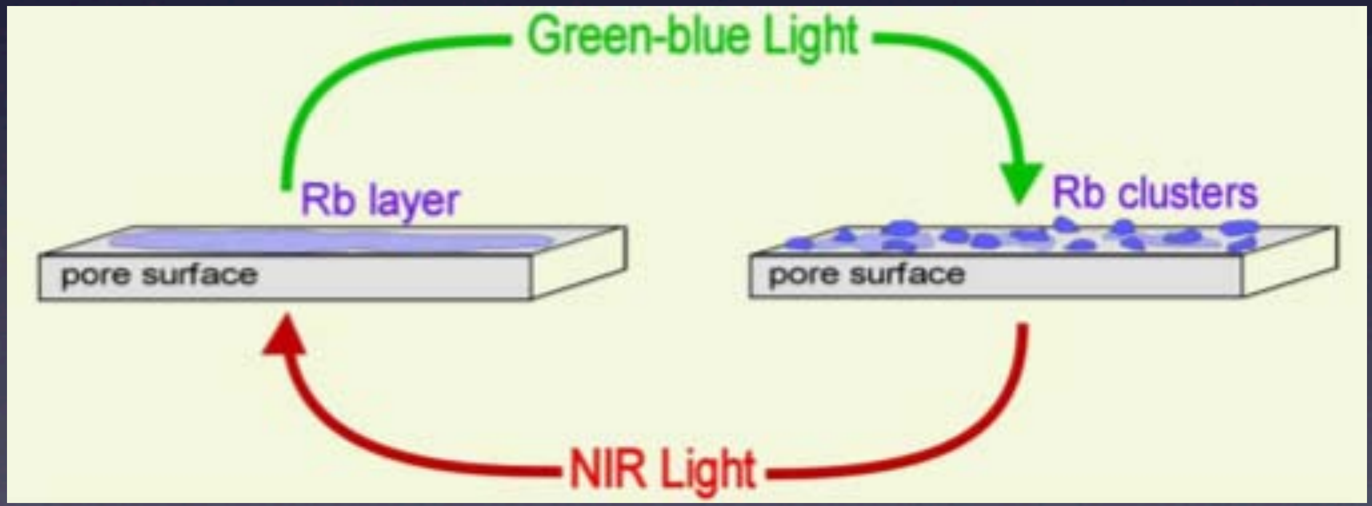

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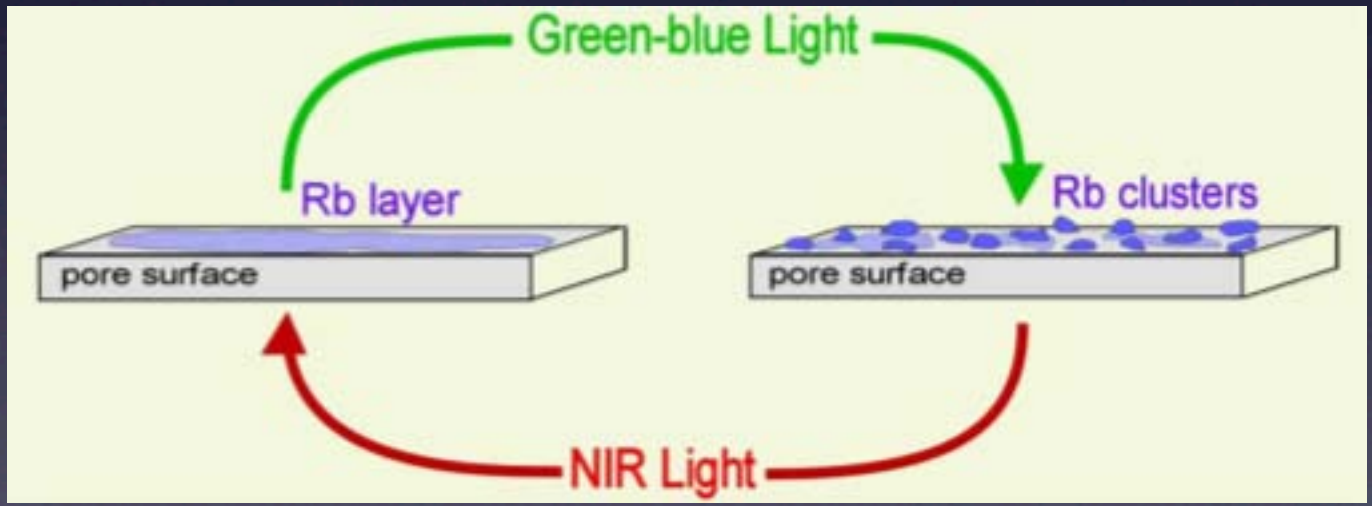
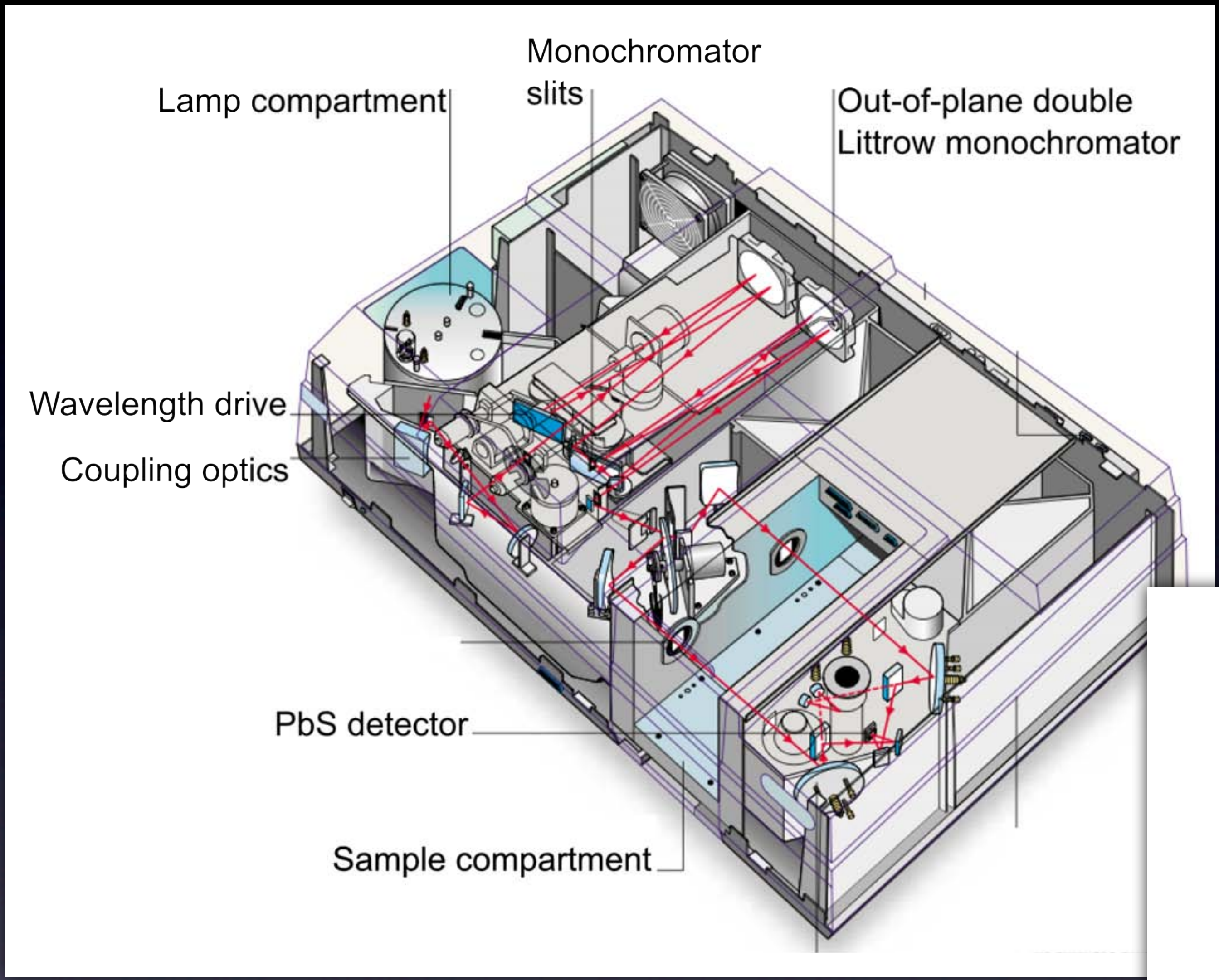


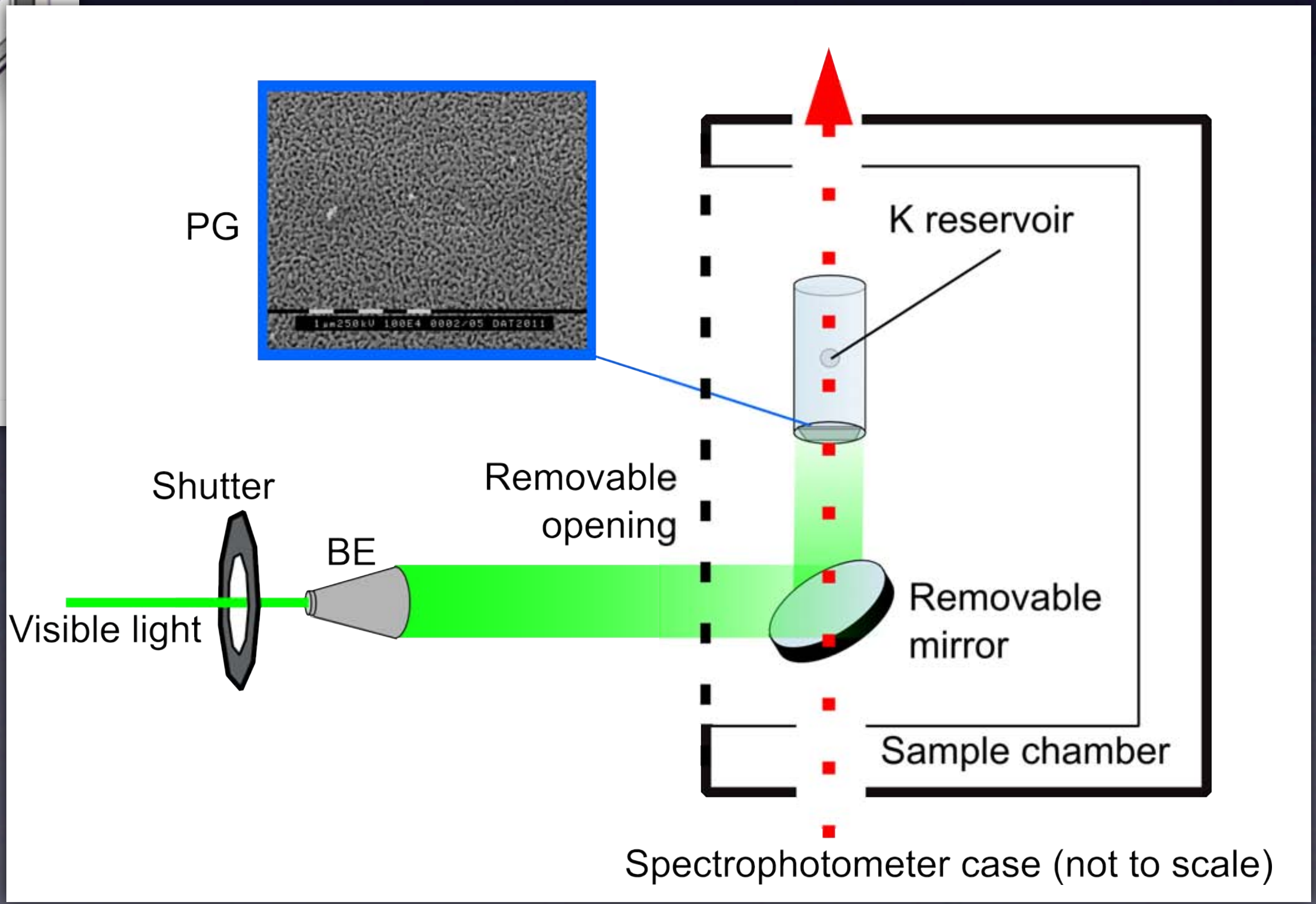
➡ Identification of spheroidal NPs [A. Burchianti *et al.*, Eur. Phys. J. D. **49**, 201, 2008].

Experimental apparatus

"Static" characterization: absorbance analysis.

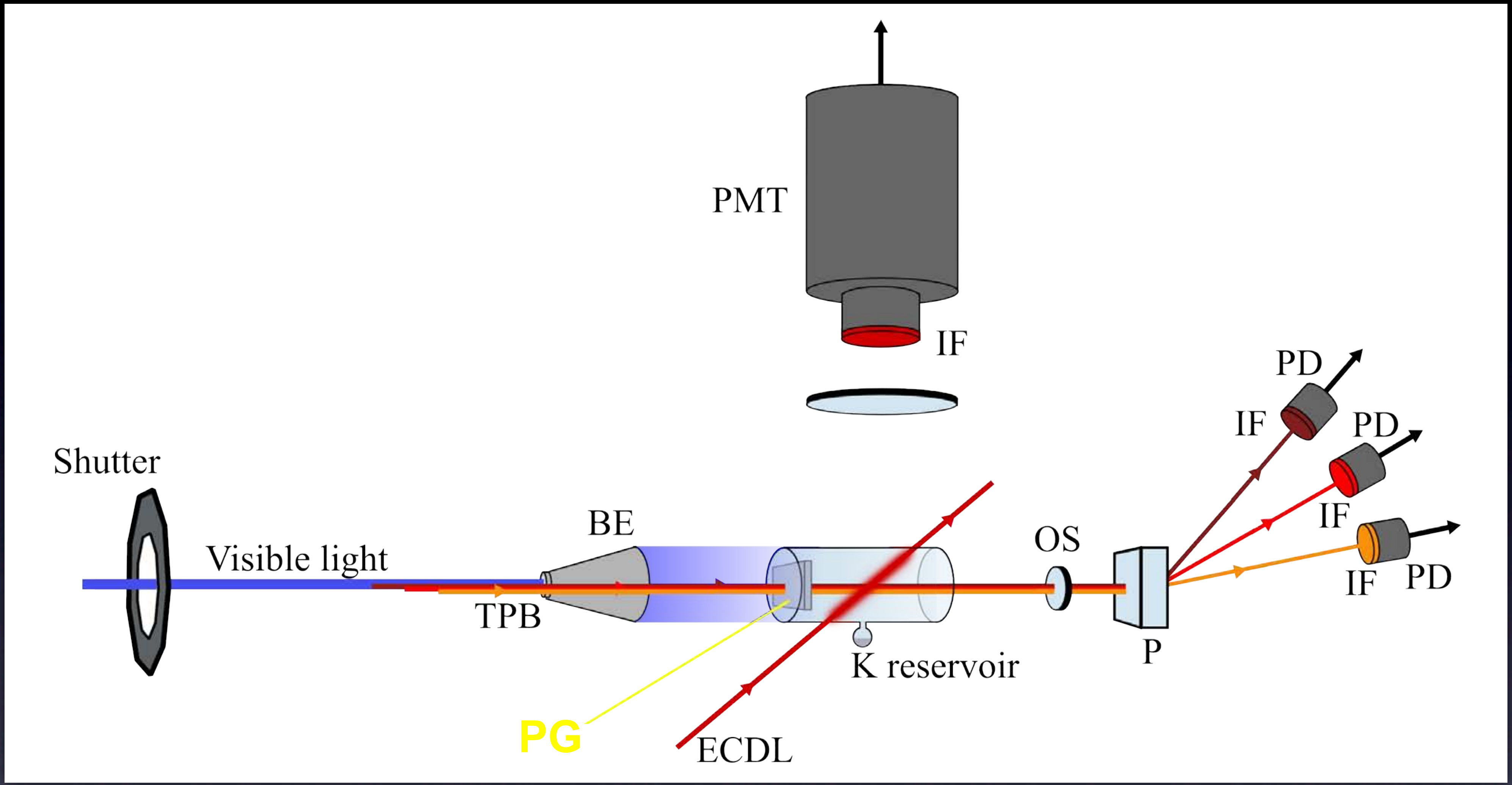


$$Abs \equiv -\log \frac{T(\lambda)}{I_0}$$



Experimental apparatus

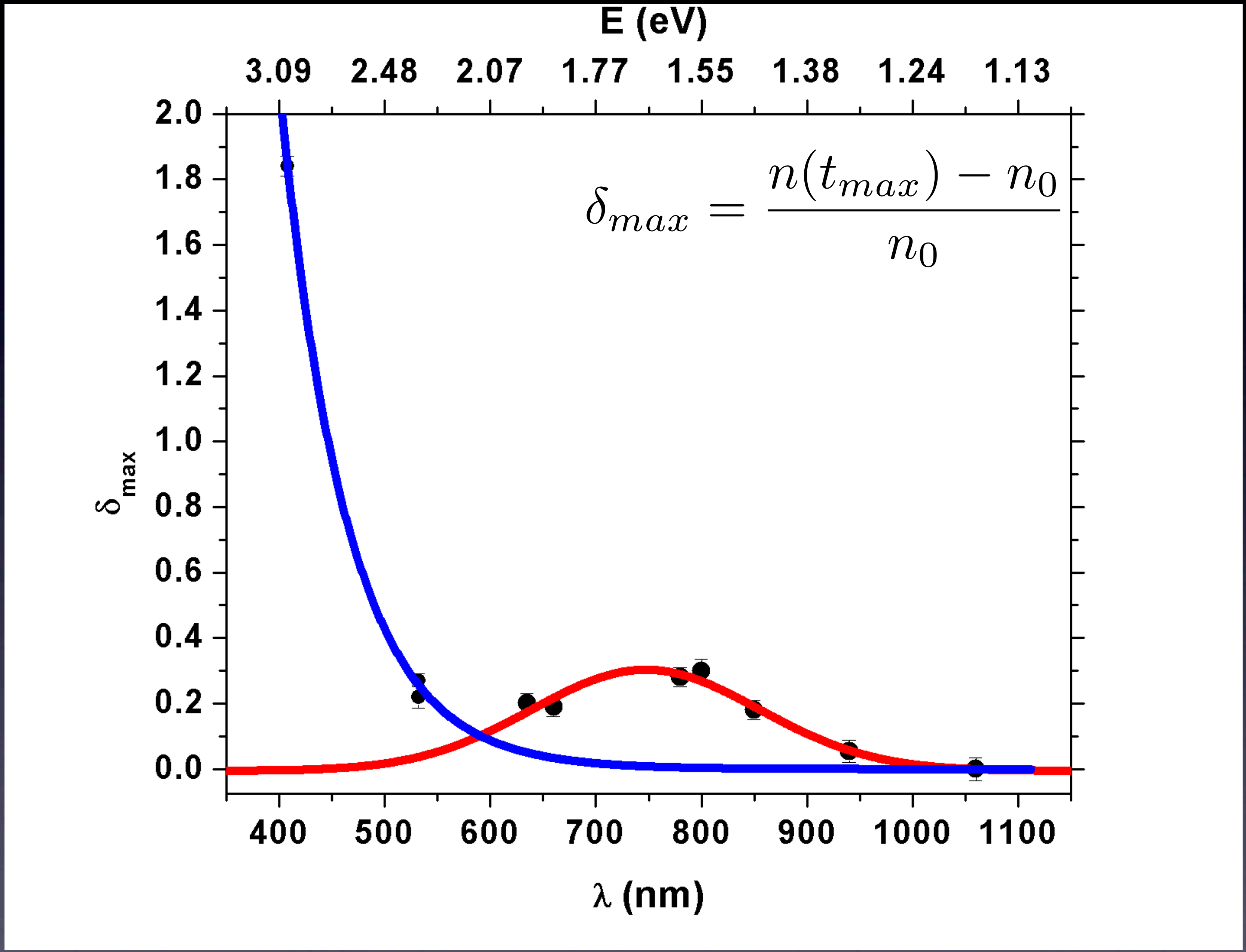
“Dynamic” characterization: time evolution.



- K vapor density: ECDL @ 770.1 nm (K D1 line), ~2.5 GHz sweep, 47 Hz
- Desorbing lights: LD @ 660 nm, DPSSL @ 532 nm, LD @ 405 nm
- TPBs: LD @ 730 nm, 780 nm, 830 nm, 850 nm, 1460 nm
- DAQ: I/O multi-channel, background subtraction+resonance following, illumination timing

Light-induced processes in K PG

Two simultaneous processes.



$$\hbar\omega_{exp} = 1.66 \pm 0.02 \text{ eV}$$

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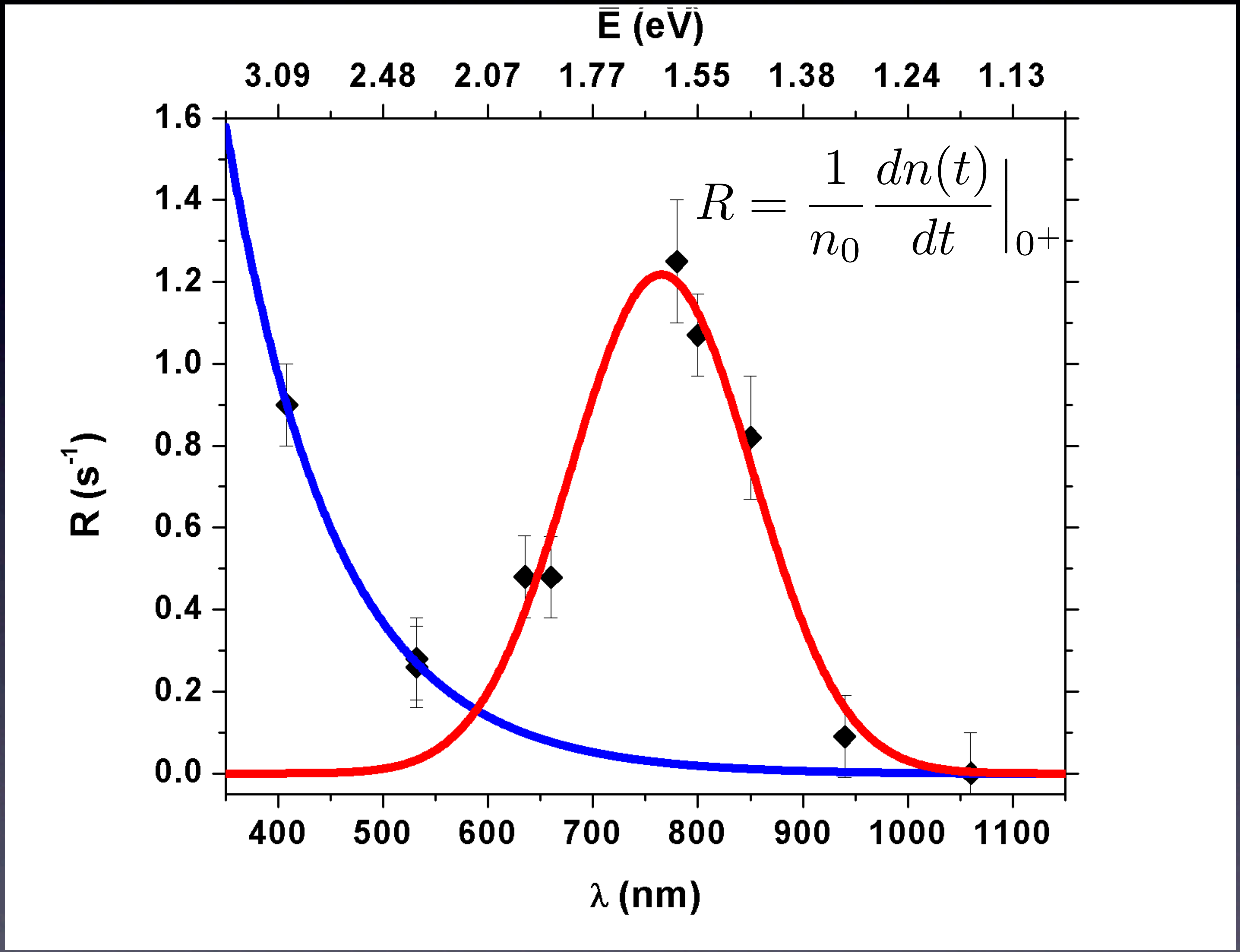

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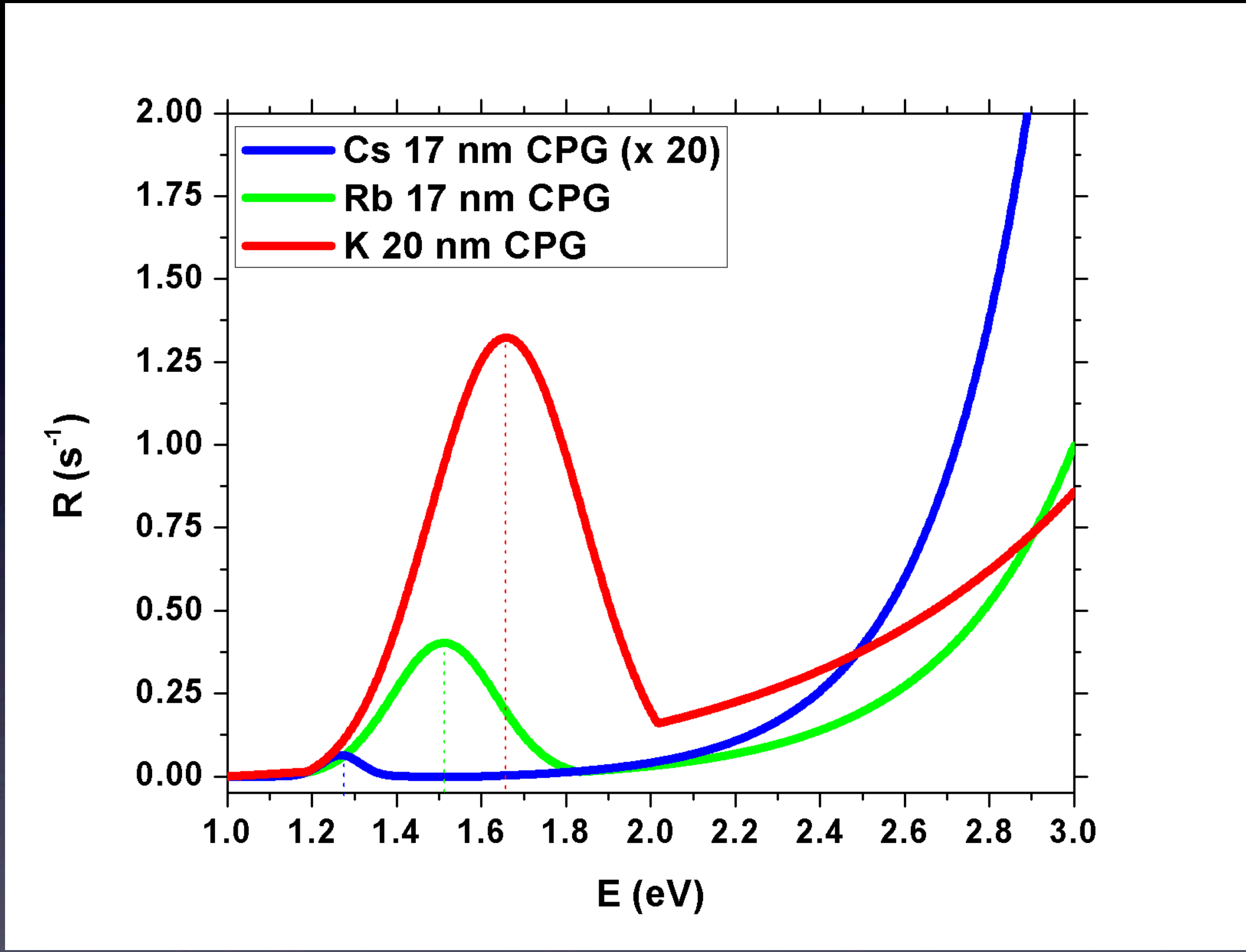

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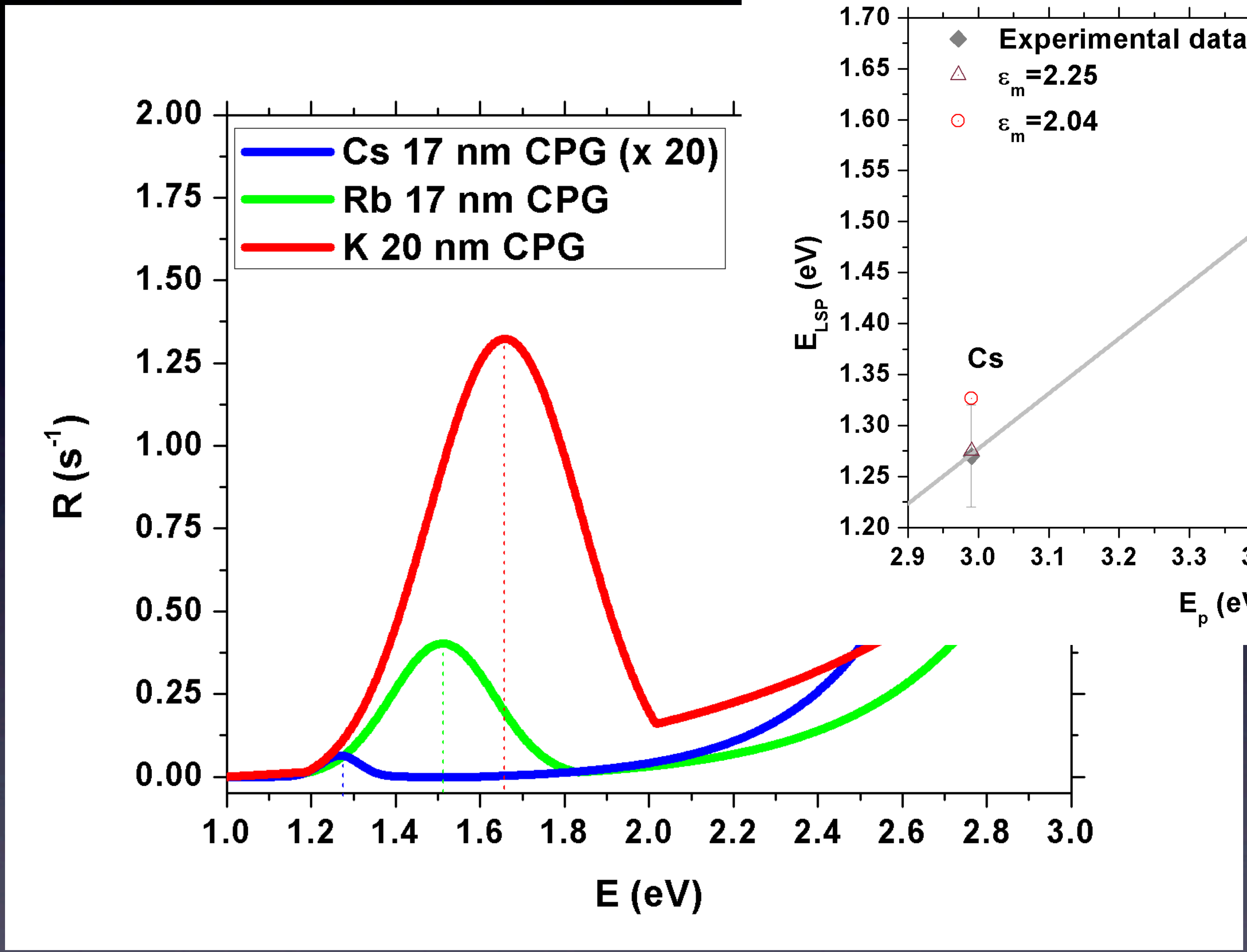

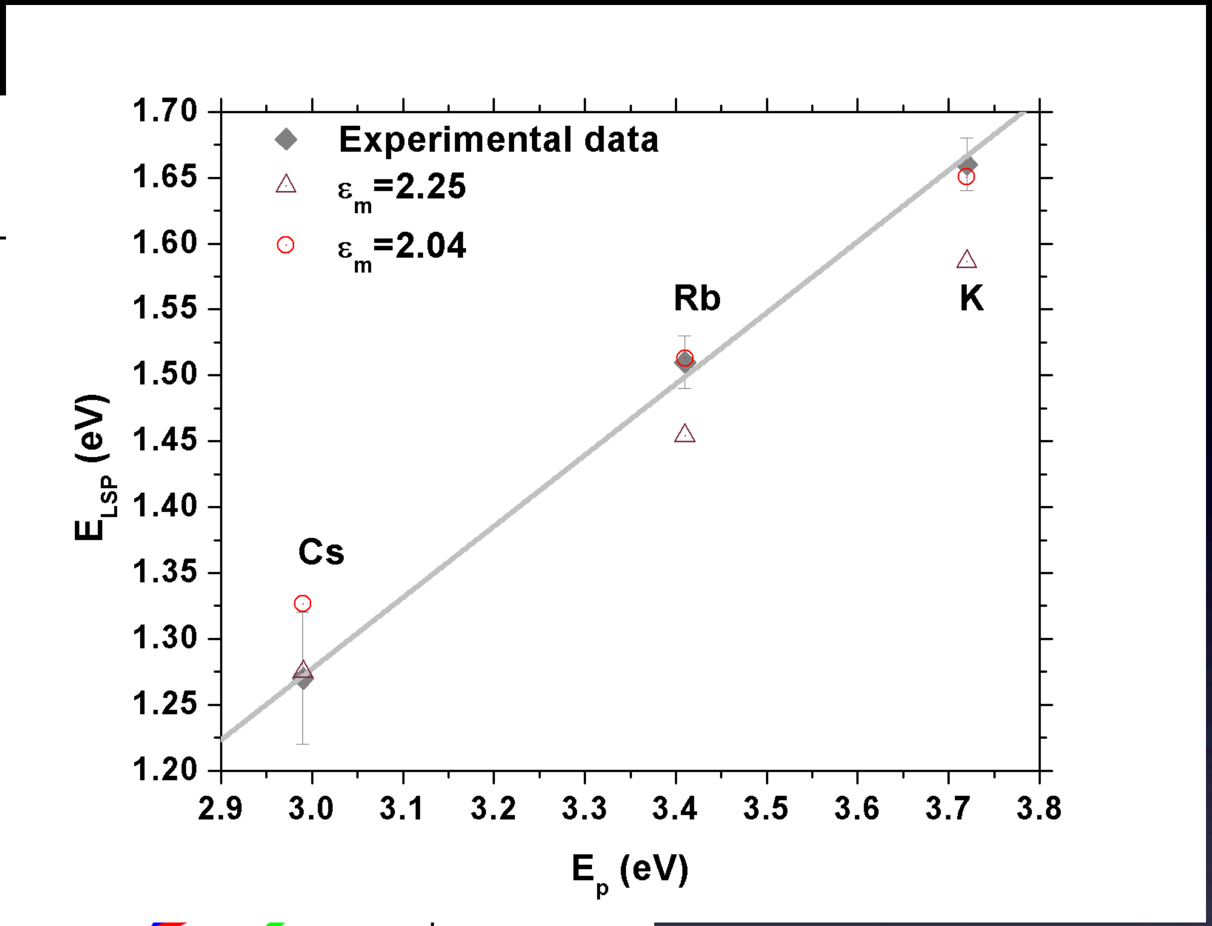

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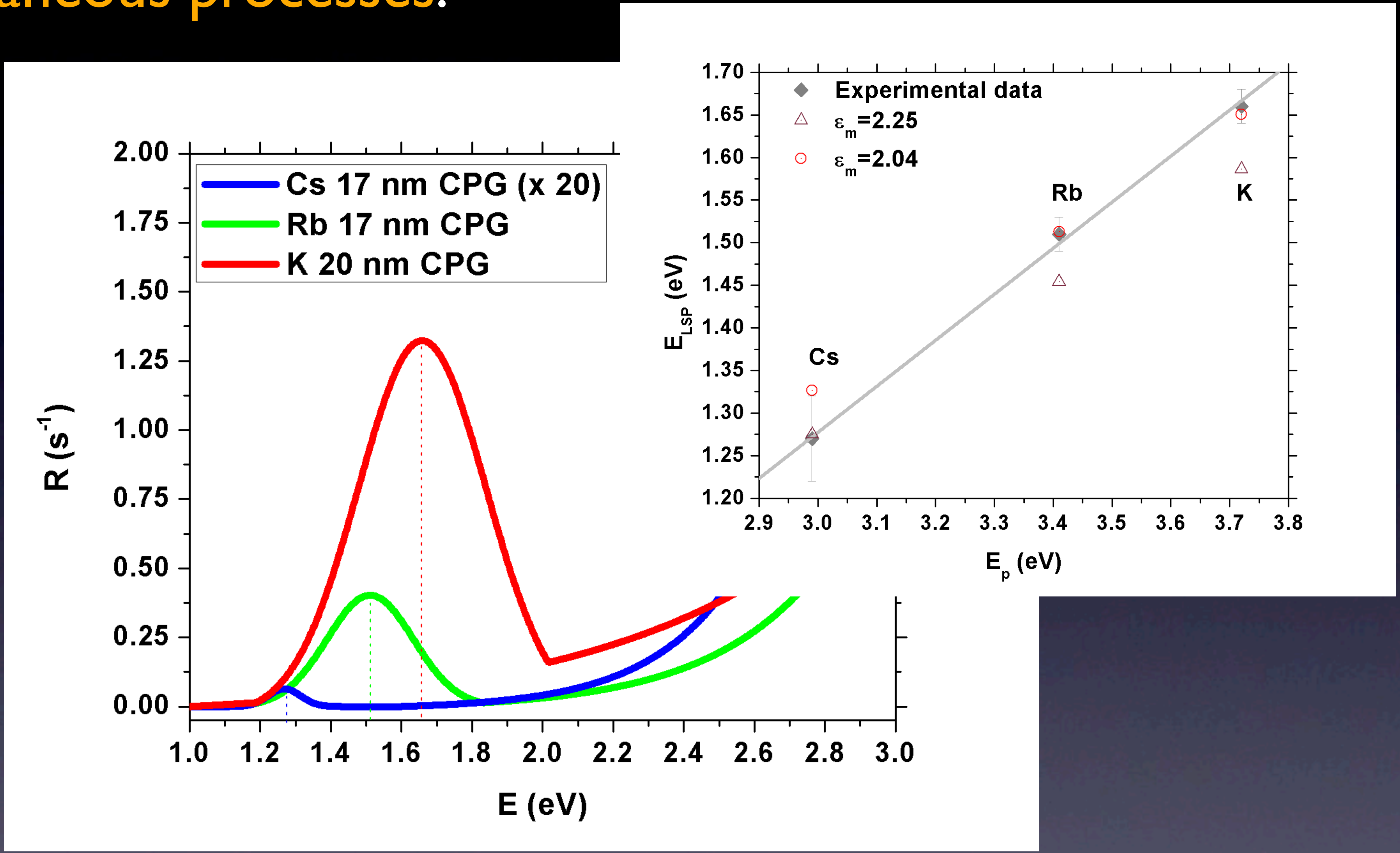
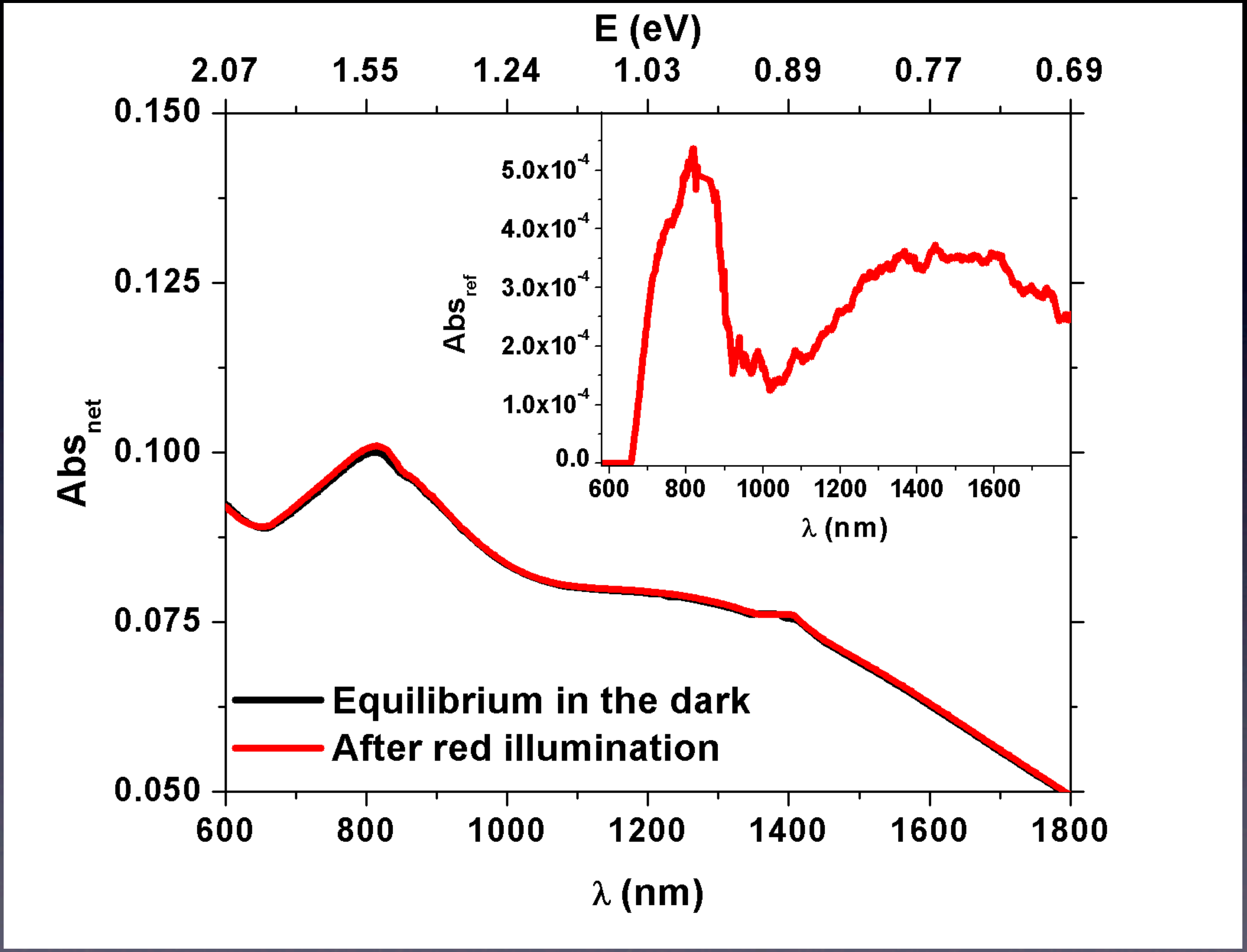


$$\varepsilon_{eff} = 2.04$$
$$\hbar\omega_p = 3.72 \text{ eV}$$

$$\hbar\omega_{LSP} = \frac{\hbar\omega_p}{\sqrt{1+2\varepsilon_{eff}}} = 1.65 \text{ eV}$$

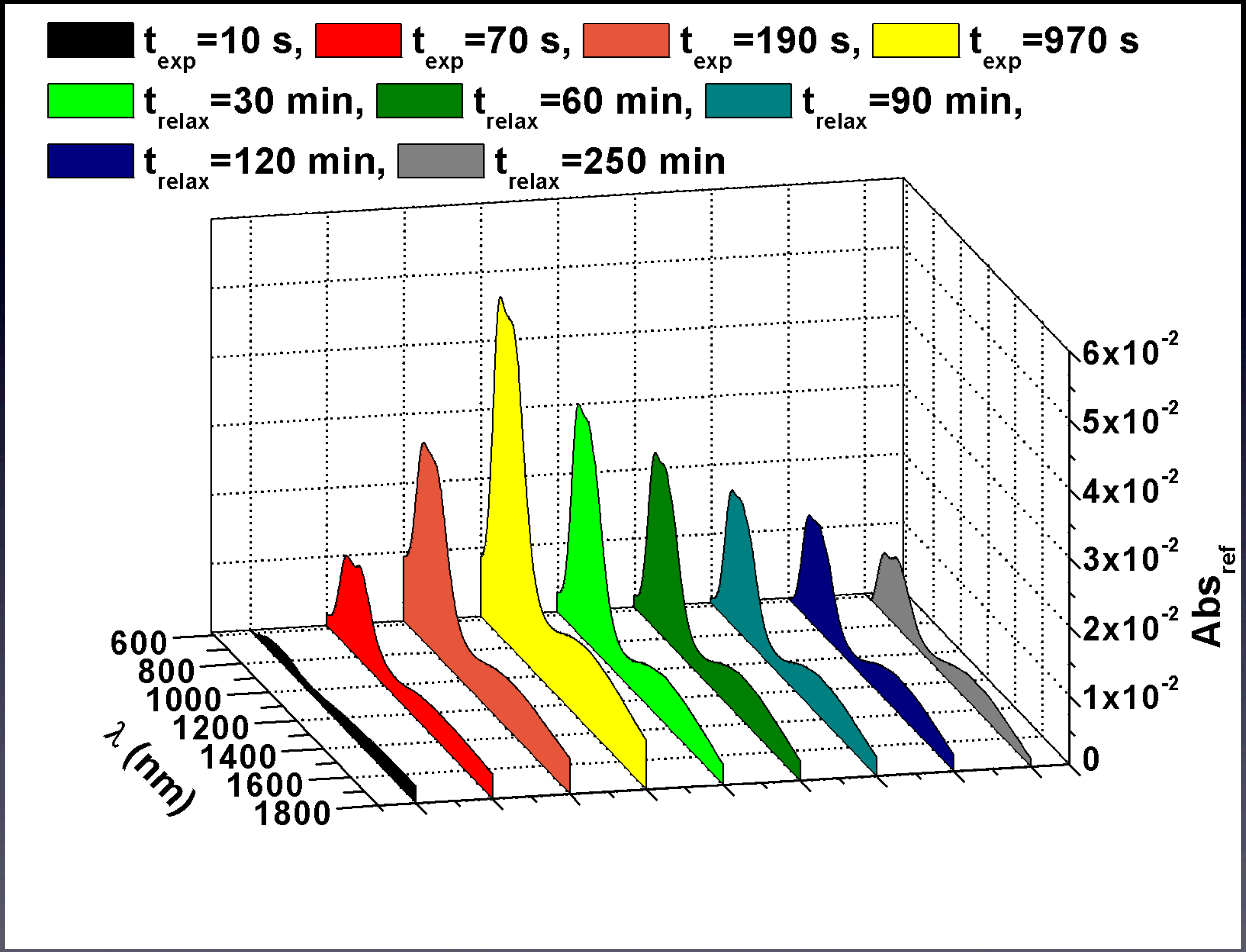
Absorbance spectra

60 mW/cm^2 at 635 nm, 120 s: low desorption regime.



Absorbance spectra

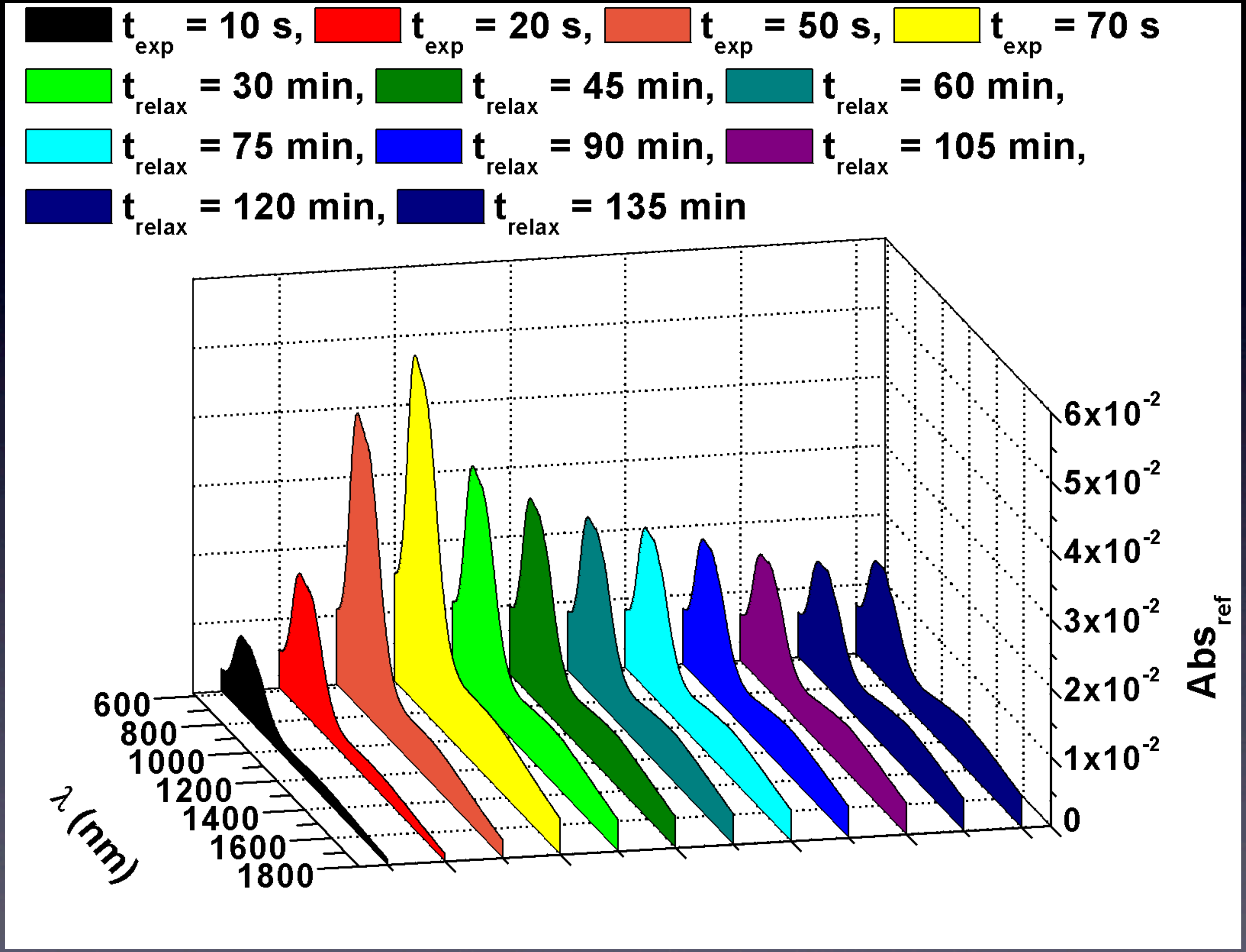
350 mW/cm^2 at 532 nm: desorption regime.



Light as a NPs maker.

Absorbance spectra

5 mW/cm² at 405 nm: efficient desorption regime.



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Near-infrared peak: light-induced self-assembly.

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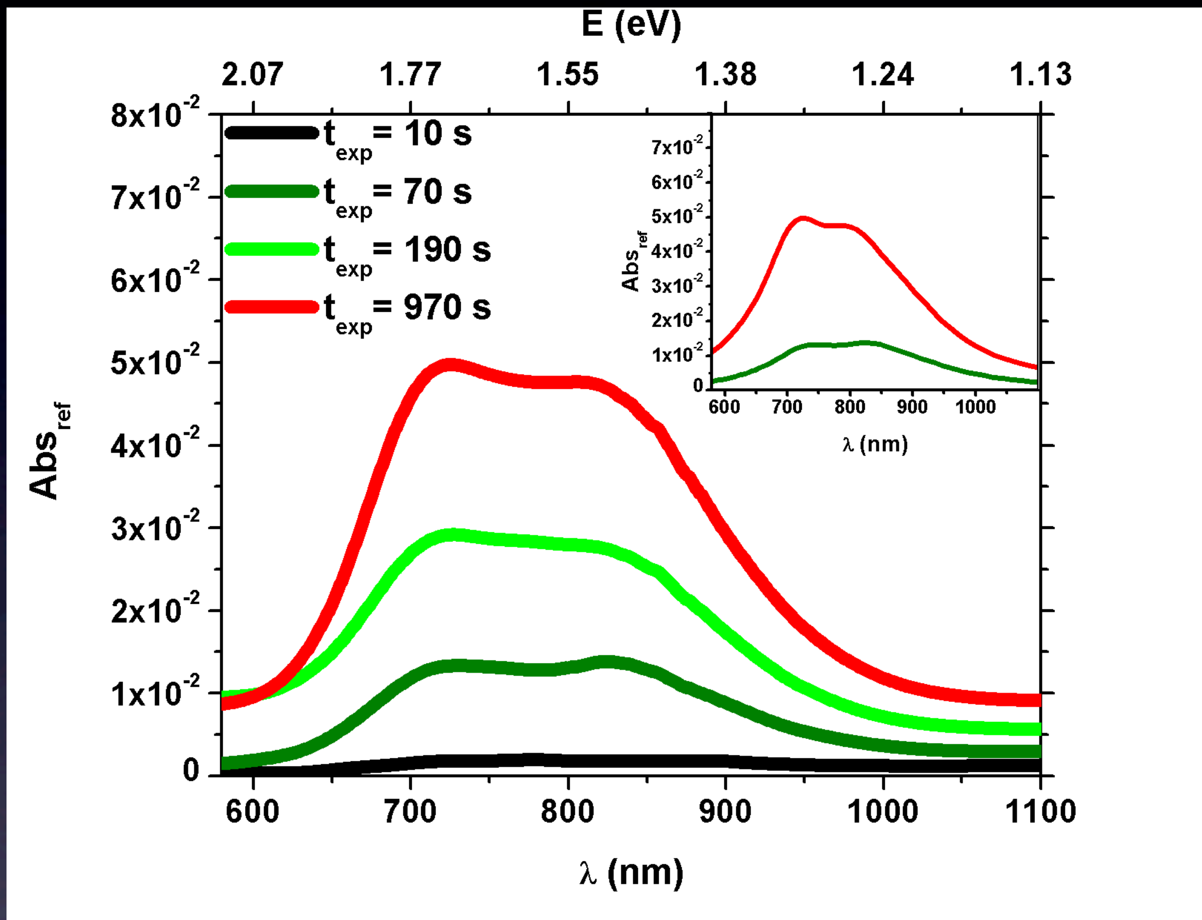

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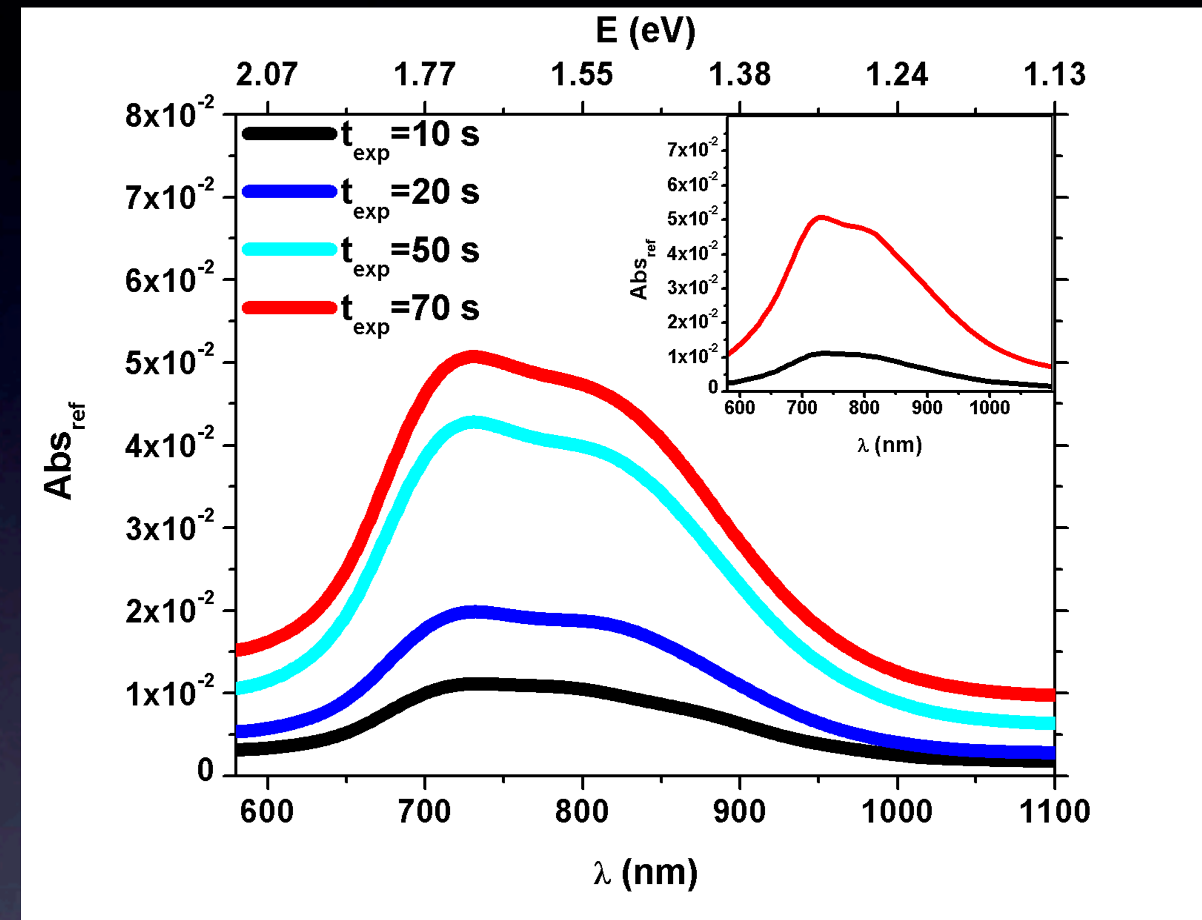

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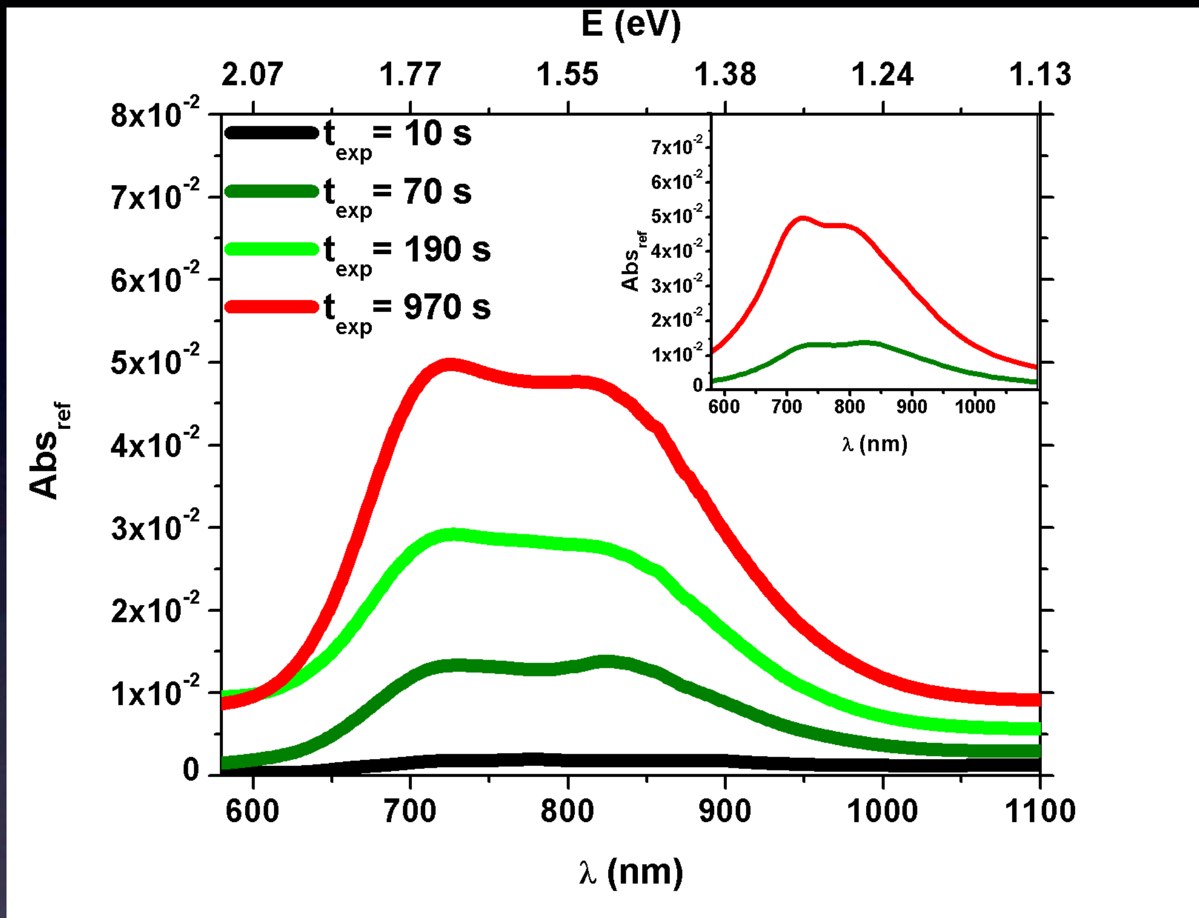

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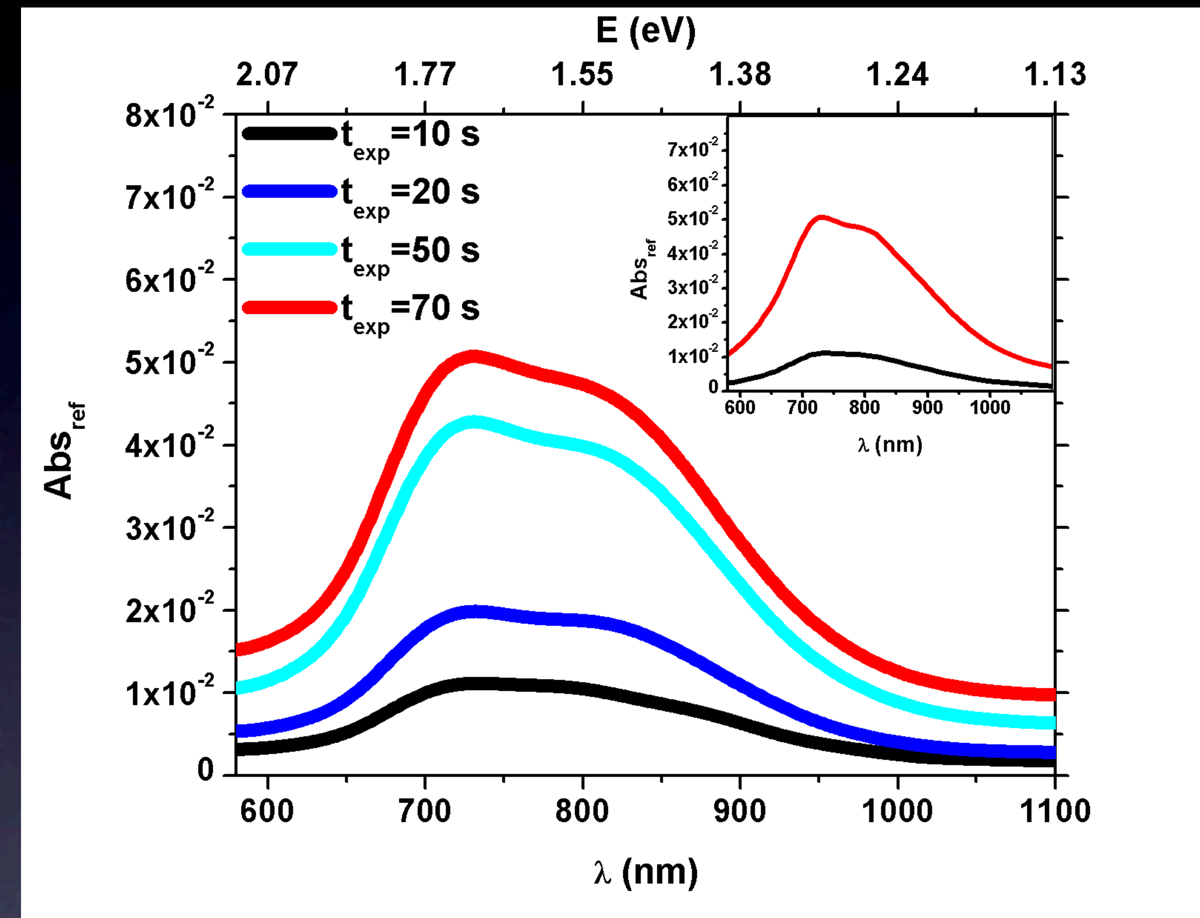
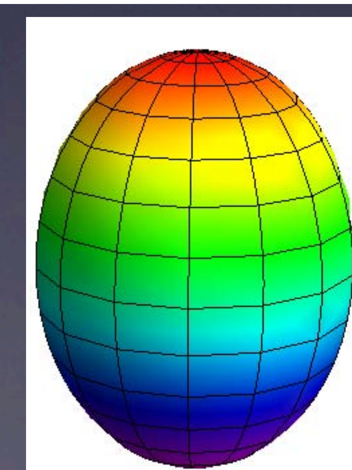


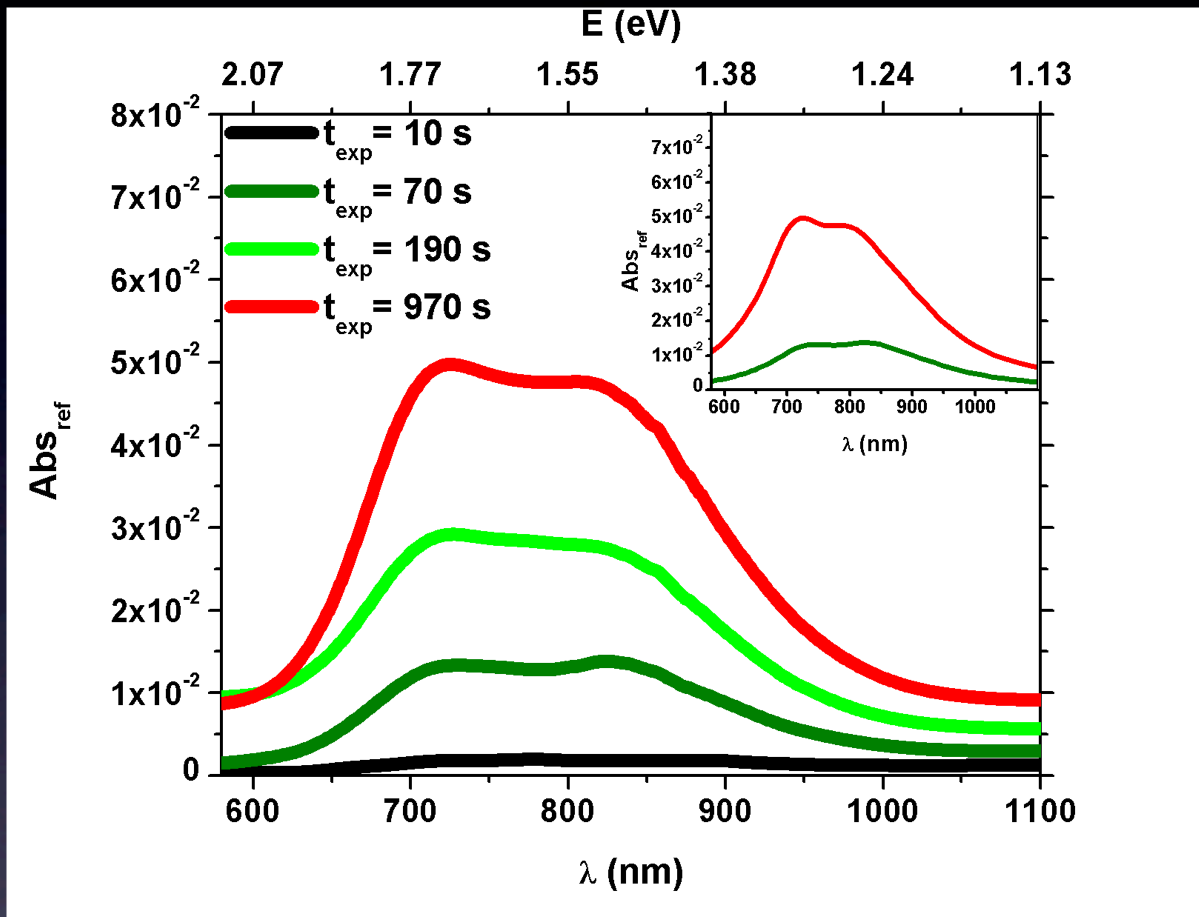


2 nm prolates, AR=0.75

Absorbance spectra

Near-infrared peak: light-induced self-assembly.

350 mW/cm² @ 532 nm



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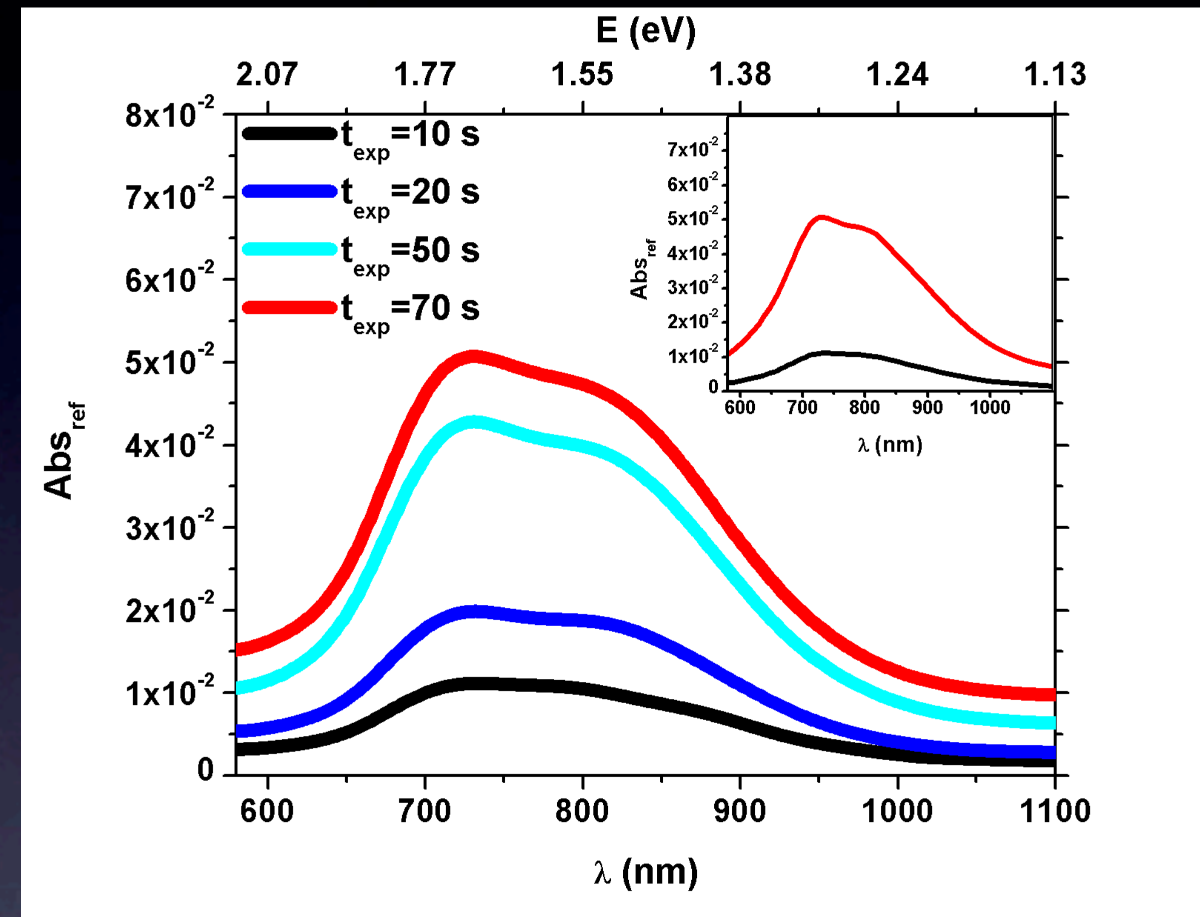
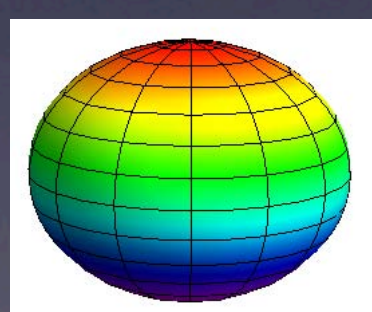
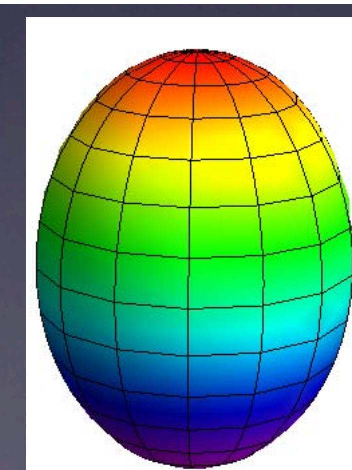




2 nm oblates, AR=1.25



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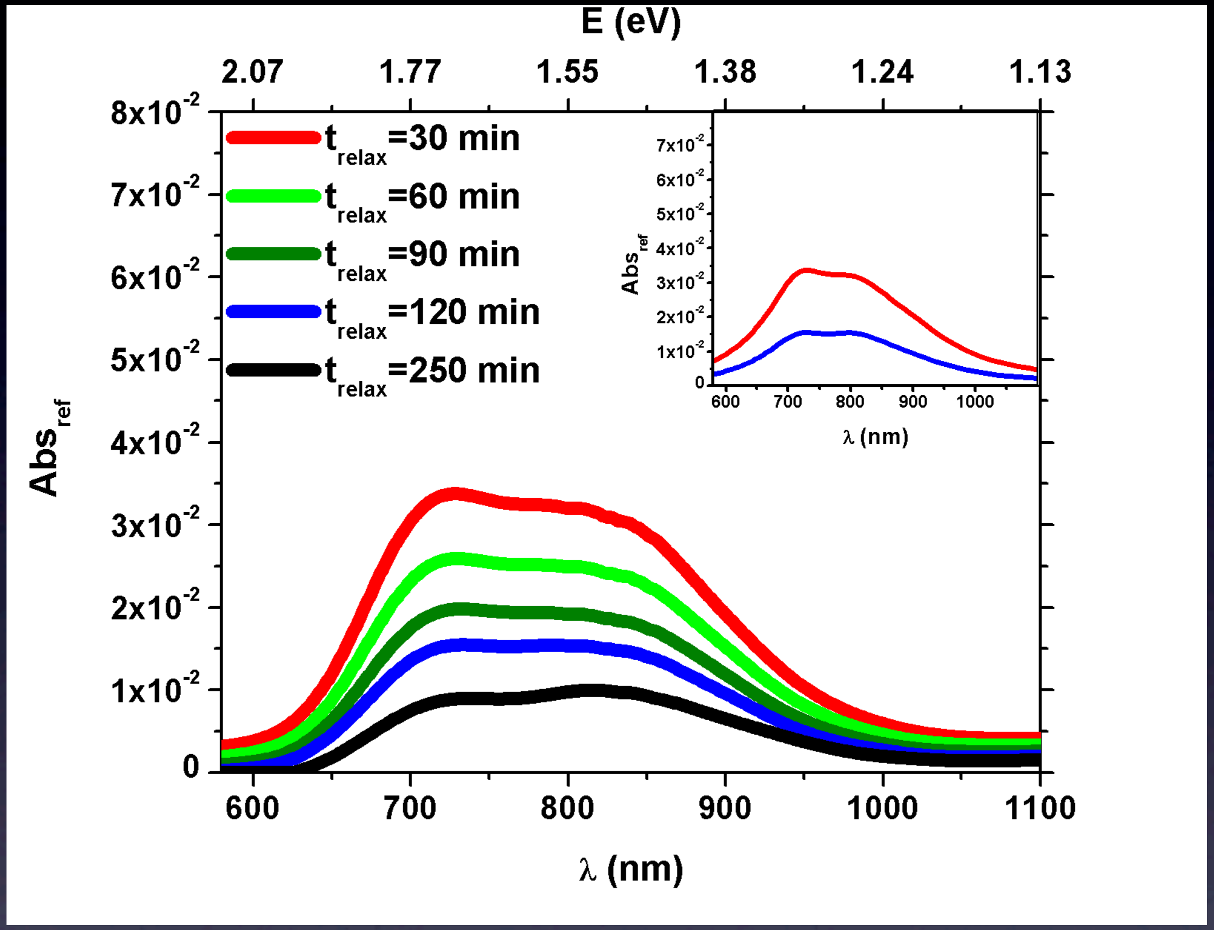
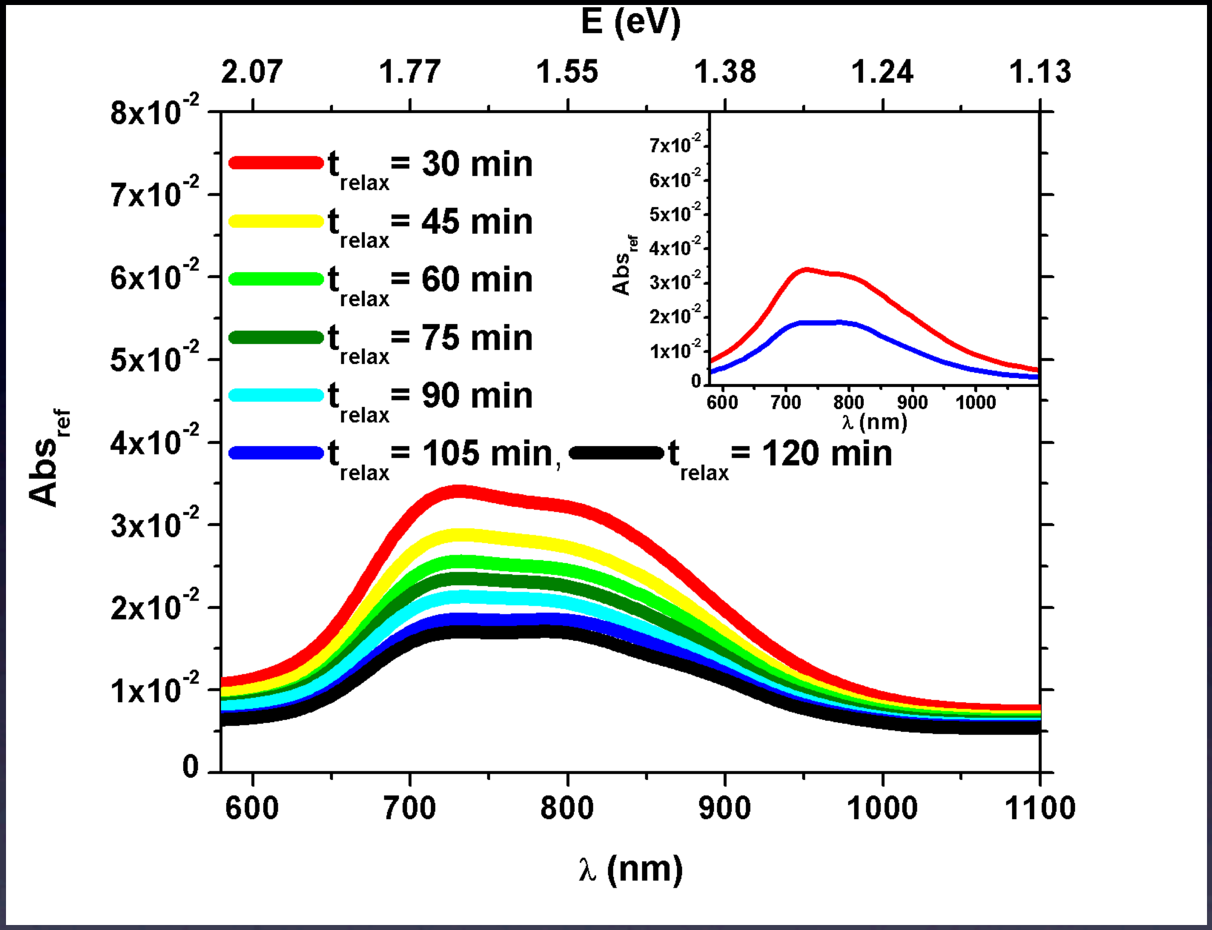
Absorbance spectra

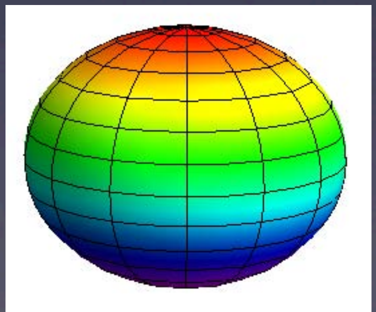
Near-infrared peak: relaxation in the dark.

After 350 mW/cm² @ 532 nm



After 5 mW/cm² @ 405 nm





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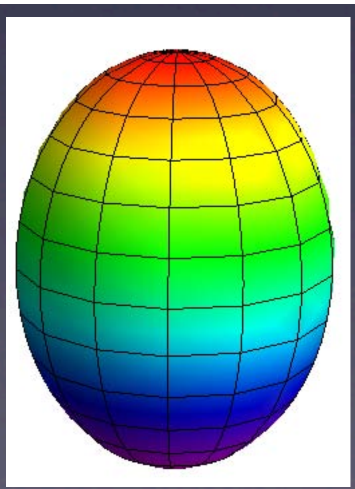

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Optical control of NPs self-assembly

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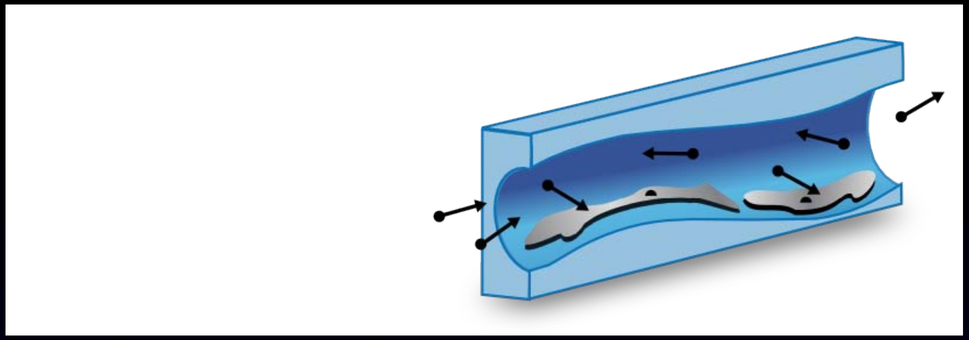

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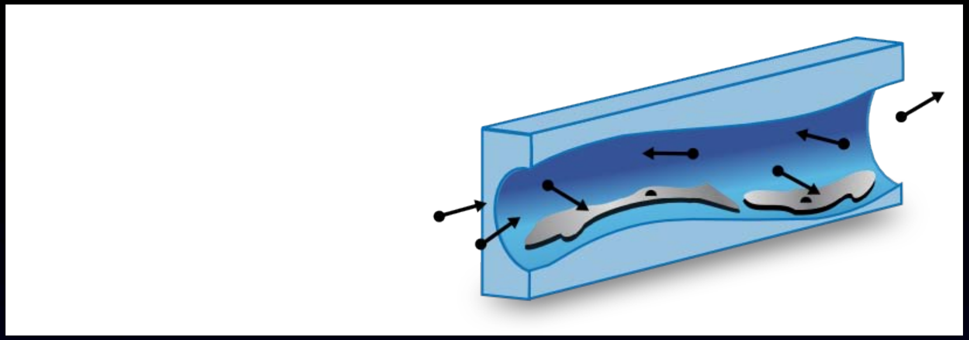
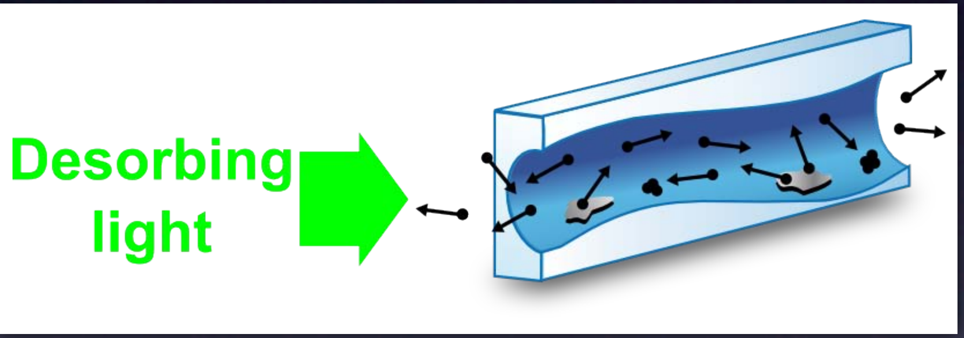


II. Light-induced desorption: enhanced atomic mobility.



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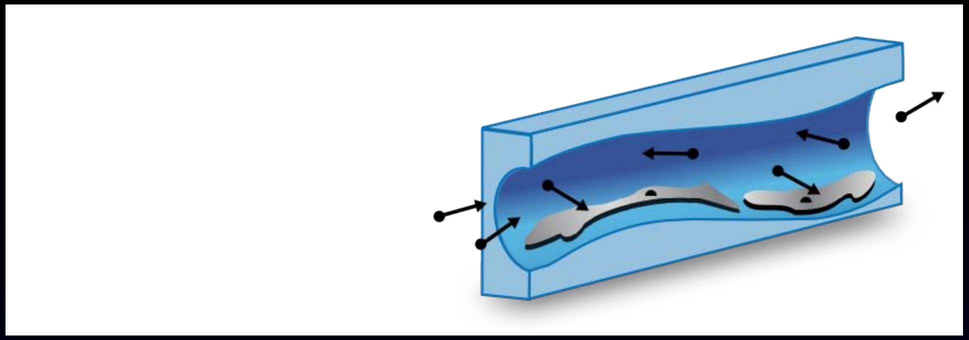

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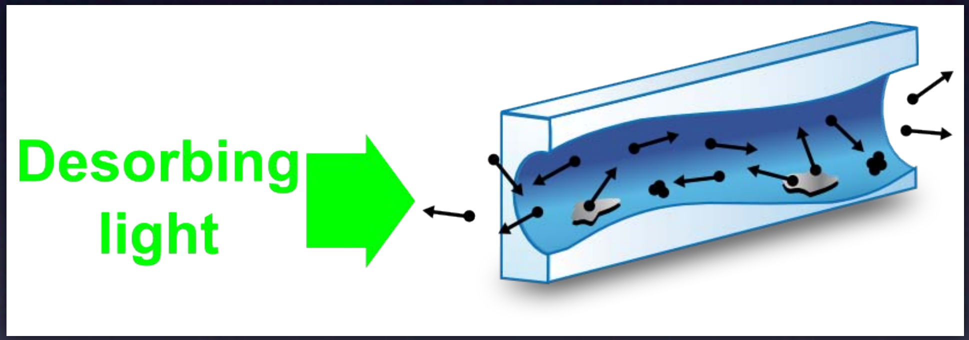

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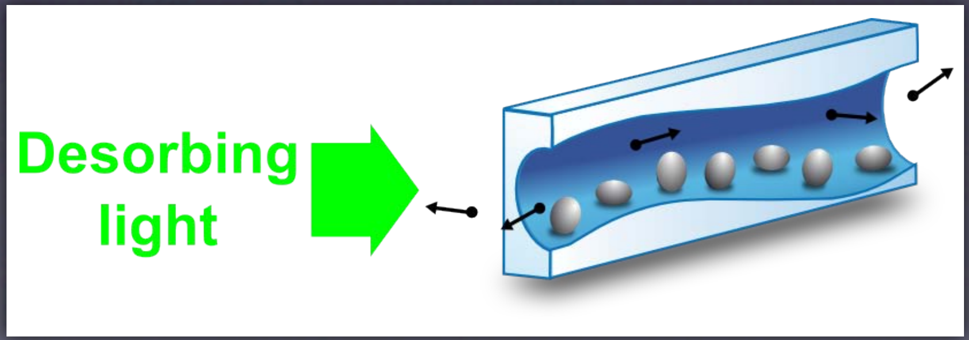

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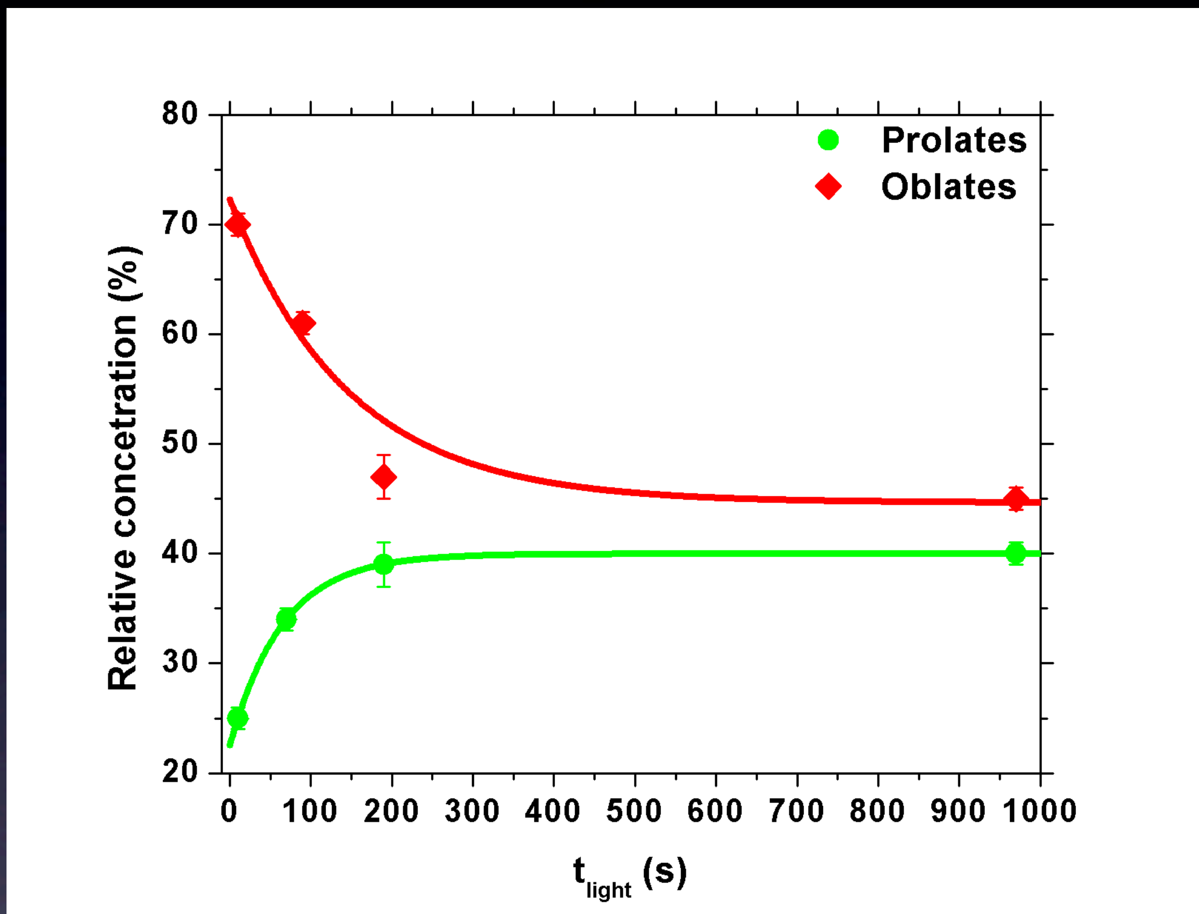

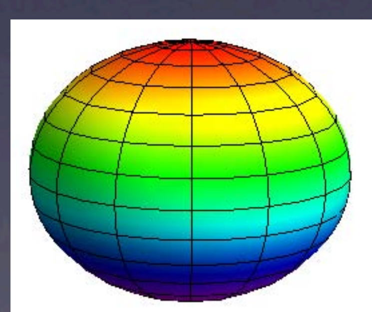

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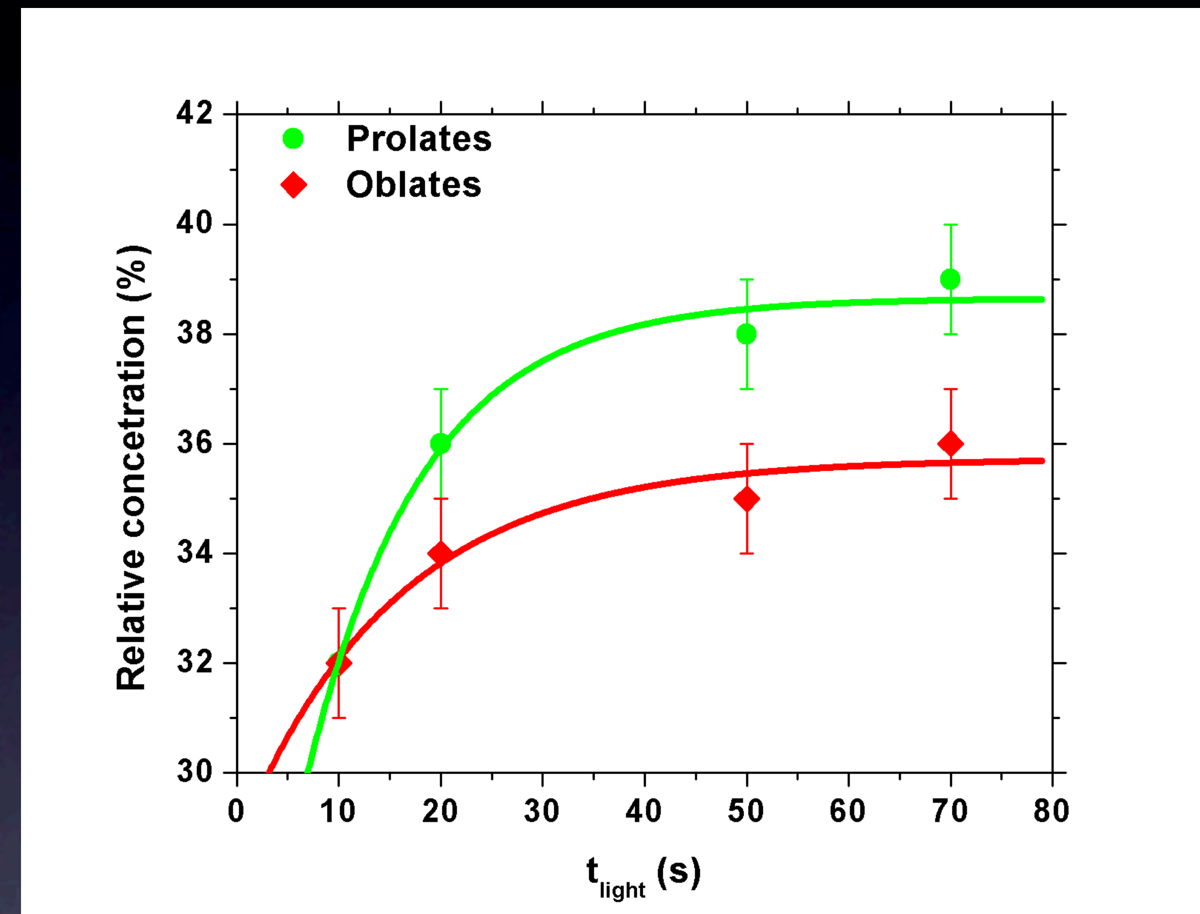

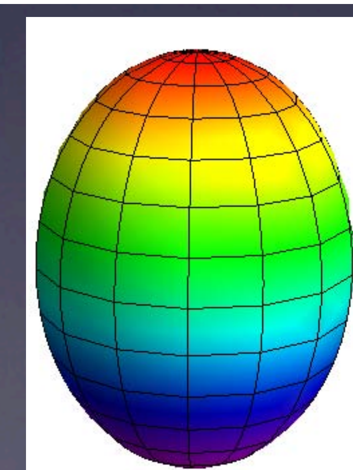

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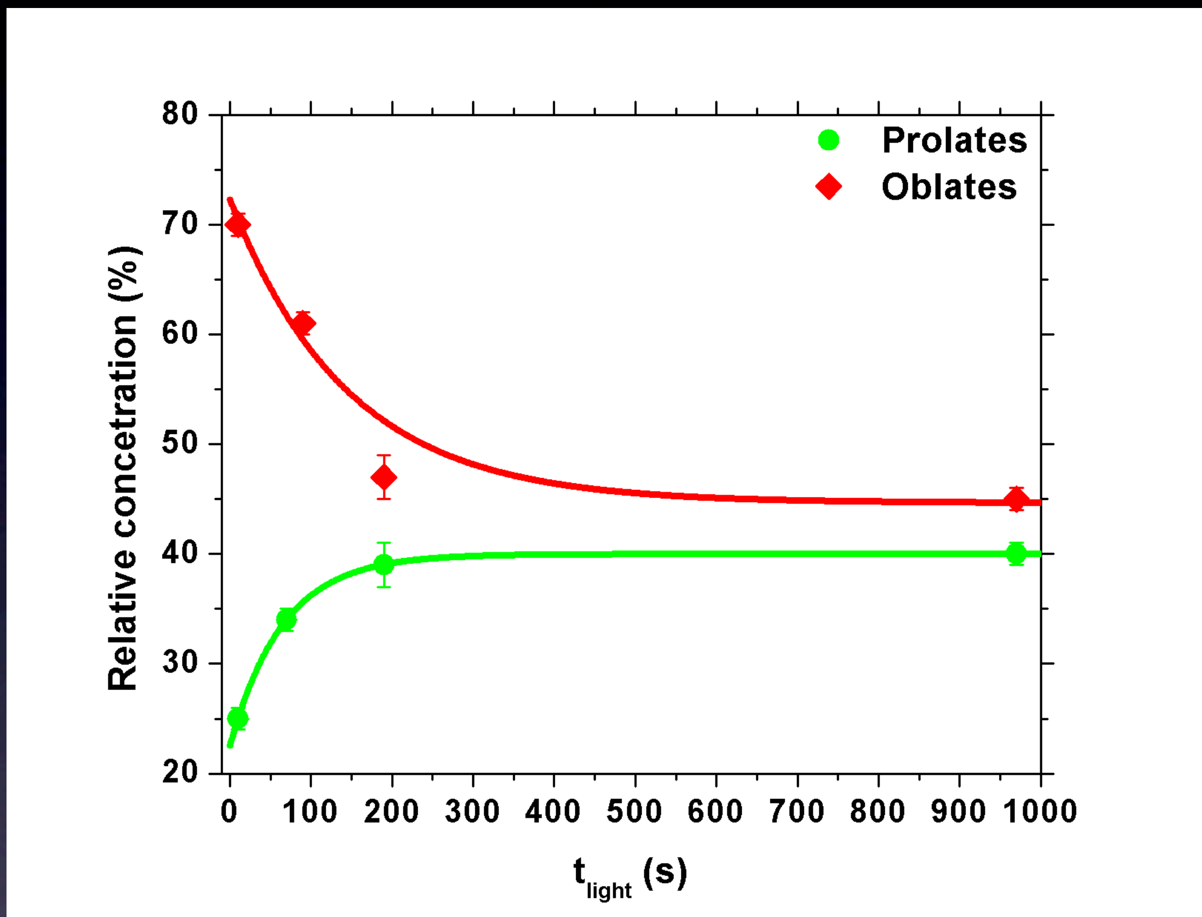

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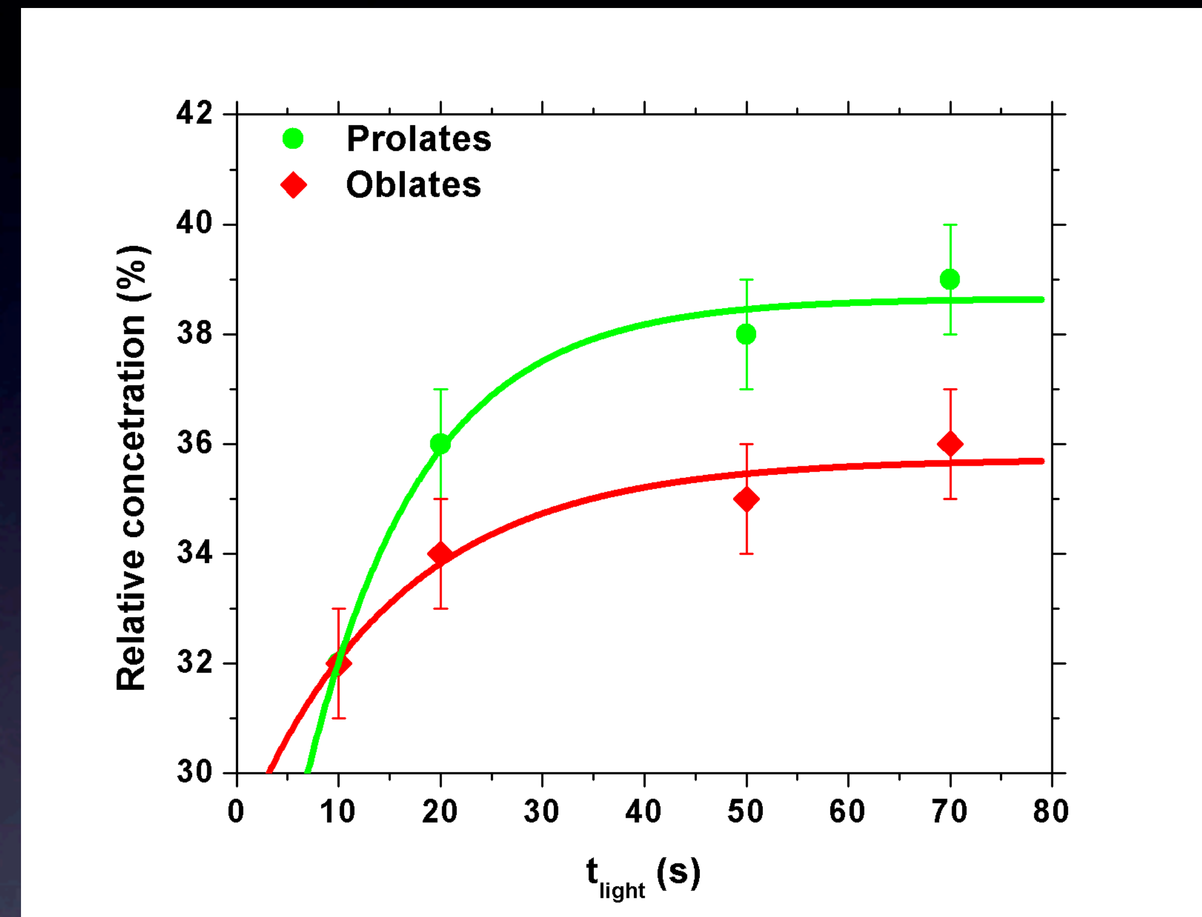
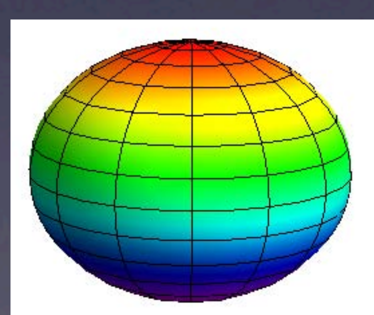
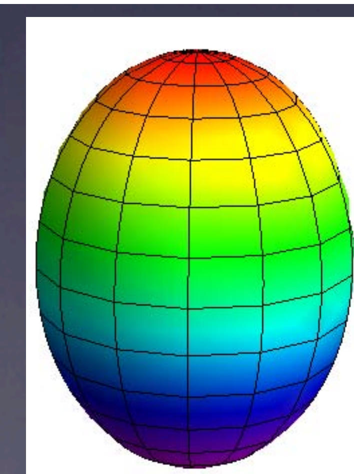




Light as a NPs shaper.

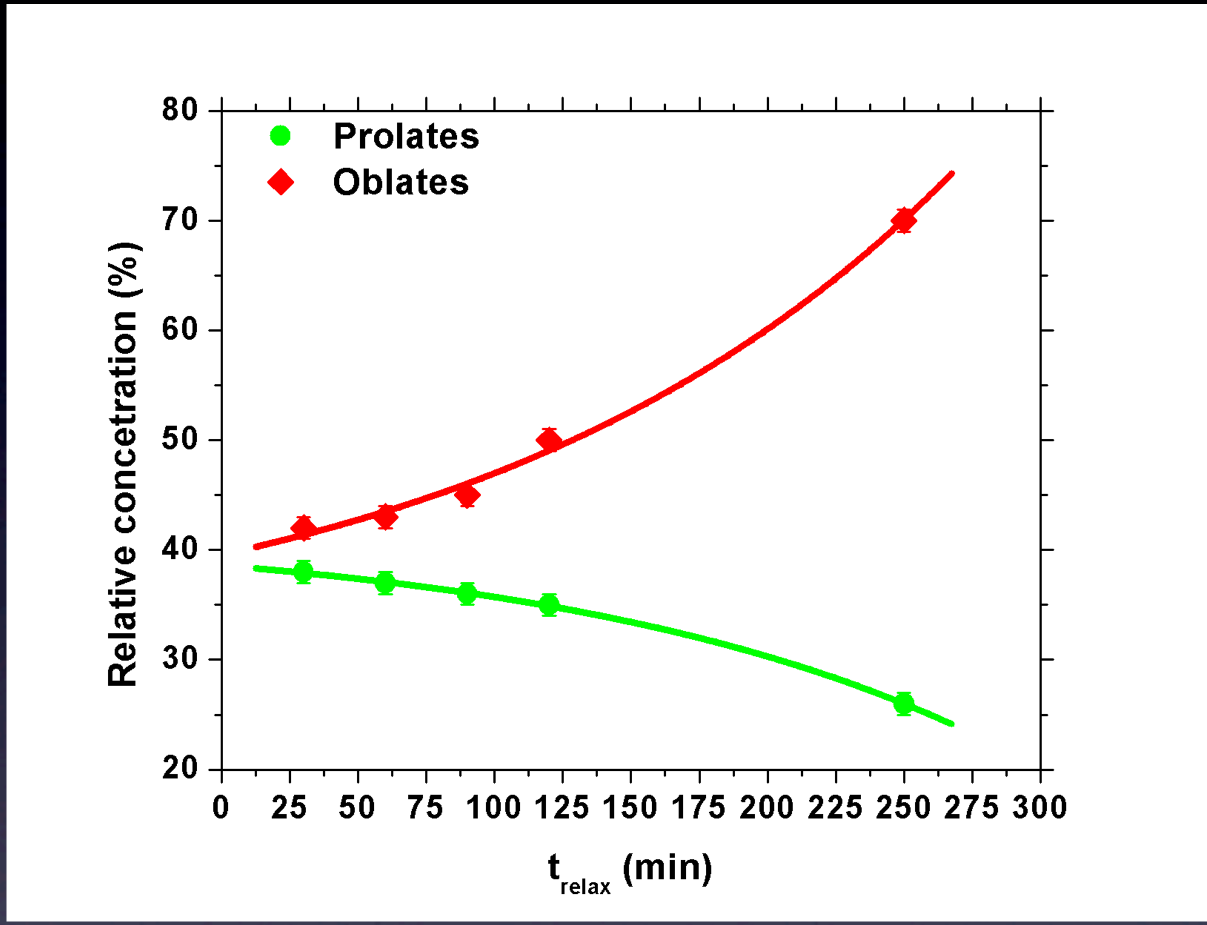


2 nm oblates, AR=1.25

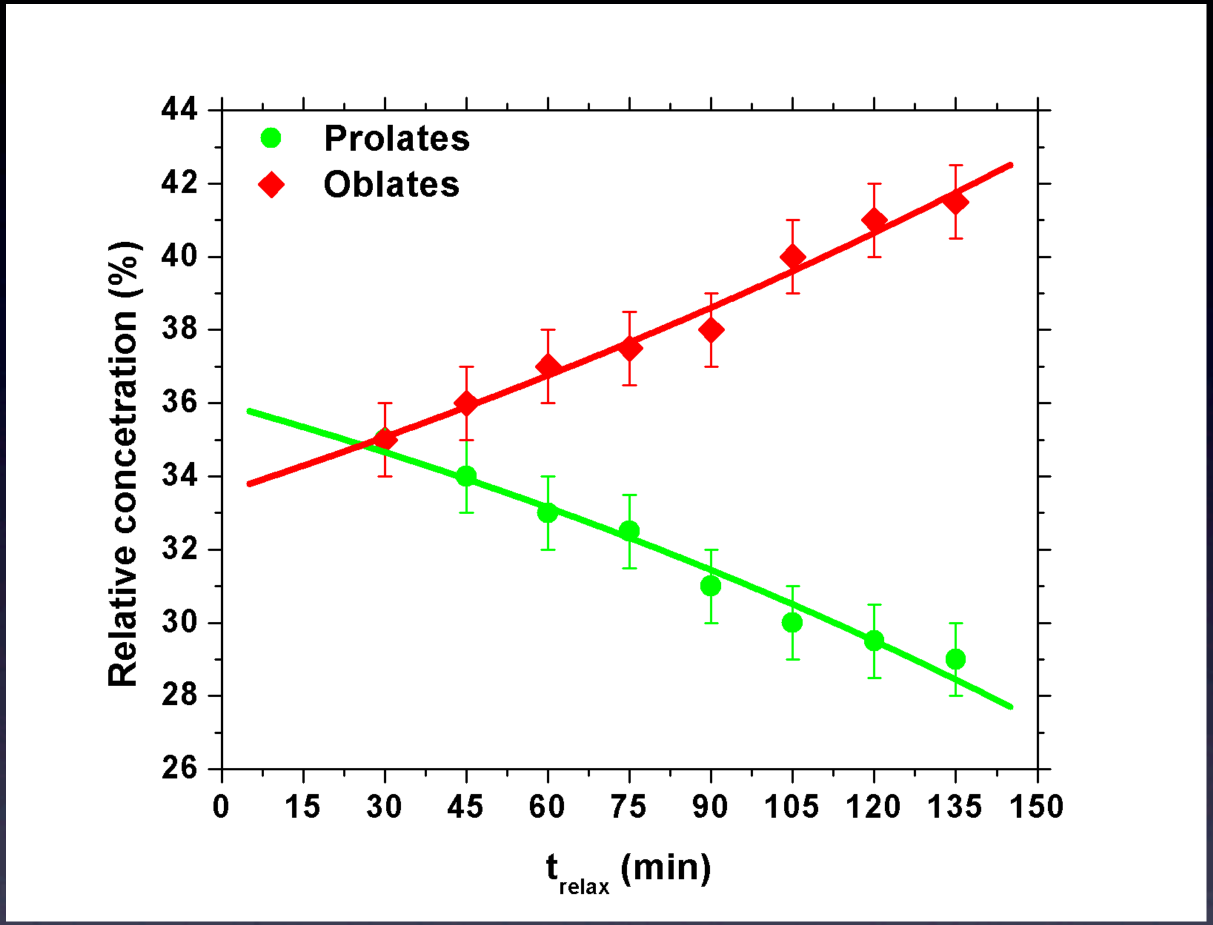
2 nm prolates, AR=0.75

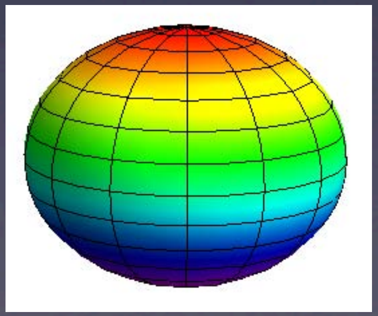
Optical control of NPs self-assembly

After 350 mW/cm^2 @ 532 nm

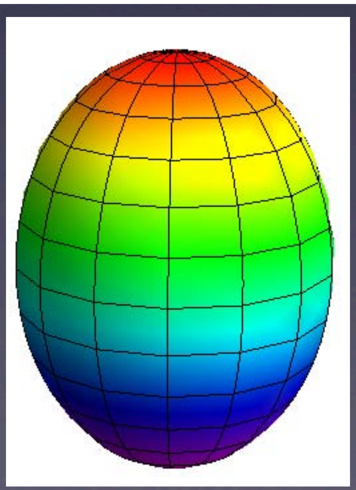


After 5 mW/cm^2 @ 405 nm





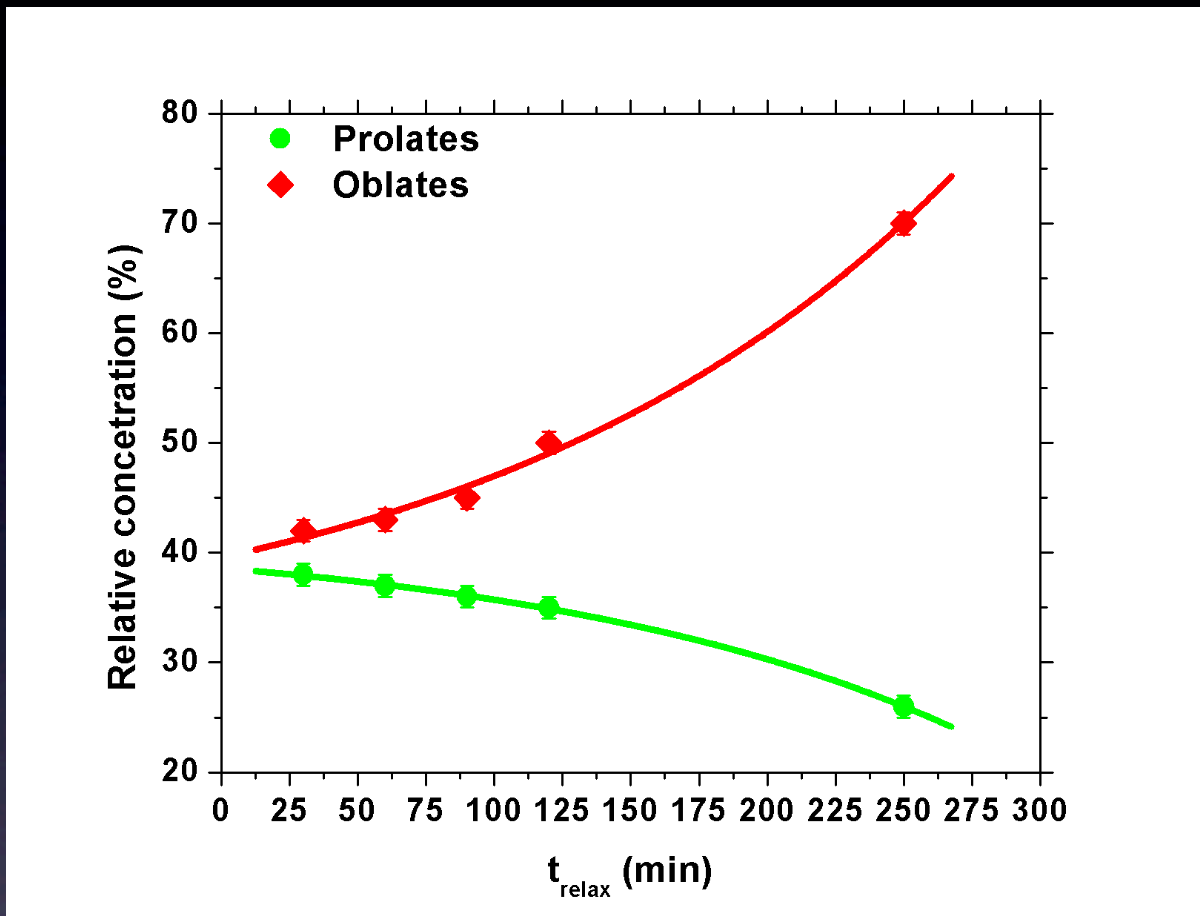
2 nm oblates, AR=1.25



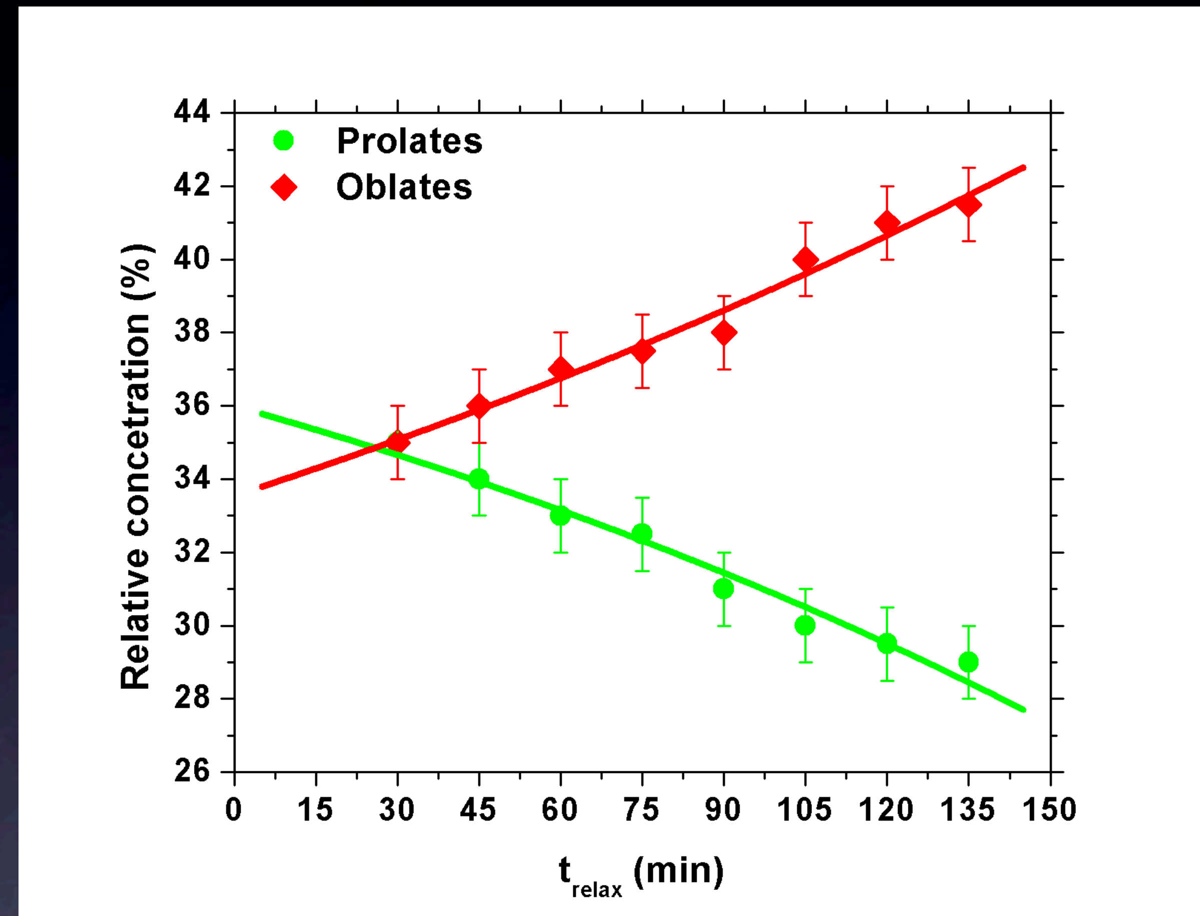
2 nm prolates, AR=0.75

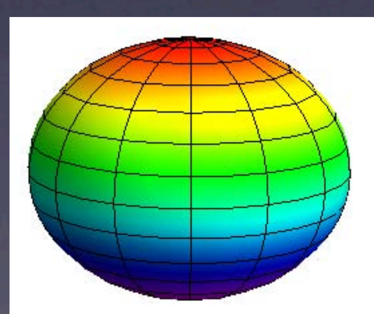
Optical control of NPs self-assembly

After 350 mW/cm^2 @ 532 nm



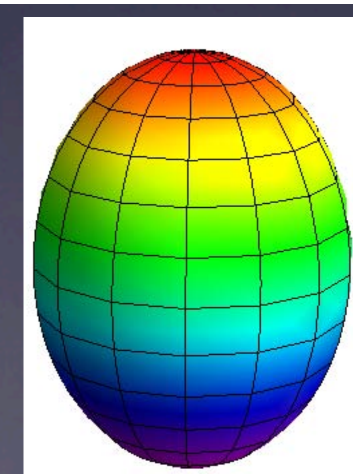
After 5 mW/cm^2 @ 405 nm





2 nm oblates, AR=1.25

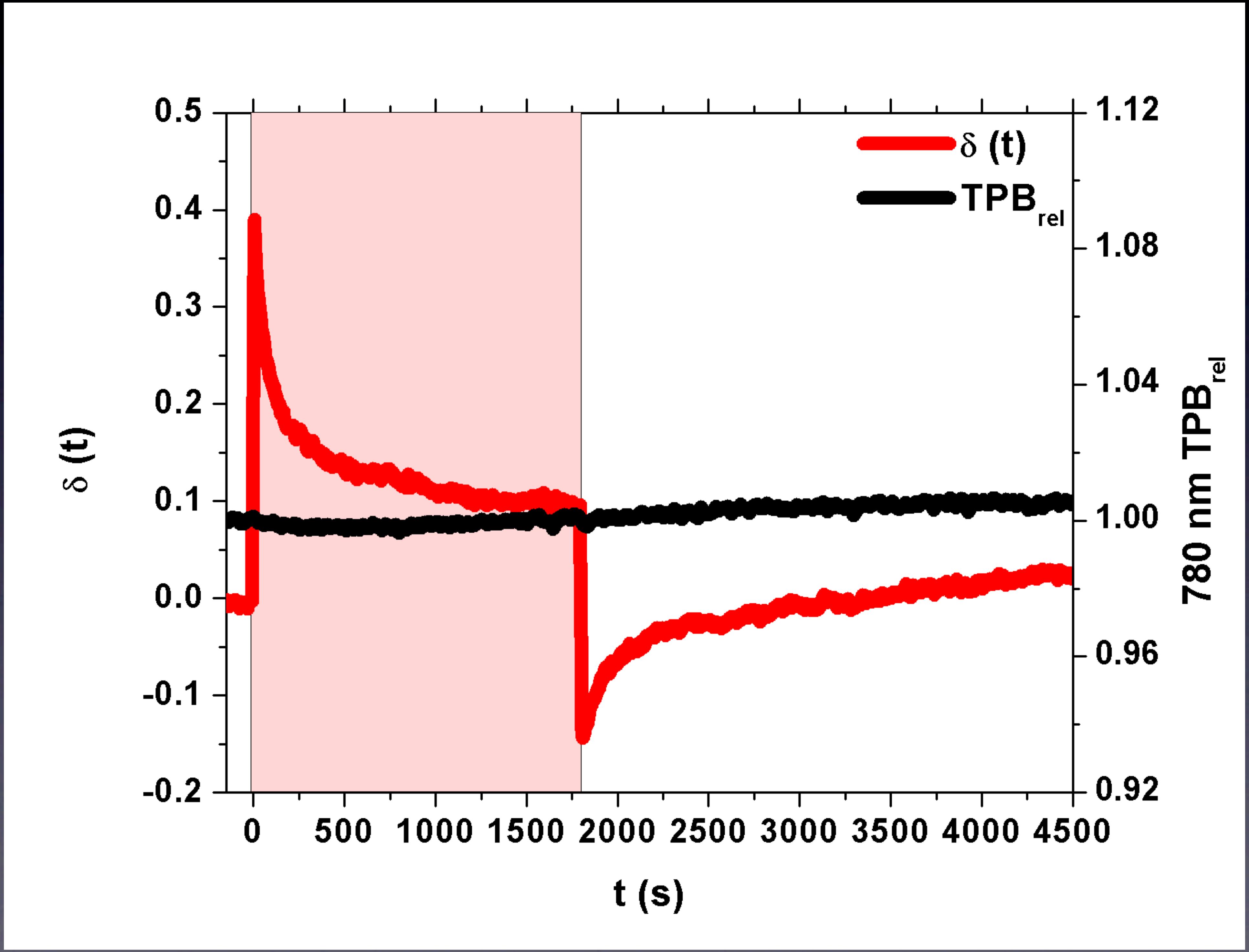
Spountaneous reversibility by intrinsic mechanisms.



2 nm prolates, AR=0.75

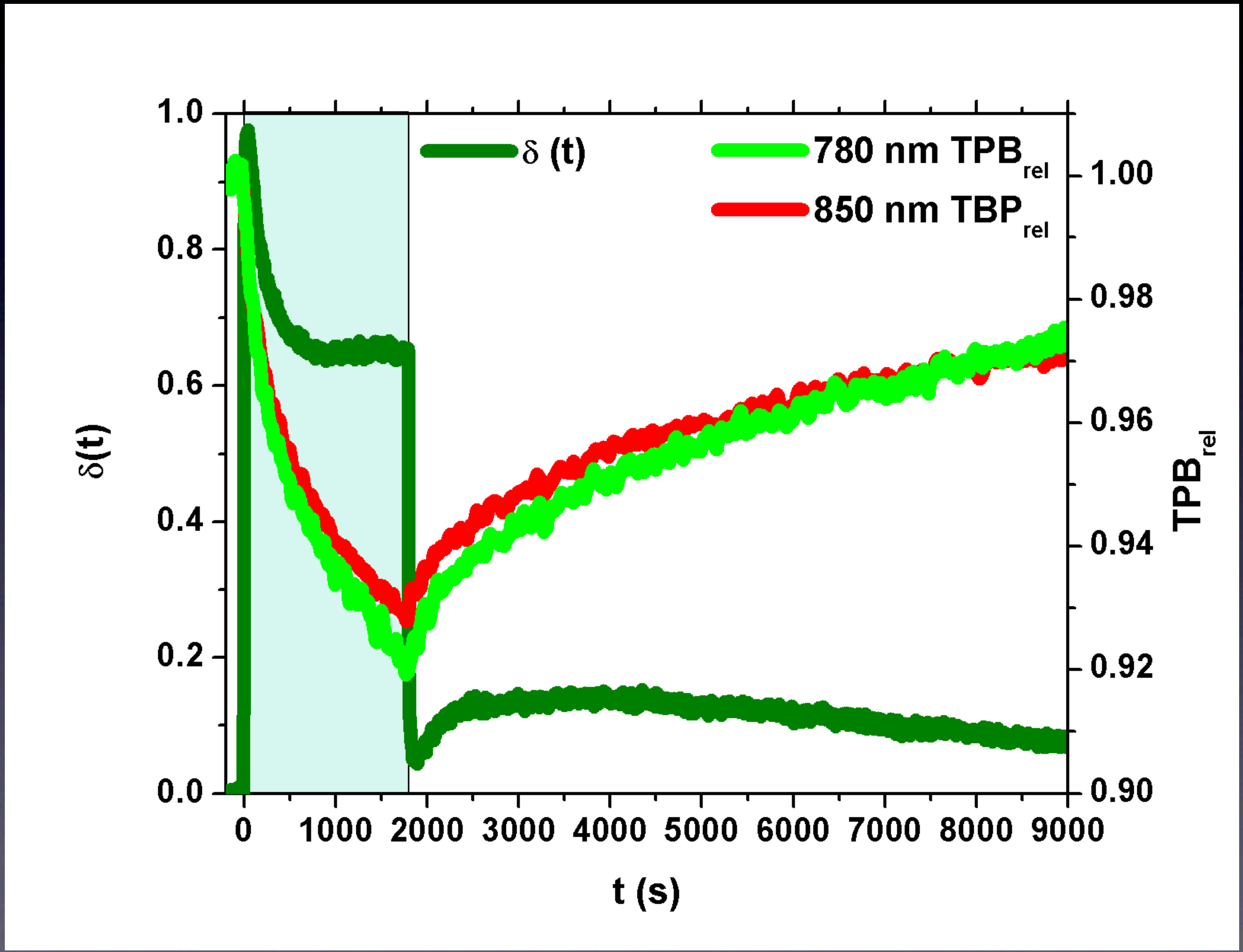
System time evolution

385 mW/cm^2 at 660 nm: low mobility regime.



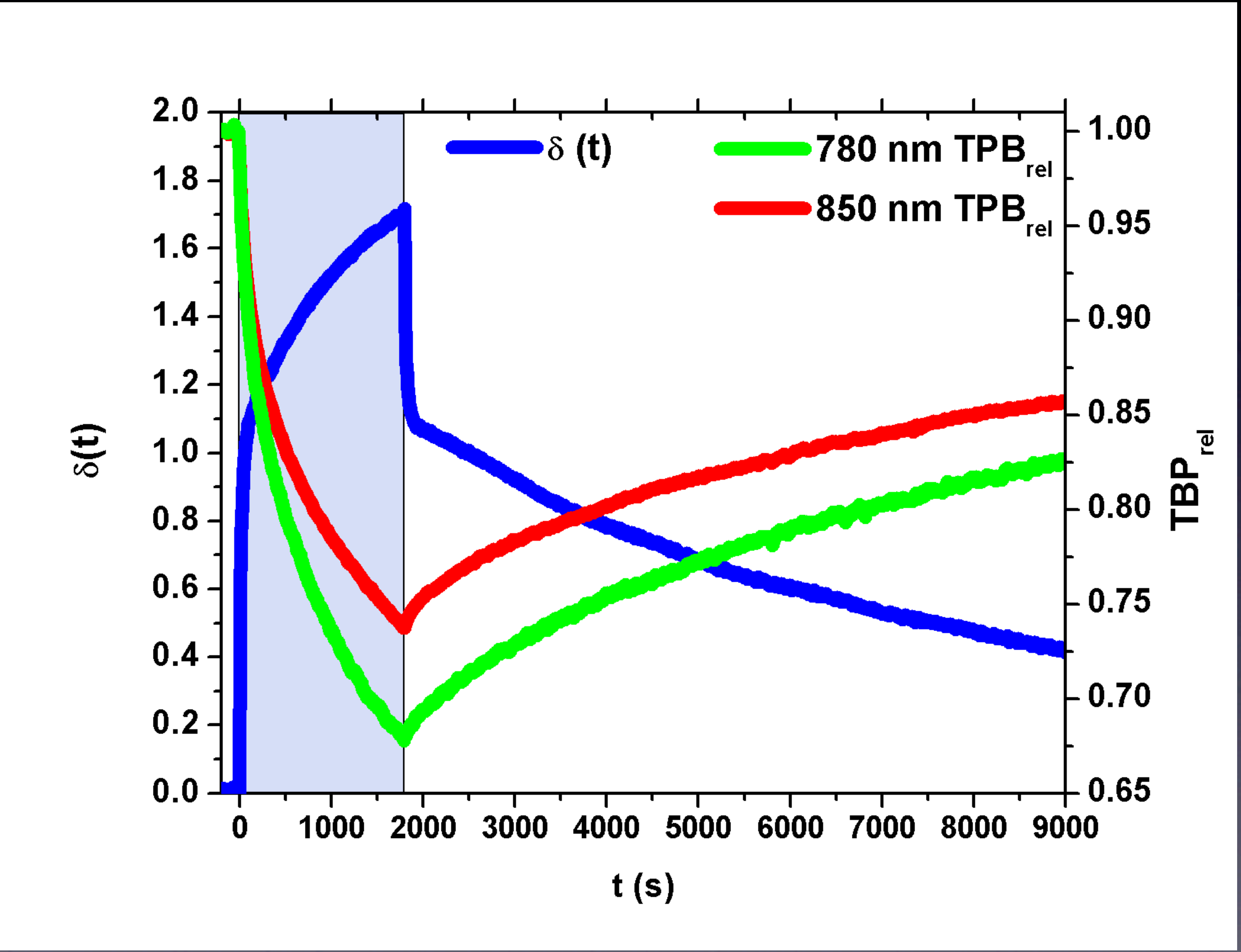
System time evolution

40 mW/cm^2 at 532 nm: light-enhanced mobility regime.



System time evolution

5 mW/cm^2 at 405 nm: light-enhanced high mobility regime.



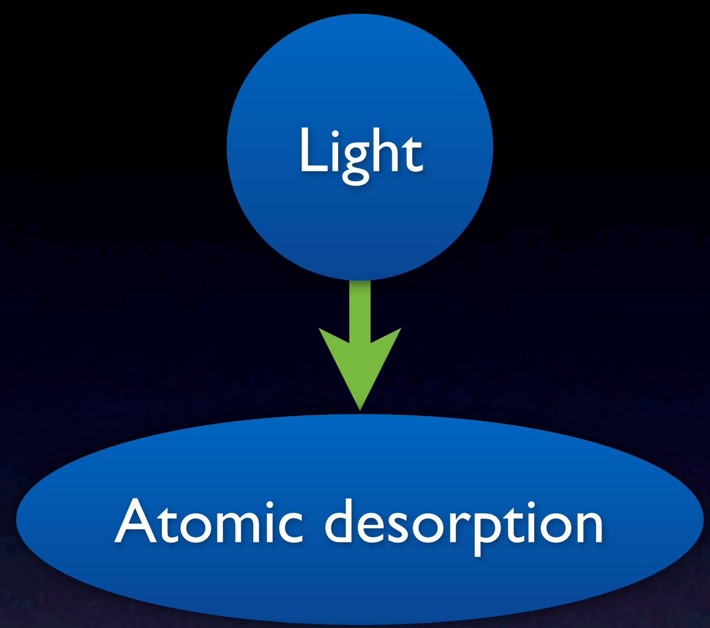
Conclusions

Light-enhanced atomic mobility, NP, atomic motion.

Light

Conclusions

Light-enhanced atomic mobility, NP, atomic motion.



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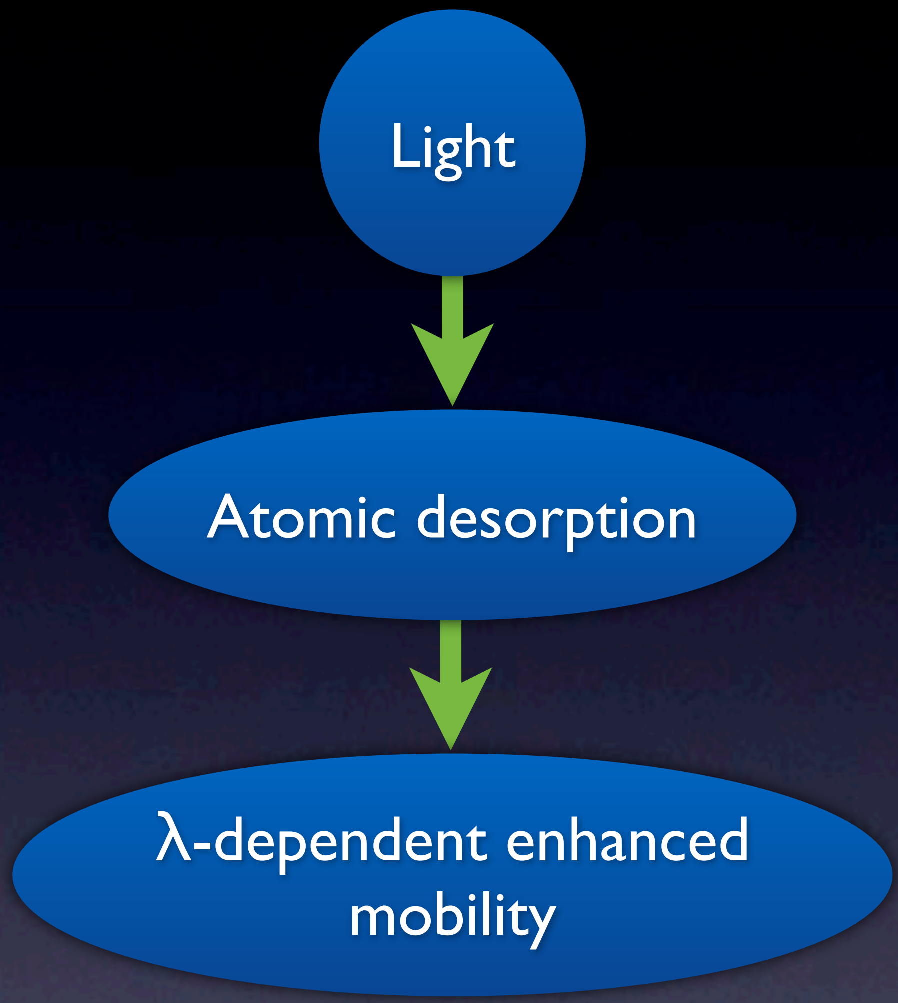
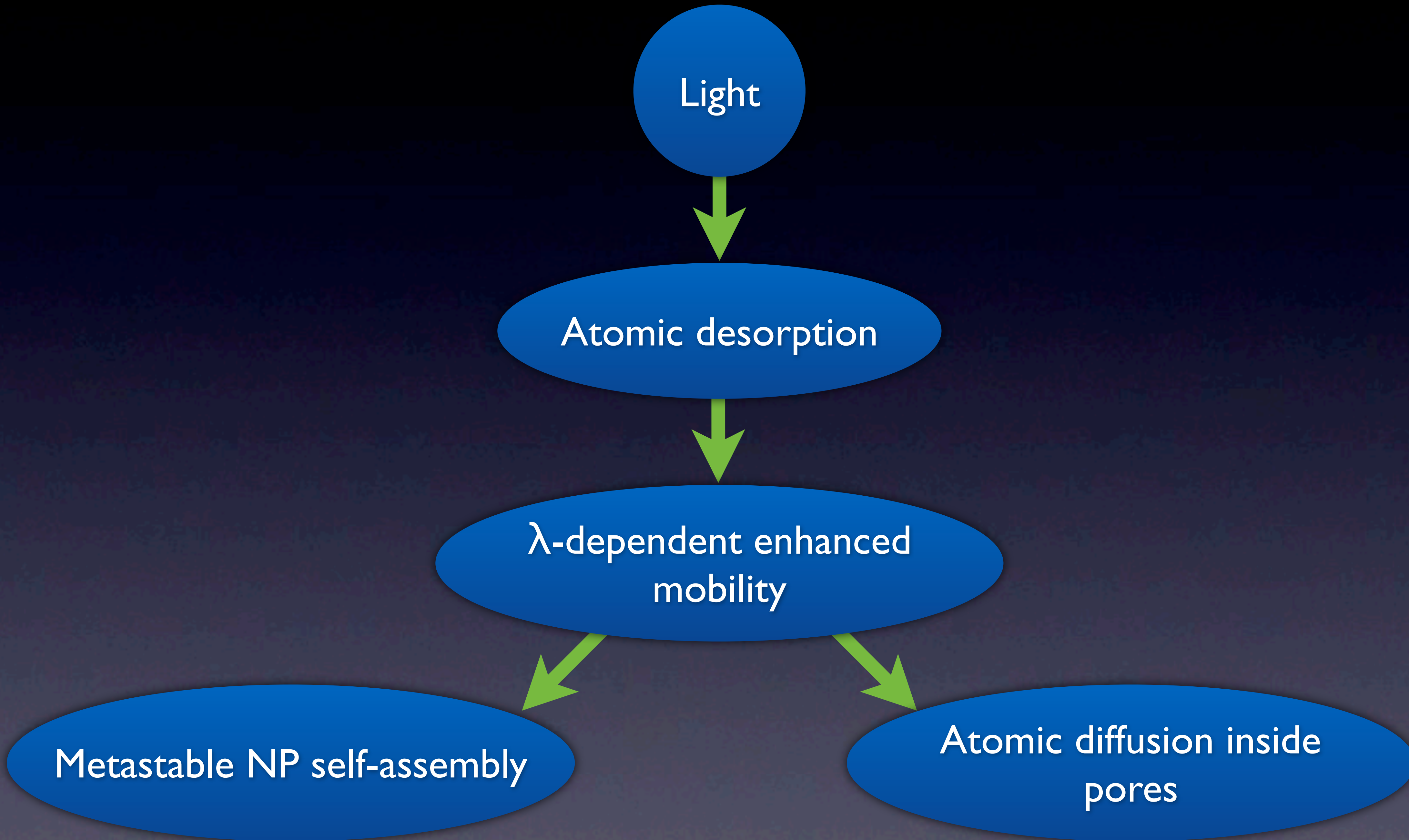
Conclusions

Light-enhanced atomic mobility, NP, atomic motion.



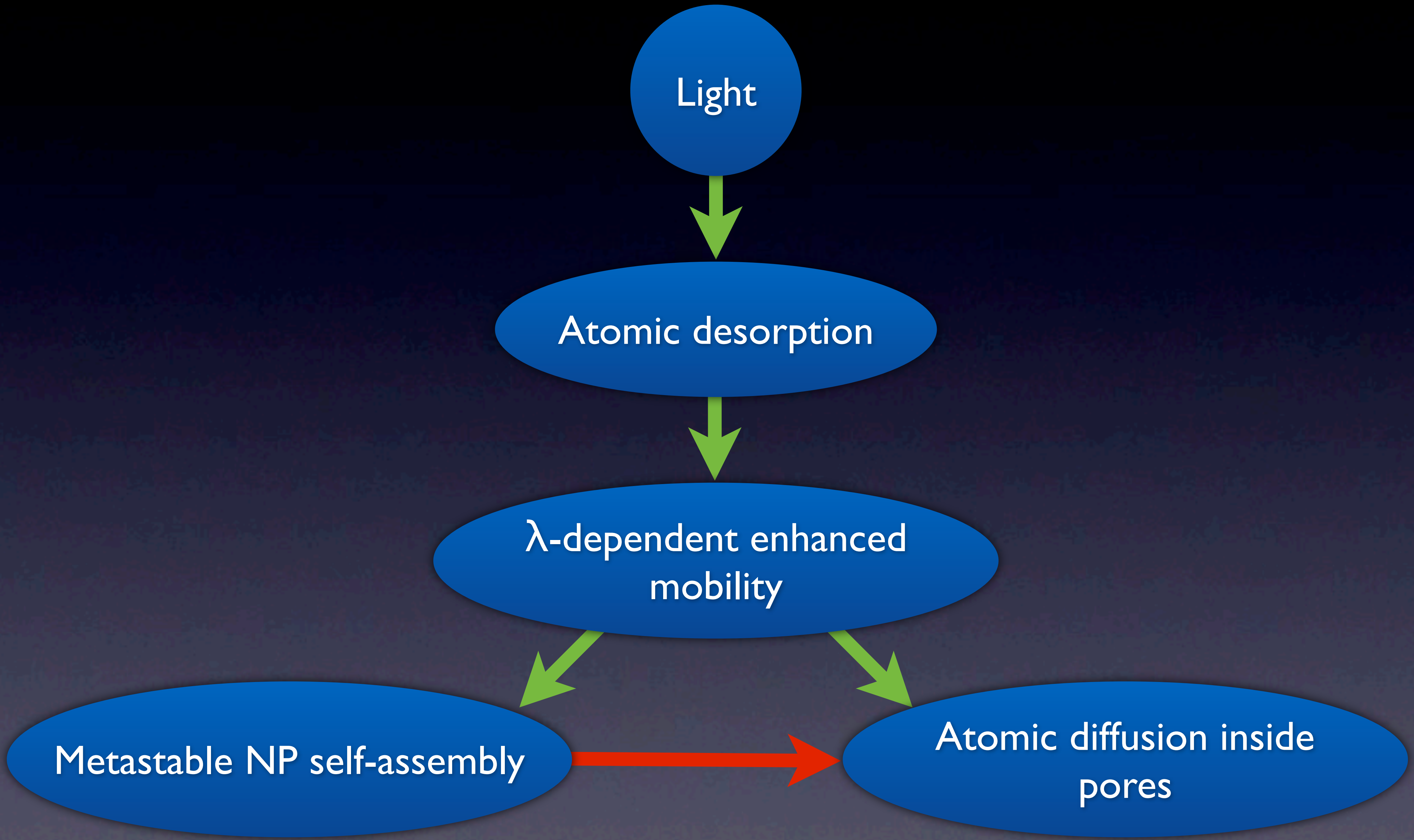
Conclusions

Light-enhanced atomic mobility, NP, atomic motion.



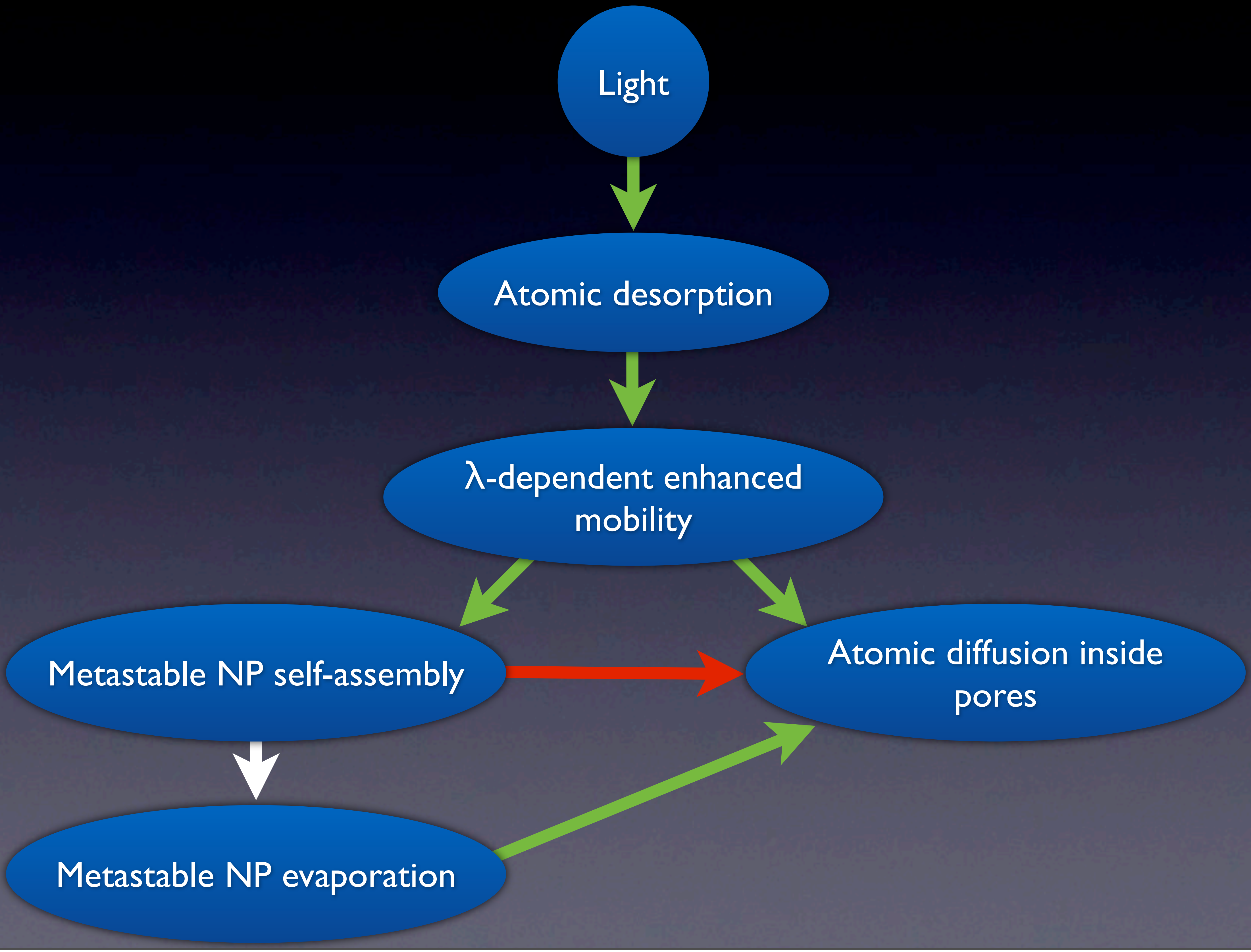
Conclusions

Light-enhanced atomic mobility, NP, atomic motion.



Conclusions

Light-enhanced atomic mobility, NP, atomic motion.



Conclusions

Thank you for your attention

and

for these wonderful years together!

(See you soon)