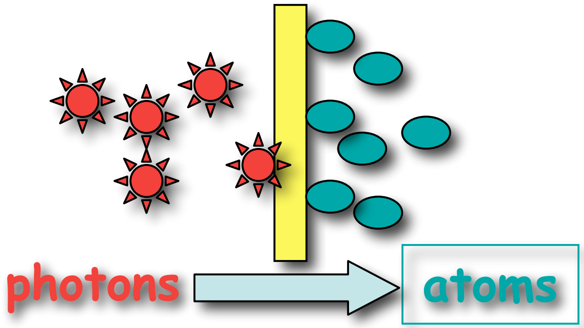
Light induced atomic desorption [LIAD] and related phenomena



L. Moi

Physics Dept Siena University - CNISM

CEWQO 2008

We are interested to processes involving

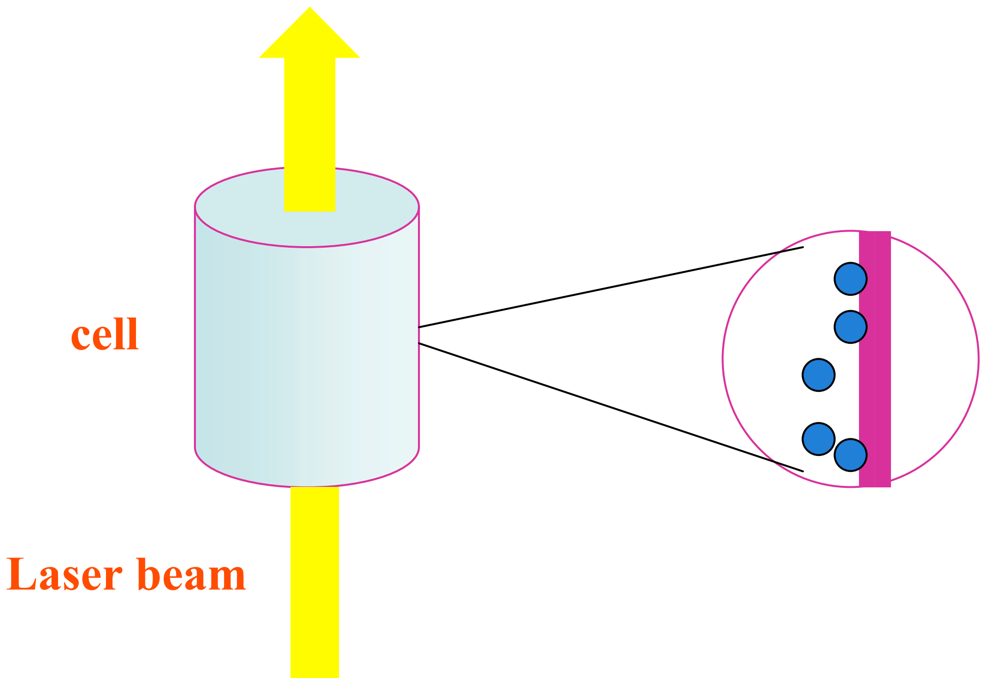
atoms+surface+light

Alkali atoms

Coated glass
Porous silica

Weak
Coherent-incoherent

LIAD



We study this effect, we look at the modifications introduced by LIAD on the whole system and at possible applications

In the past atom-surface interaction [no light!] was a crucial problem

In optical pumping atom-wall collisions destroy spin orientation

In light induced drift atoms adsorbed at the surface make drift velocity very slow
surface density in fact grows up with the adsorption energy
Solution --> walls coating with organic film

New momentum grew up because of new experiments made with ultra-thin cells and nano structured materials, because of miniaturization of many apparatus (traps, atom chips etc.) and the discovery of new phenomena.

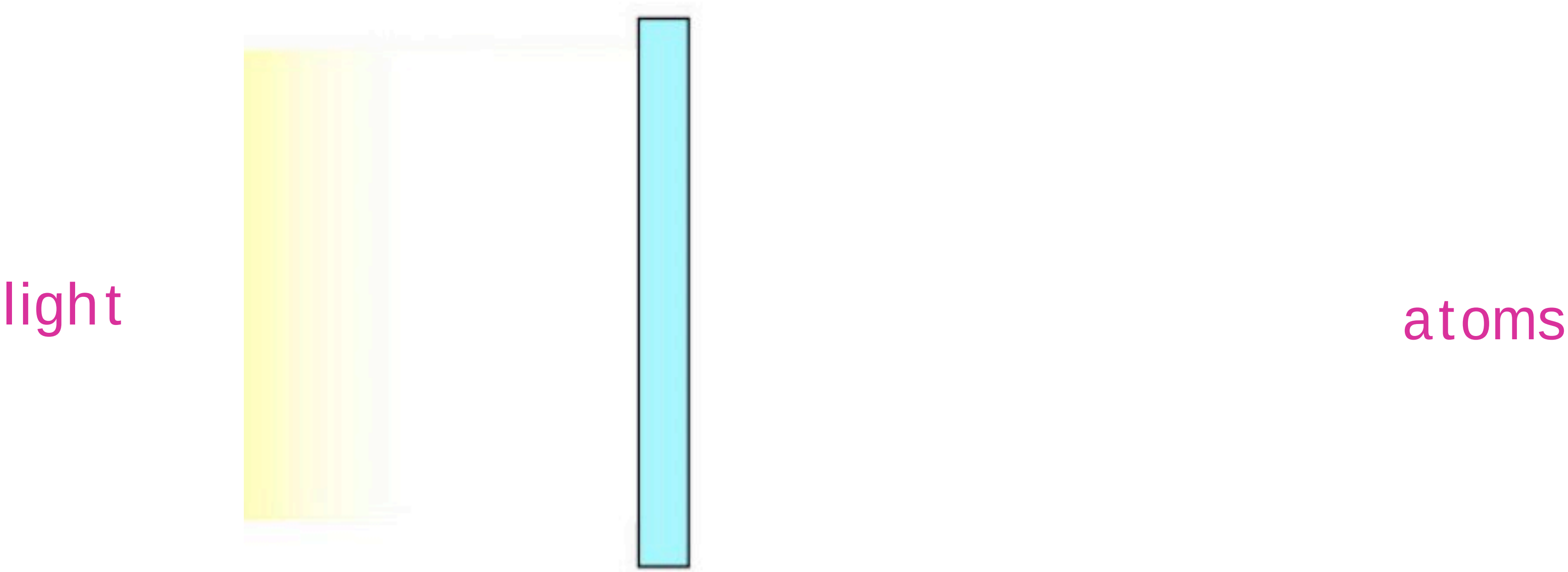
+ light !

It is well known that Light hitting a surface triggers many different processes depending on its intensity, frequency, pulsed or c.w. regime. High intensity produces ionization, plasma formation, ablation etc.

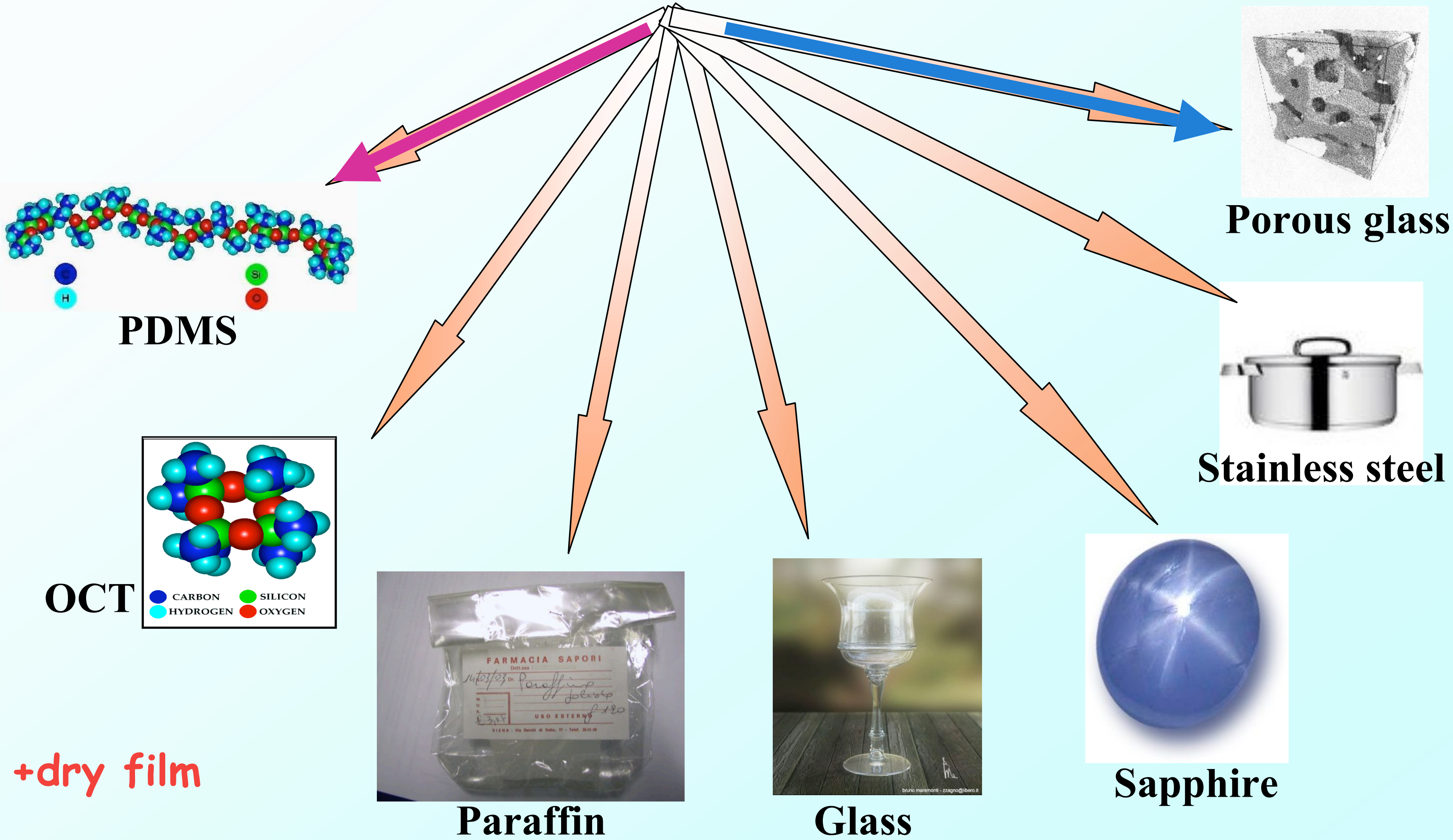
+Low intensity

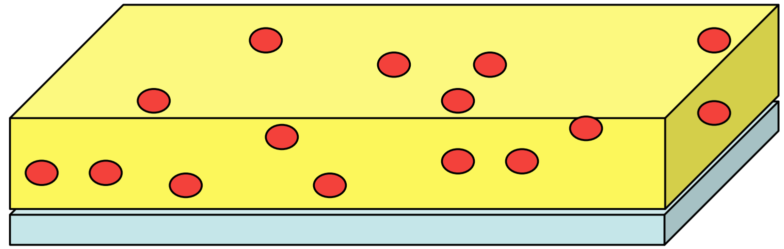
Weak light triggers other interesting effects with alkali atoms in coated cell and nanoporous silica.

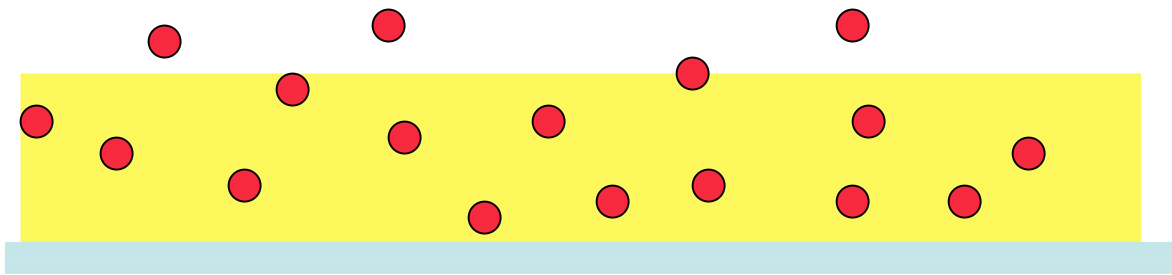
LIAD



Light Induced Atomic Desorption



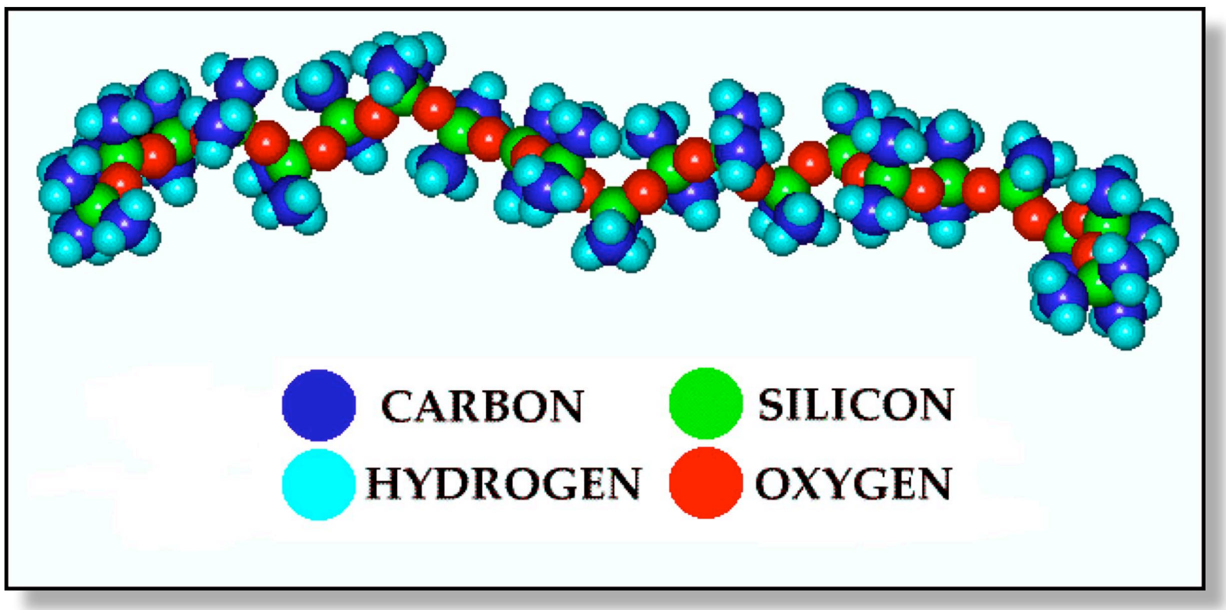




PDMS OCT

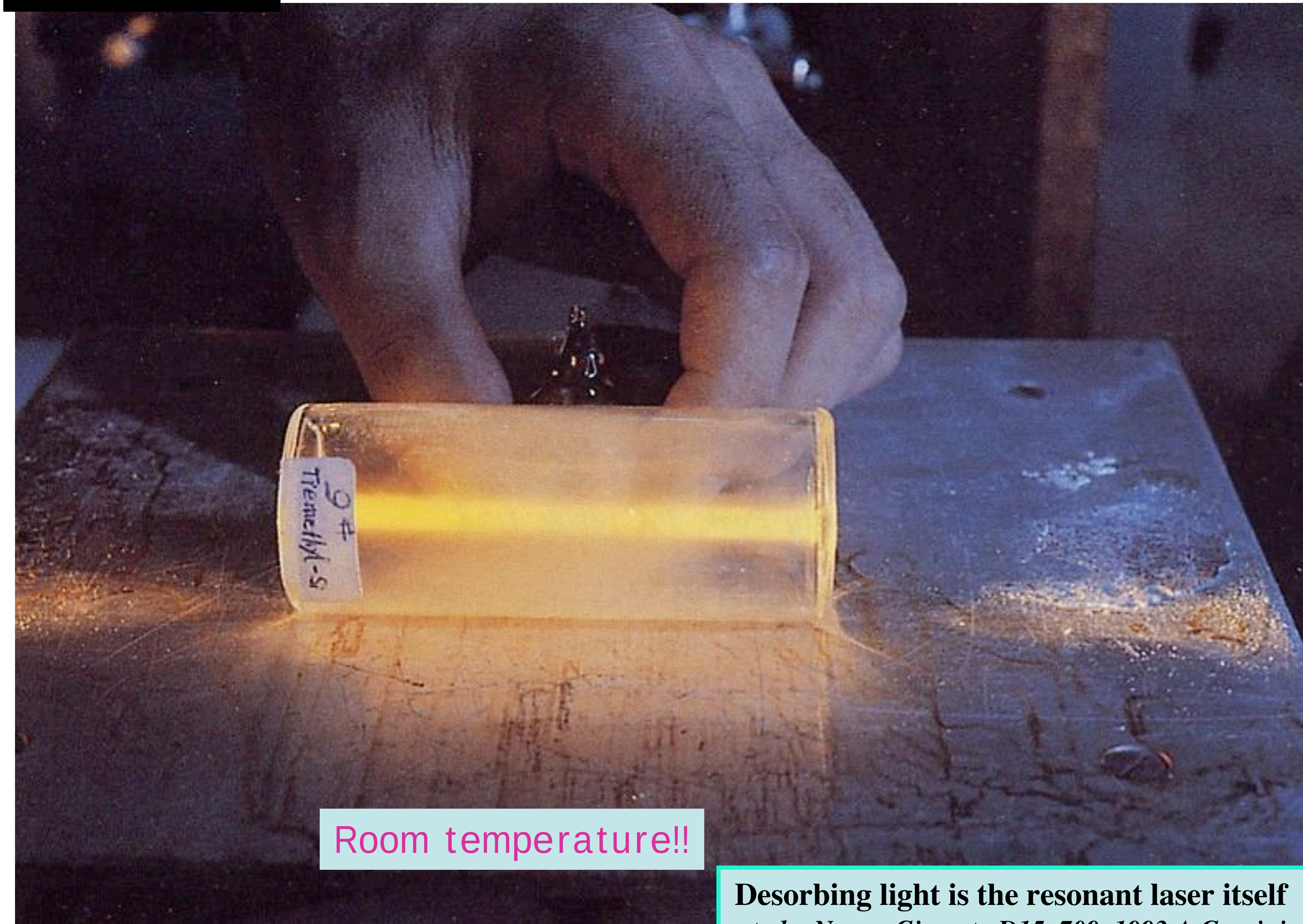
$$E \leq 0.1eV$$

Few isolated atoms at the surface



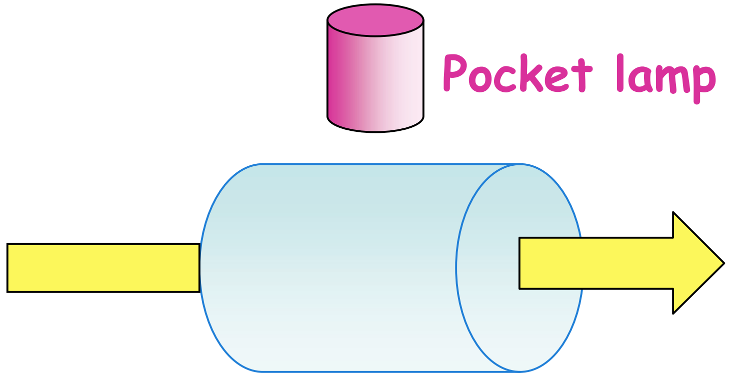
PDMS

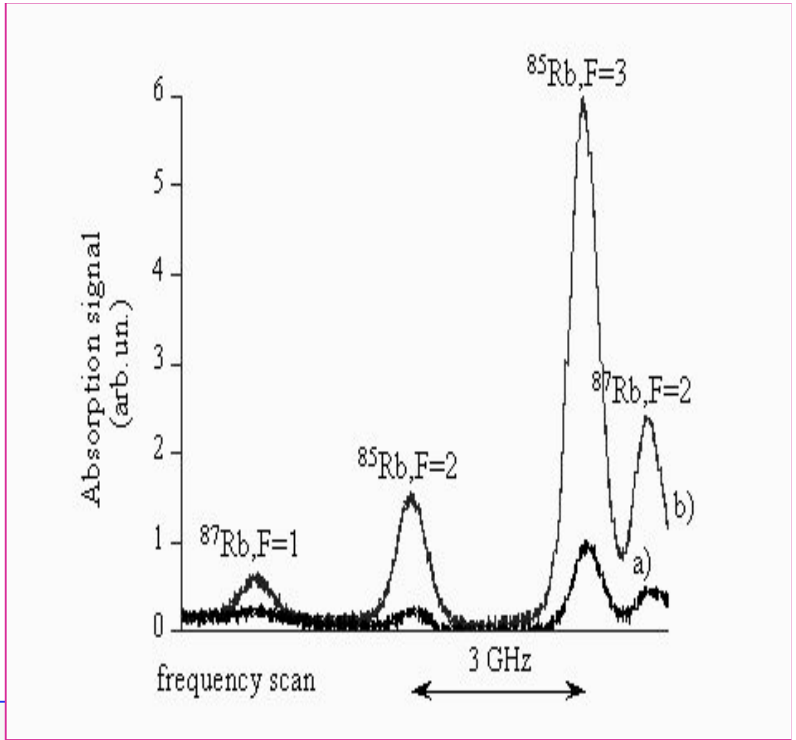
LIAD Effect



Room temperature!!

Desorbing light is the resonant laser itself
et al., Nuovo Cimento D15, 709, 1993 A.Gozzini





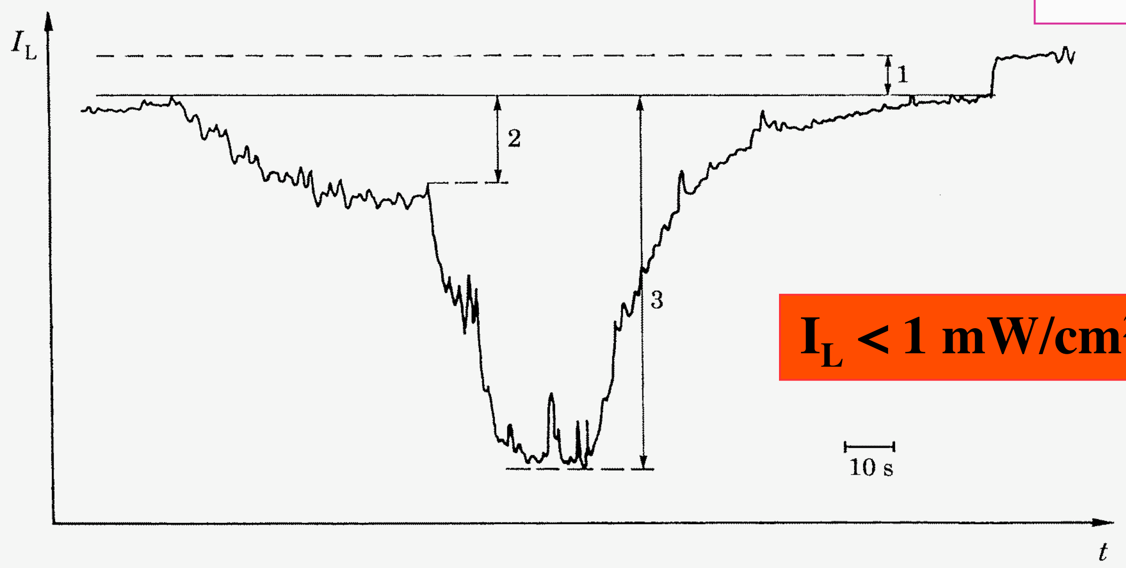
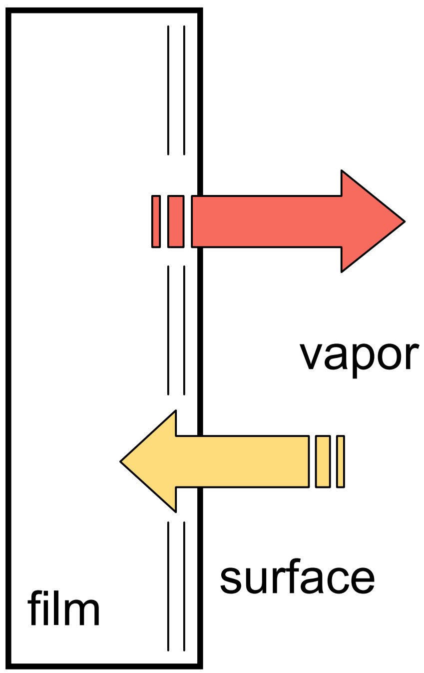


Fig. 18. – Transmission of a coated cell at room temperature. The laser frequency is kept on resonance with the Rb atoms. 1 corresponds to the cell transmission in the dark; 2: transmission when the ceiling light is on; 3: flash-lamp + ceiling light on.

I. Moi :"Gas manipulation by light"; Frontiers in laser spectroscopy (1994) North Holland - T.Hansch and M. Inguscio Eds. Pg. 167



Taking into account both desorption from surface and diffusion inside the film, two parameters characterize the LIAD effect:

$$\delta_{\max} = \frac{n_{\max} - n_0}{n_0} \propto \sqrt{I_L}$$

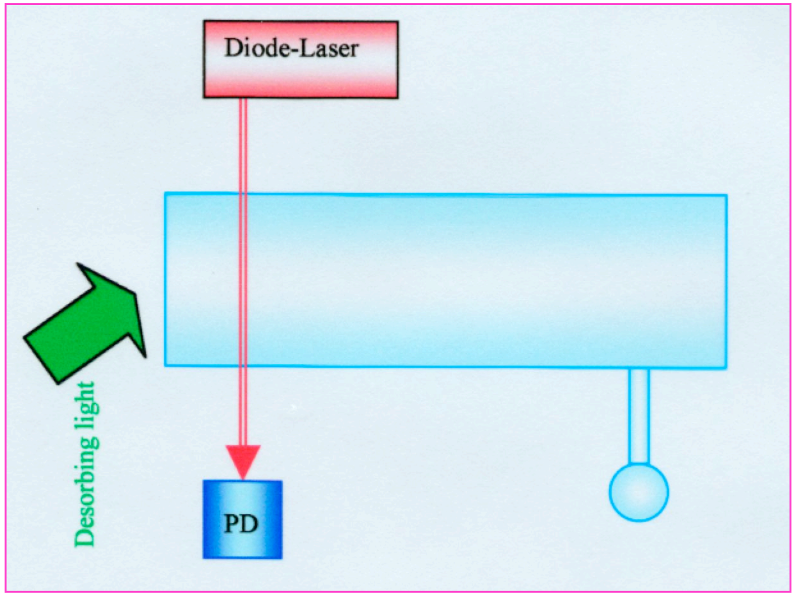
$$R = \frac{1}{n_0}\left(\frac{dn}{dt}\right)_{t=t_0} = kI_L$$

S.N.Atutov et al. PRA 60 (1999) 4693

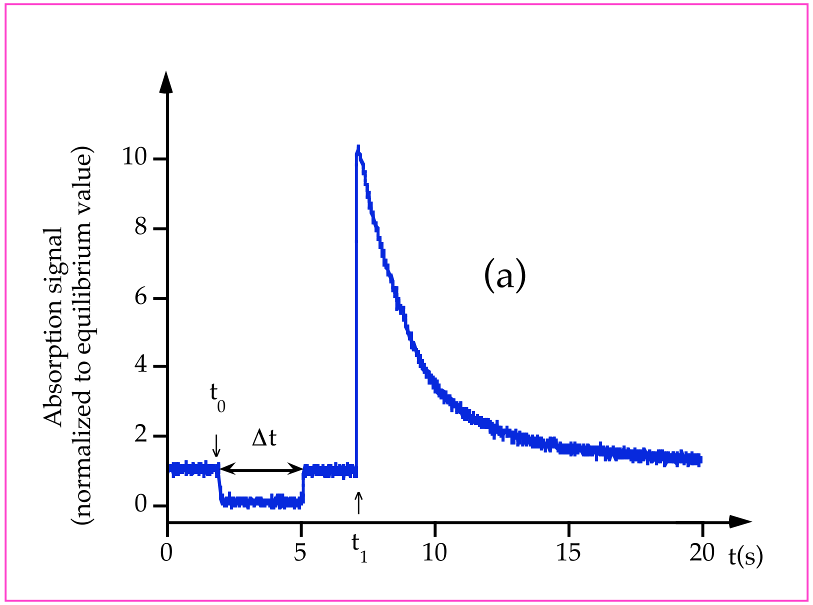
C. Marinelli et al. Eur. Phys. J. D13 (2001) 231

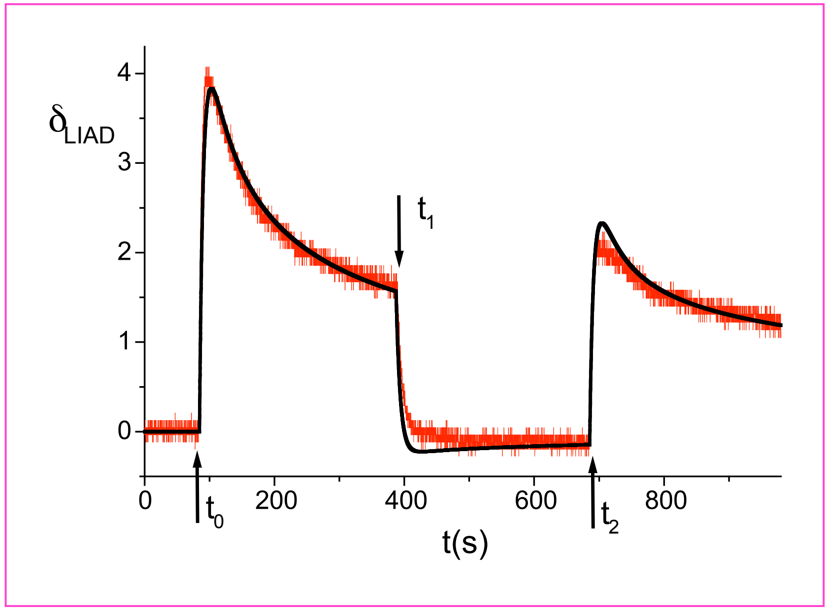
C. Marinelli et al. Eur/ Phys. J. D 37 (2006) 319

Similar one dimension model has been proposed by Budker et al. for paraffin. PRA 66 (2002) 042903 with essentially the same results.



Surface + bulk effect
Light modifies the atom diffusion inside the coating.
The coating becomes an atomic reservoir.



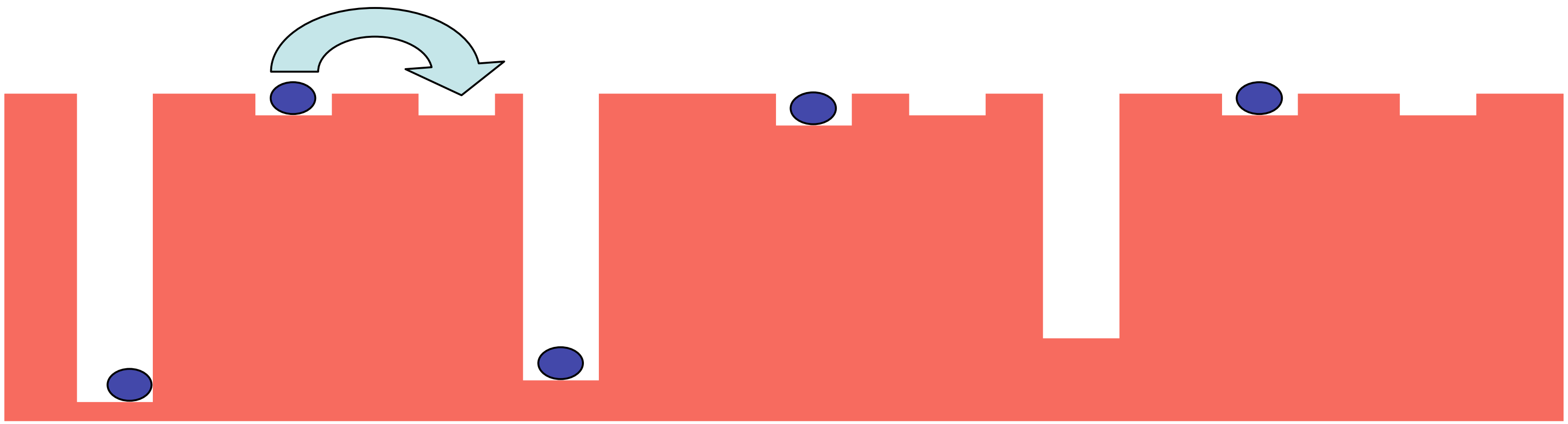


Budker et al. PRA 66 (2002) 042903

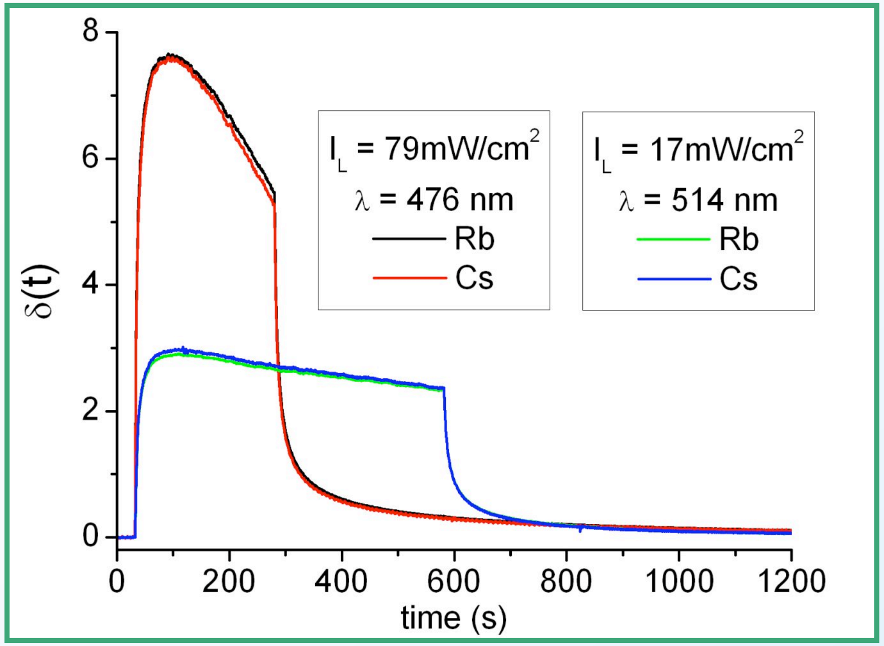
“ there are several proposals to explain the dependence of LIAD on the frequency of the desorbing light. Bonch-Bruevich et al. suggest that the frequency dependence is related to the **absorption spectrum of adsorbed atoms**. Another idea is that the alkali-metal atoms form **quasimolecular bonds** with the coating and the photon energy must exceed some threshold. It is still difficult to distinguish between these various possibilities with our present data”.

pulsed excitation --> high T -
“cw” weak illumination --> diffusion - no dependence on atom

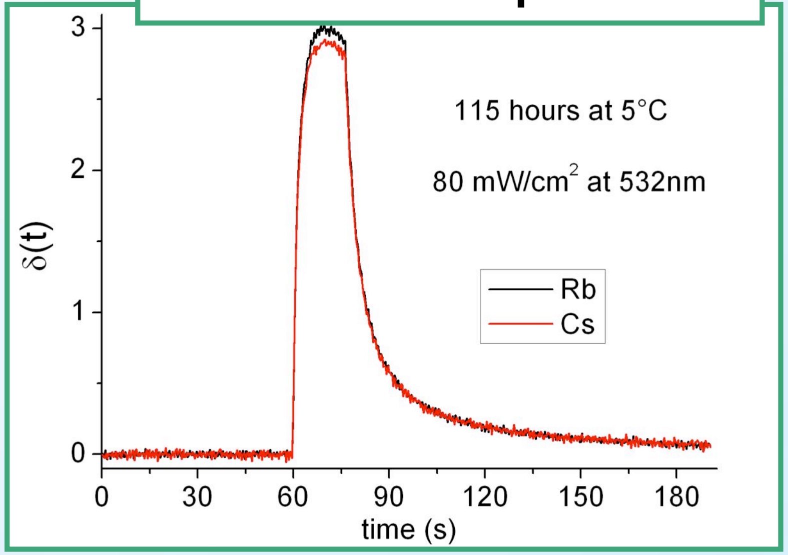
Different regimes different mechanisms -
PDMS film quite complex system and diffusion goes on in the dark!

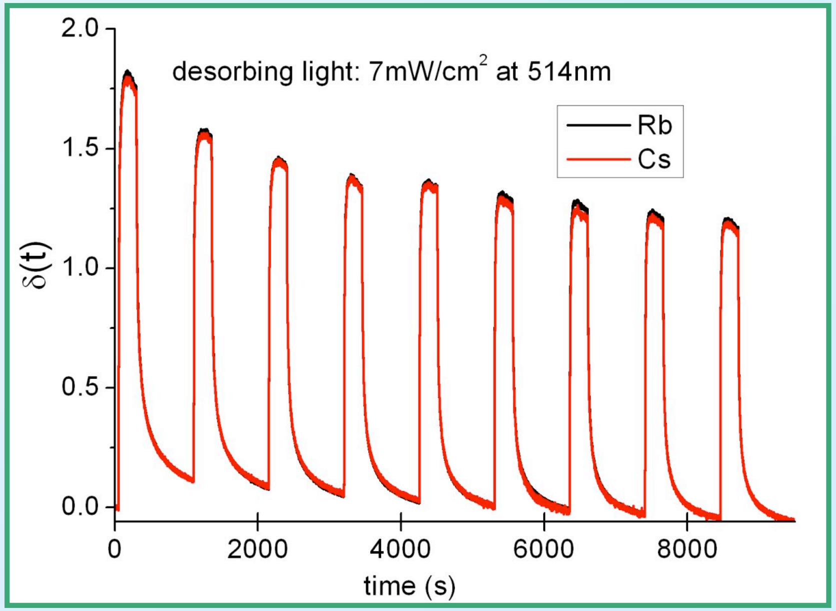


Desorption dynamics of Rb and Cs in the same cell



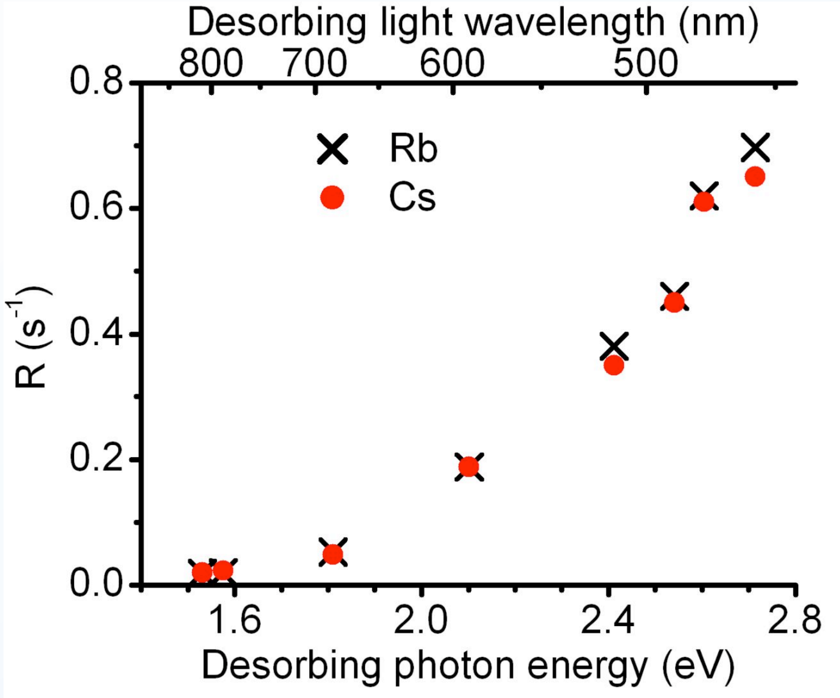
At different temperature



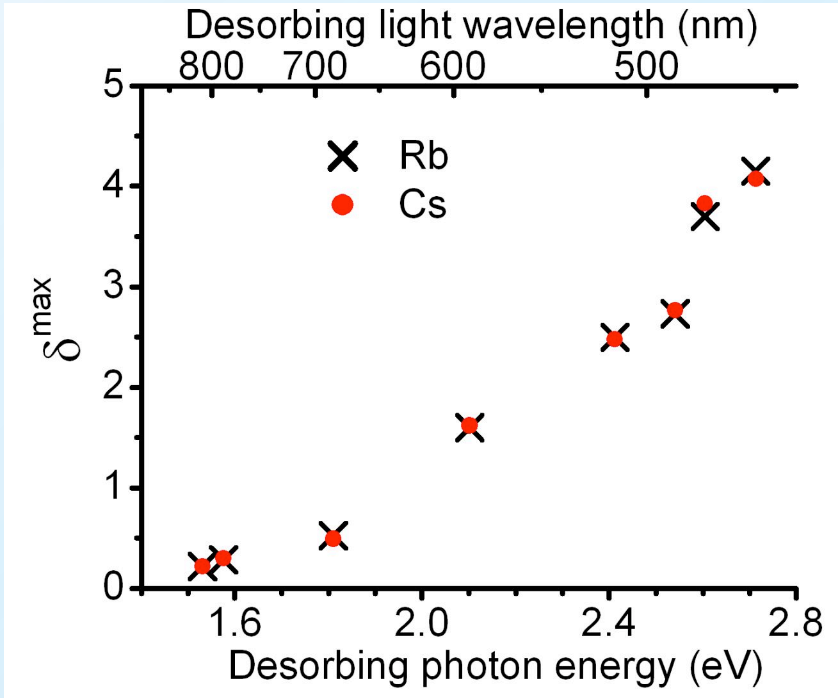


C. Marinelli et al., Eur.Phys.J. D 37 (2006)

LIAD from polymers Desorption as a function of photon energy

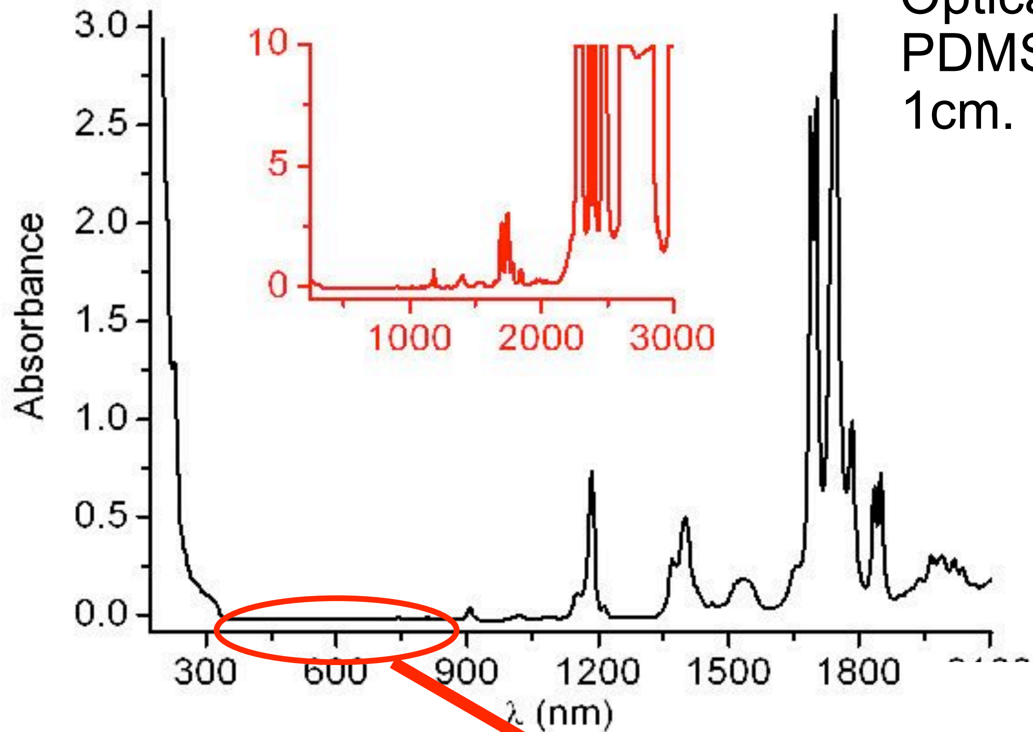


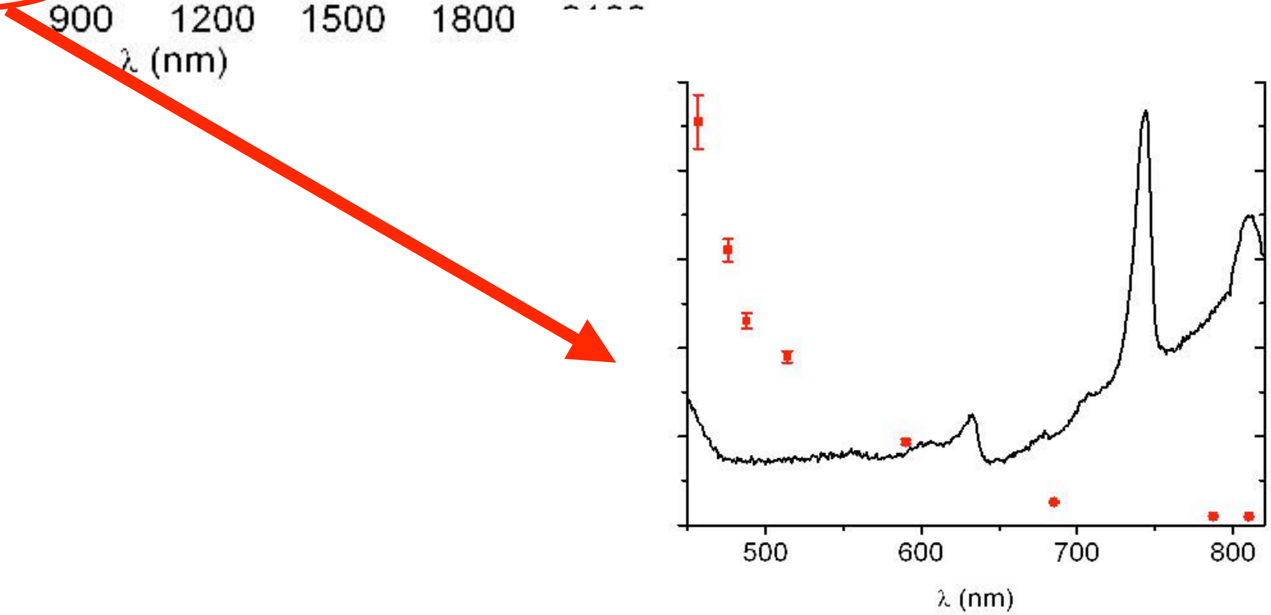
is the same for Rb and Cs



C. Marinelli et al., Eur.Phys.J. D 37 (2006)

Optical absorption spectrum of a PDMS sample with a thickness of 1cm.





LIAD from polymers

An explanation of LIAD from PDMS

Evidences

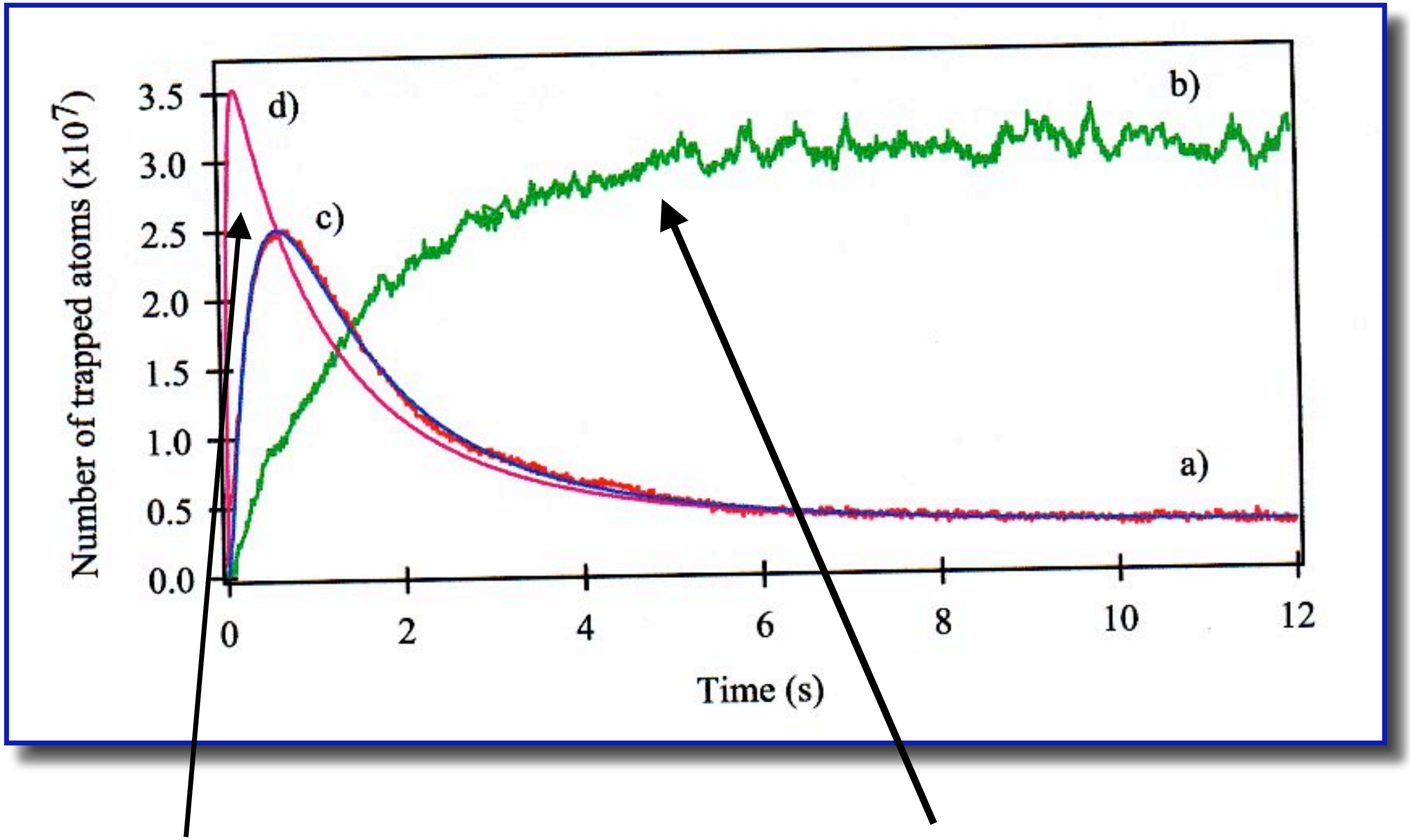
- low desorption energy
- increase of desorption efficiency with photon energy
- no resonant behavior or threshold with desorbing photon energy
- desorption characteristics independent from the alkali species

Non resonant inelastic light scattering

Desorbing light interacts with the polymer → Excitation of polymer phonons via Raman and Brillouin scattering → Increase of the atomic diffusion and desorption probability

Light off

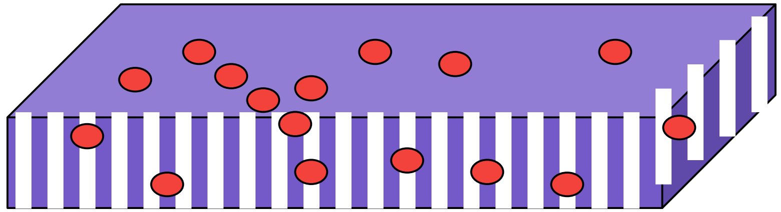
Light on

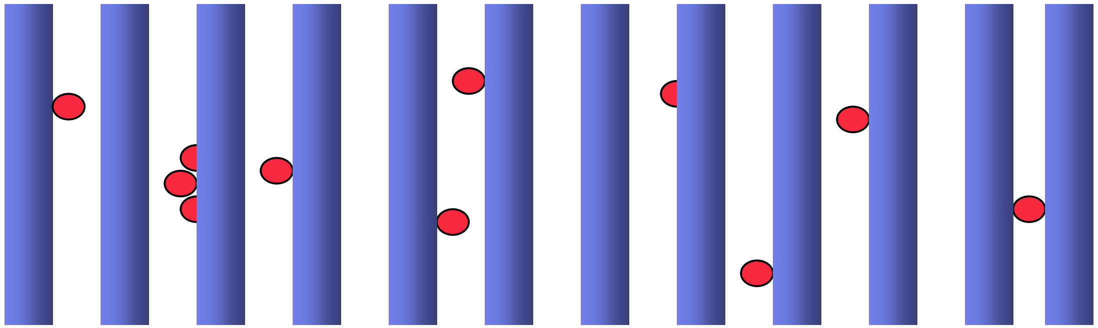


8 10^6 atoms in 40ms
Rb source @T<0°C

10^7 atoms in 2s
Rb source at room temperature

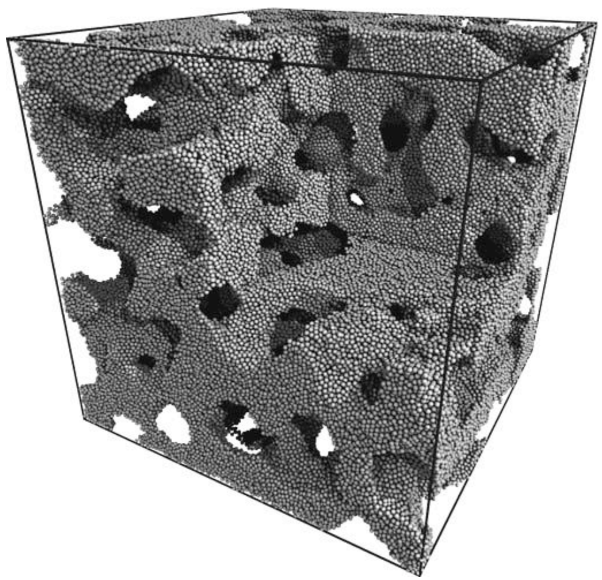
Porous silica





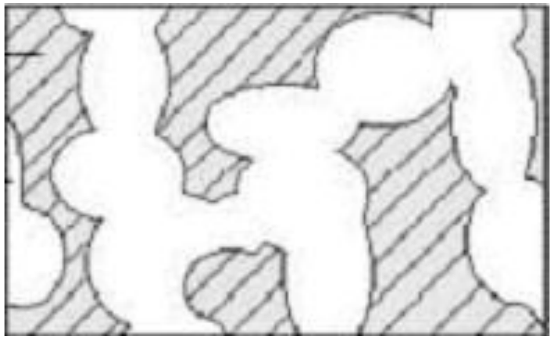
Pore size 5-20 nm

$$E \leq 1eV$$



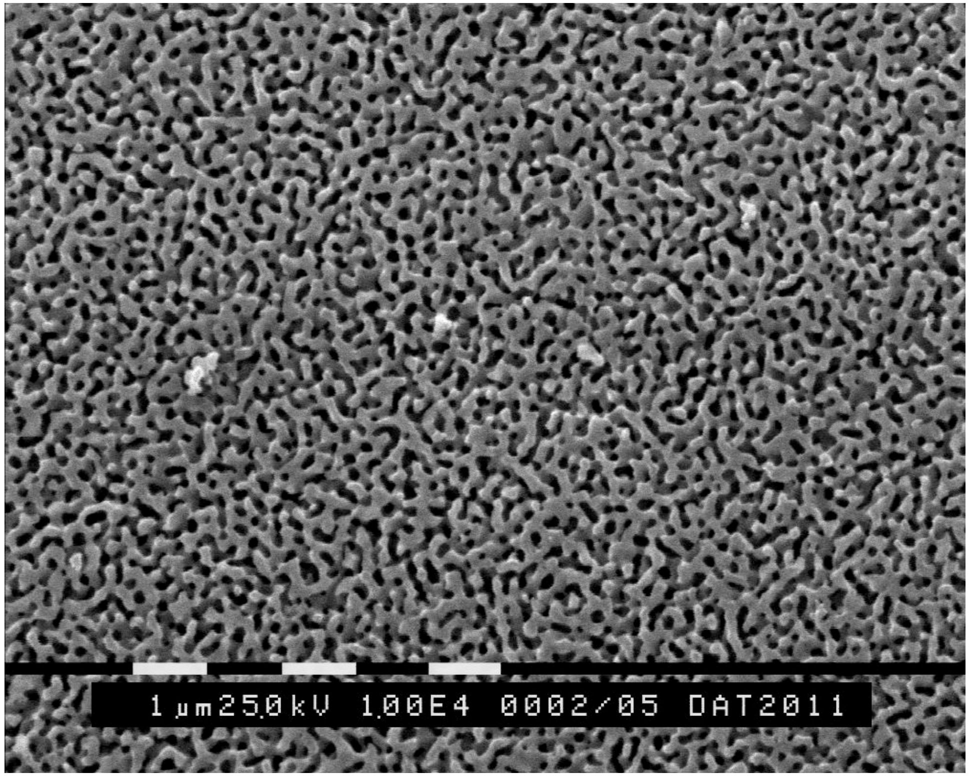
We use as host matrix for atoms and nanoparticles porous silica with a mean pore diameter of 17 nm and a free volume of about 50% of the whole silica mass.

Pore volume: 500mm^3/g
Pore surface: 100m^2/g
Mean pore diameter: 17nm
SiO_2>96%

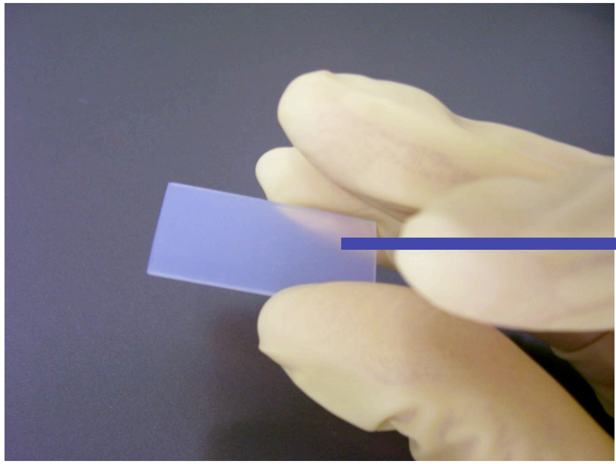


~17nm

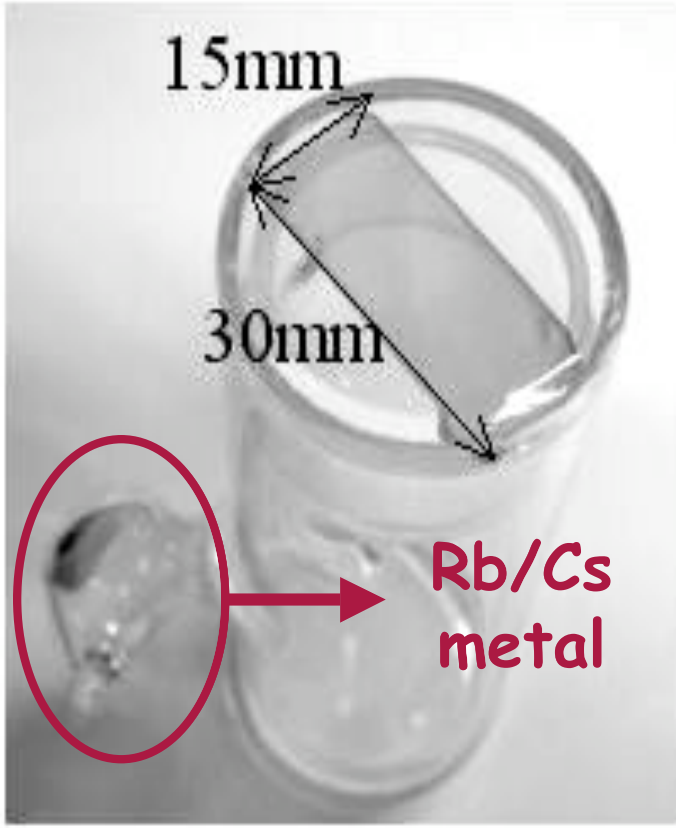
REM picture - VitraBio



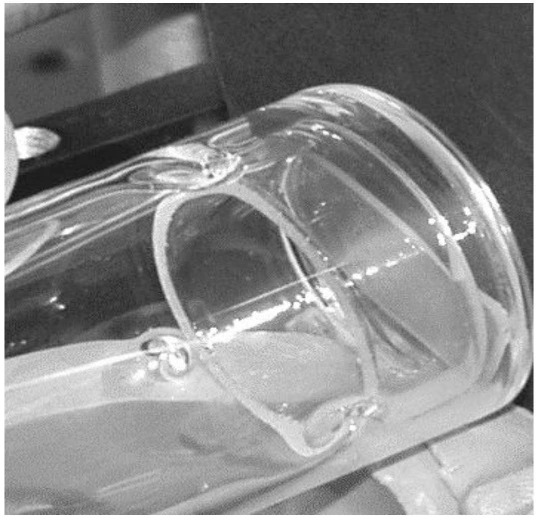
The porous glass sample is a rectangular plate 30x15x1mm^3 in size. It is placed inside a Pyrex resonance cell, kept at room temperature, and filled with rubidium or cesium.



0.4g=40m^2

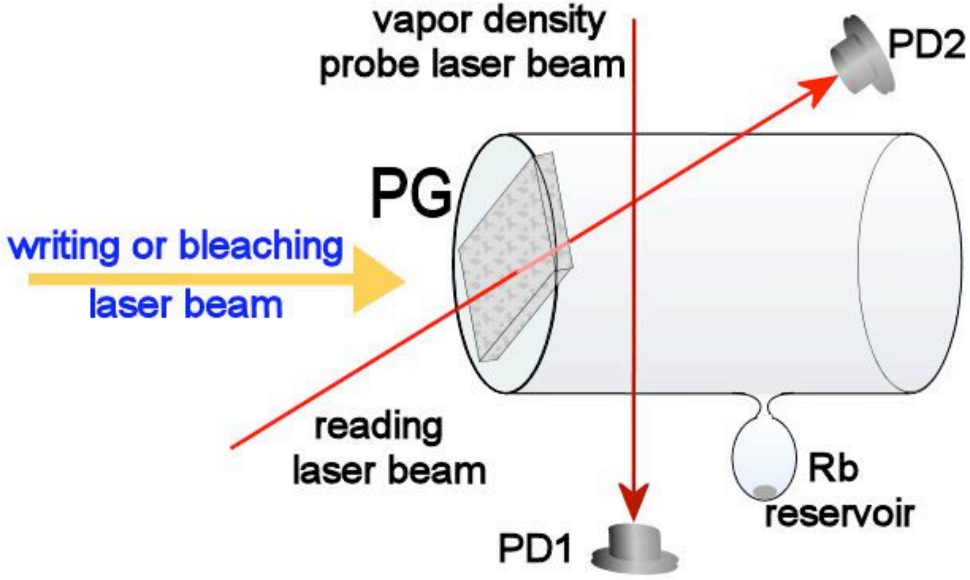


The sample is fixed close to one of the cell windows by a Pyrex Ring sealed to the cell body



Optics Express 16, 1377 (2008)

Phys. Rev.Lett. 97 157404 (2006)

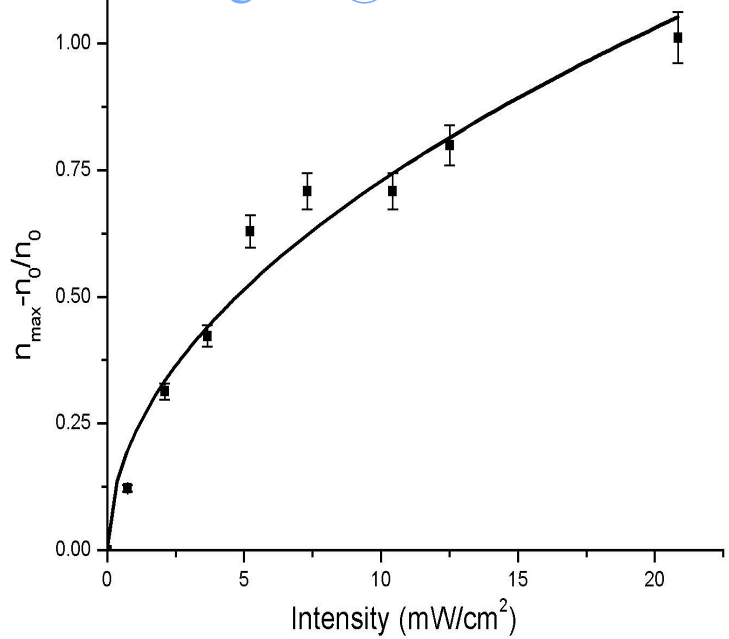


The desorbing rate **R** and the maximum increase of the vapour density δ_{max} are measured as function of the desorbing light intensity and frequency.

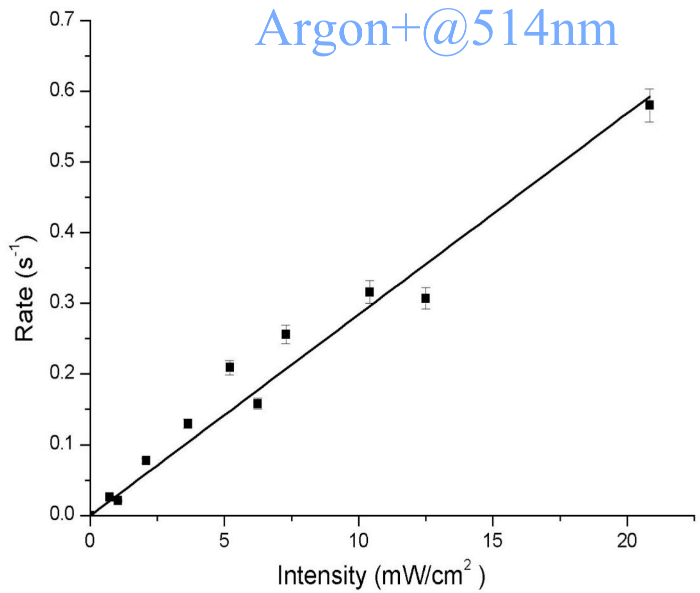
$$\delta_{\max} = \frac{\Delta n_{\max}}{n_0} = \frac{n_{\max} - n_0}{n_0}$$

$$R = \frac{1}{n_0} \left.\frac{dn}{dt}\right|_{t=0}$$

Argon+@514nm

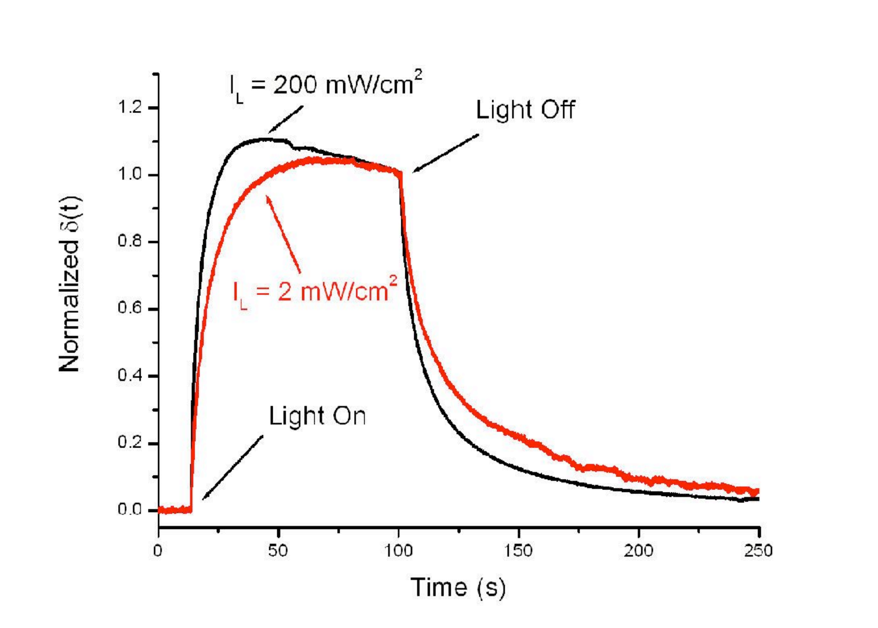


Argon+@514nm



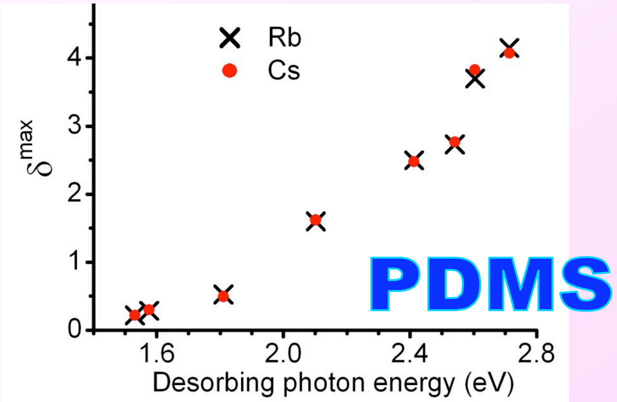
Photodesorption dependence on light intensity

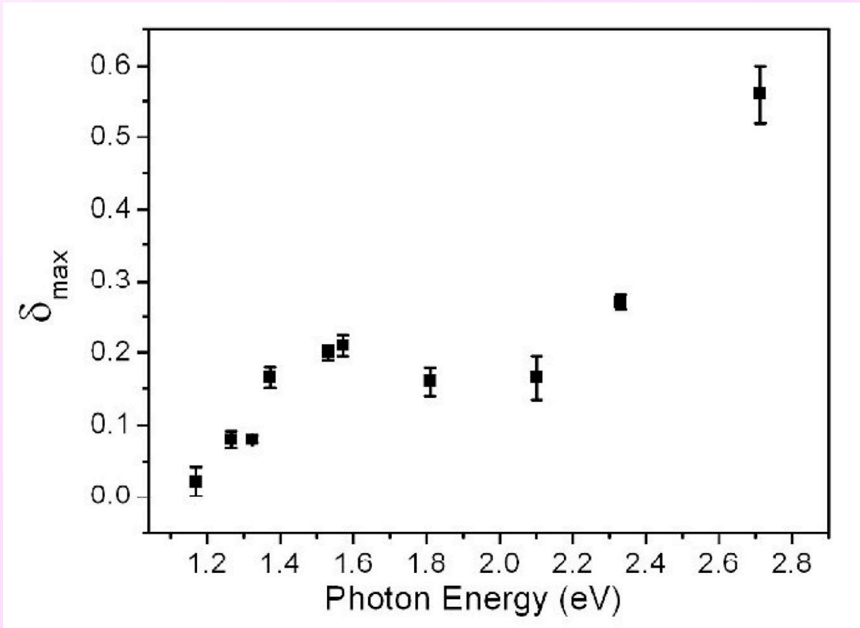
Photo-induced processes in 17nm porous glass



The decay time depends on the desorbing light intensity, wavelength and on the illumination time

The behavior with the desorbing photon energy is not monotonic

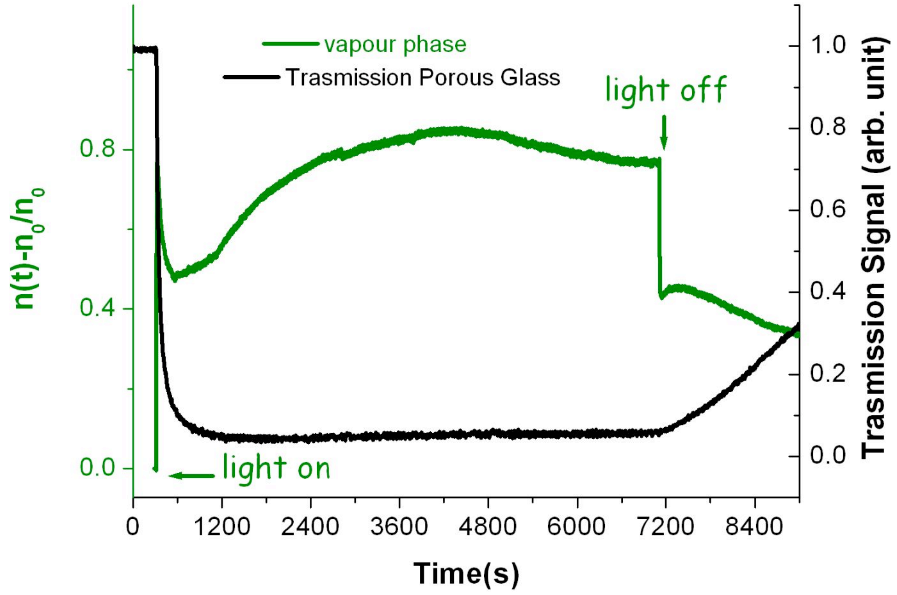




A. Burchianti et al. Physical Review Letters 97 (2006)

Photodesorption dynamics

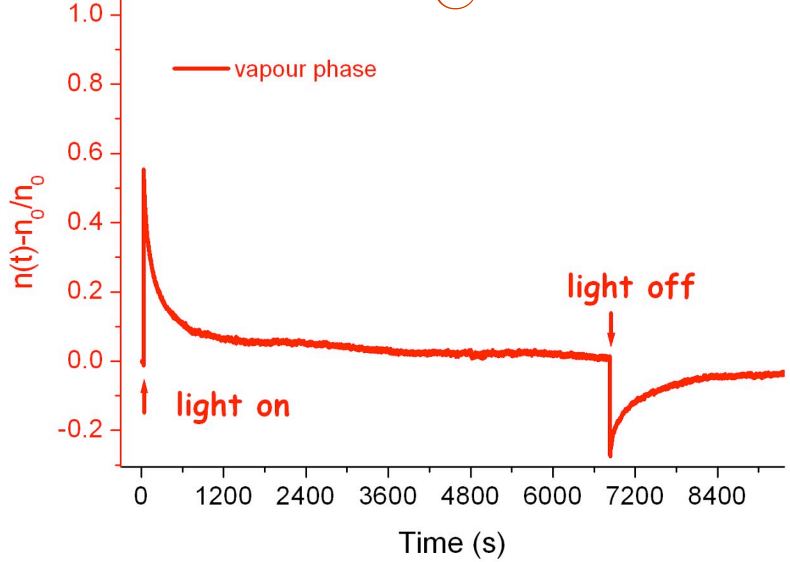
15mW/cm²@514nm



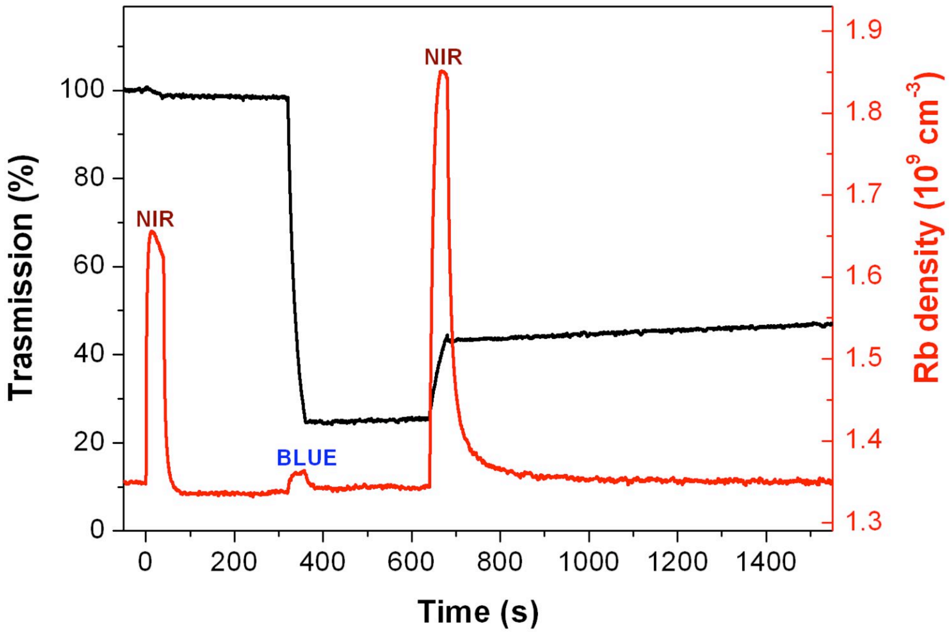
Green illumination

NIR illumination

27mW/cm²@810nm



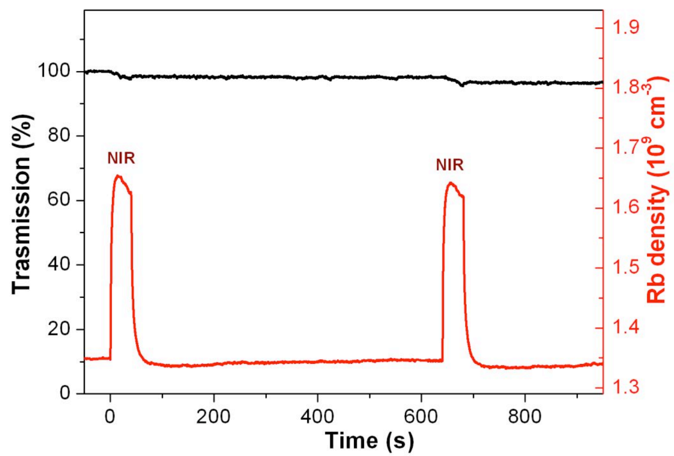
NIR-BLUE-NIR sequence of colours



488nm 5.6mW/cm^2
illuminated area 0.3 cm^2

808nm 2W/cm^2
illuminated area 0.1 cm^2

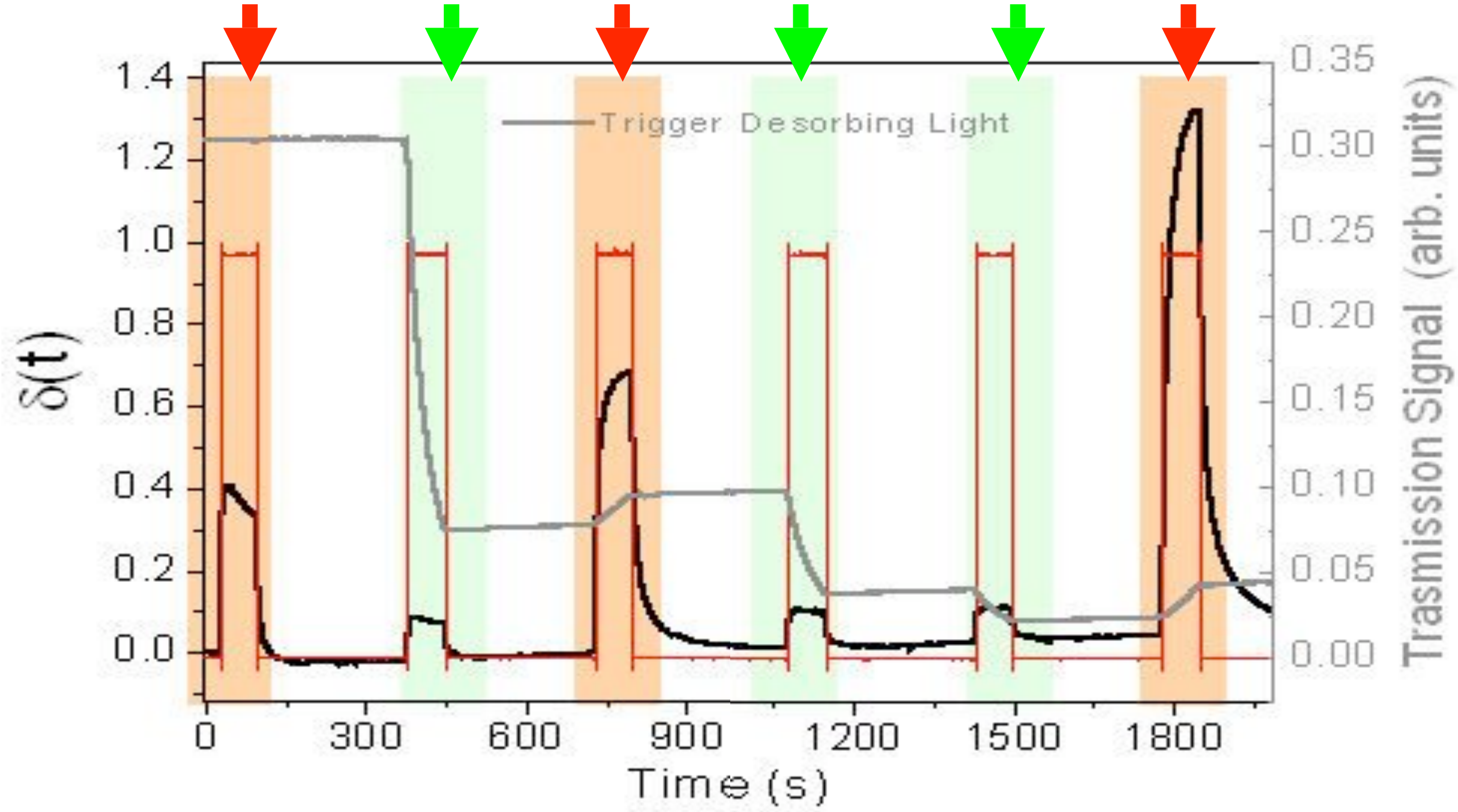
Double NIR illumination



Six shots

By alternately illuminating the sample with blue-green and NIR light we find that the PG sample remembers the illumination sequence

Sequence light pulses: red+green+red+2green+red



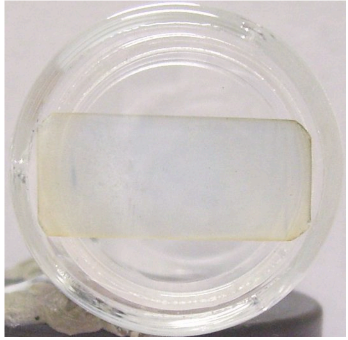
Burchianti et al., PRL 97 157404 (2006)

20mW@532nm/ 50mm^2

260mW@810nm/16mm^2

Storing and erasing images in Rb loaded PG

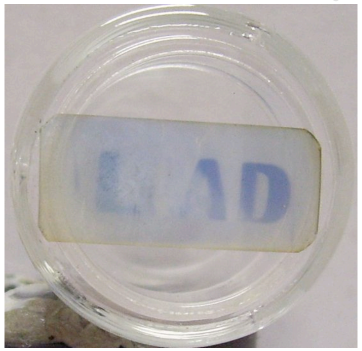
Optics Express 16, 1377 (2008)

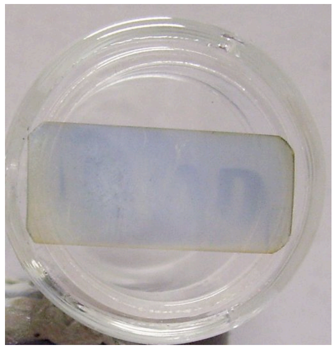


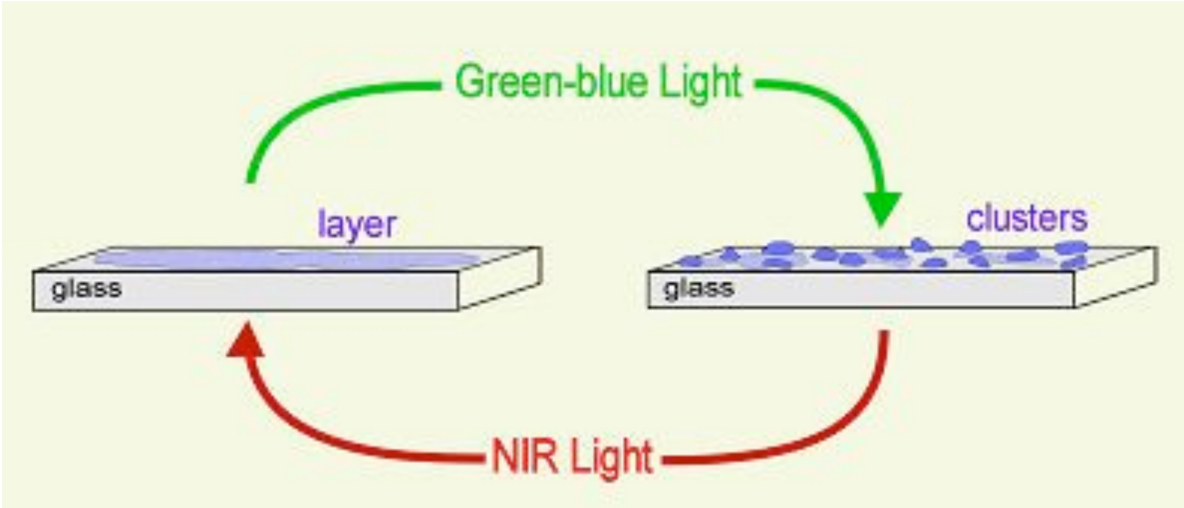
20mW/cm^2 at 2.3eV; 2min

2.5W/cm^2 at 1.5eV; 30s

In the dark the system relaxes to the equilibrium condition







Cluster growth induced by UV-visible light
is correlated to LIAD

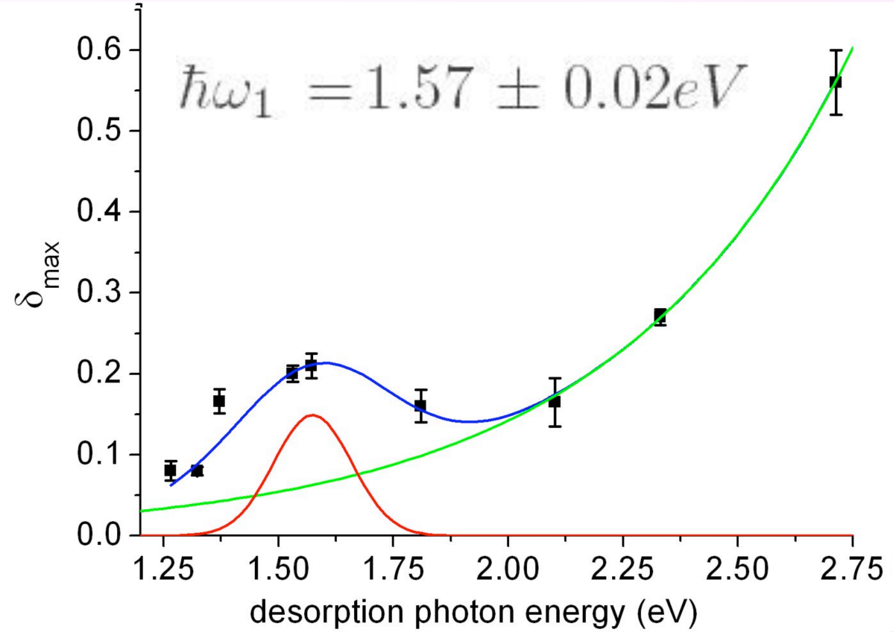
NIR light induce both cluster evaporation via SPID and
cluster growth via LIAD

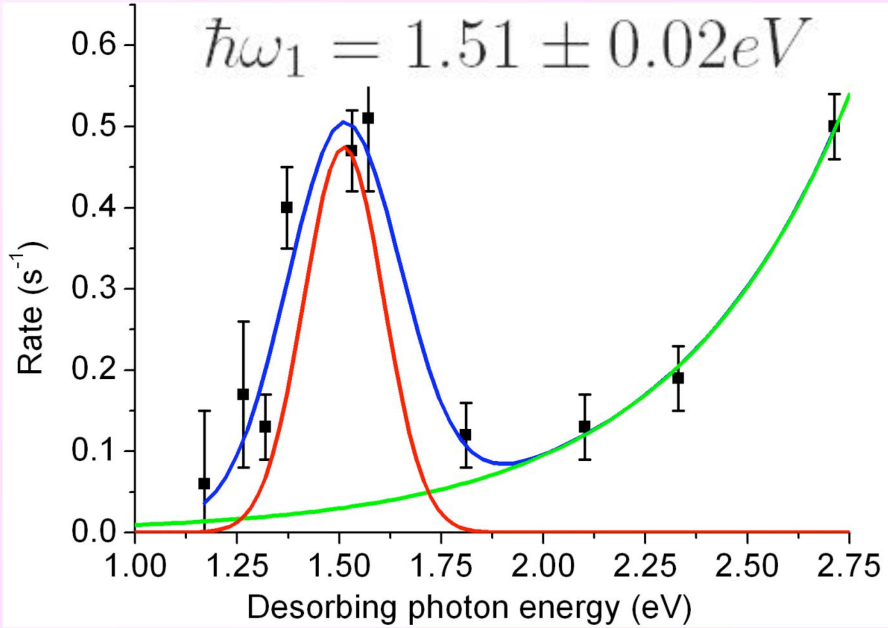
Separation of two desorption contributions

$$\delta_{max}(\hbar\omega) = A_1 \cdot \exp(c_1 \hbar\omega) + A_2 \cdot \exp\left(-\frac{(\hbar\omega - \hbar\omega_1)^2}{W^2}\right)$$

Desorption from layers — **Desorption from clusters**

Rb adsorbed on porous silica

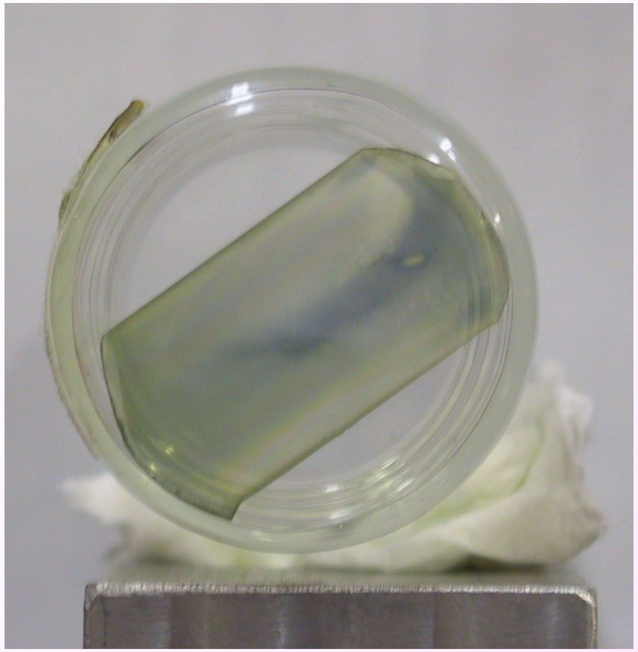


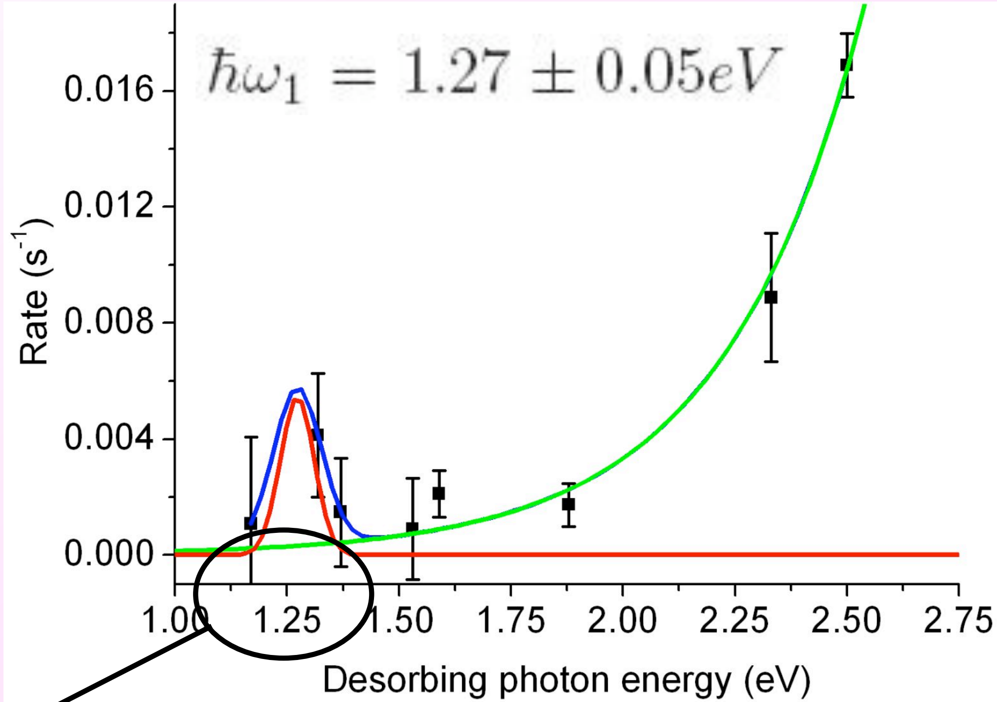


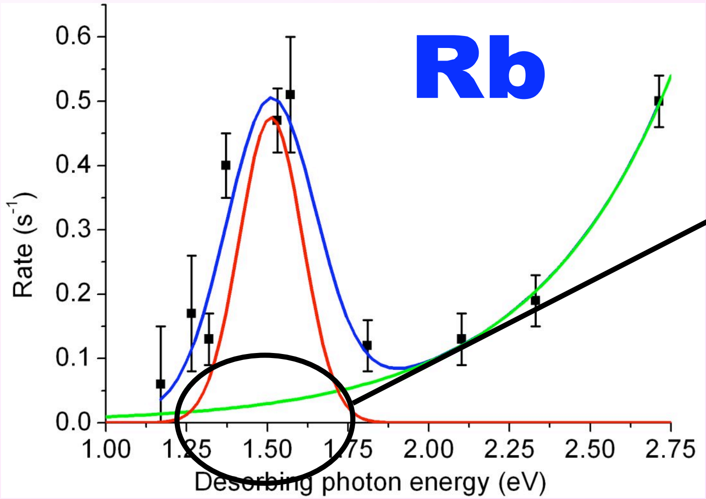
Theoretical surface plasmon resonance $\hbar\omega_1 = 1.65 eV$

Photo-induced processes in 17nm porous glass

Cs adsorbed on porous glass







Theoretical surface plasmon resonance

$$\hbar\omega_1 = 1.54 eV$$

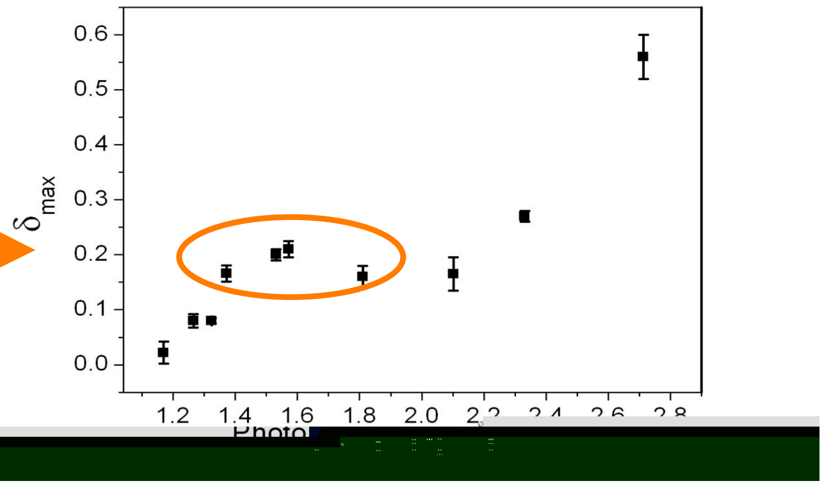
Change of PG Absorbance Cluster Formation

The photon energy dependence of **Surface Plasmon Induced Desorption** is dominated by dipolar surface plasmon frequency. For a spherical metal particle we get

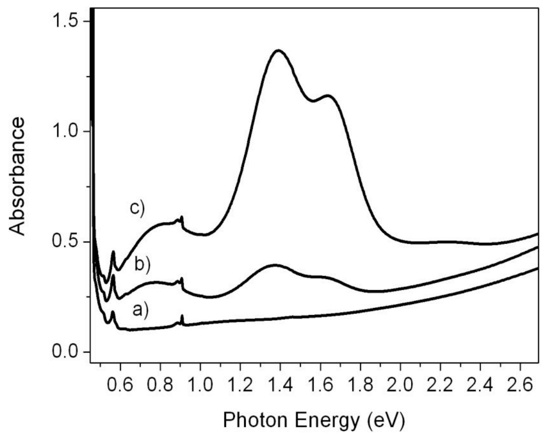
$$\omega_1 = \frac{\omega_p}{\sqrt{1+2\varepsilon_m}} \Rightarrow \hbar\omega_1 = 1.65eV$$

$$\hbar\omega_p = 3.41eV$$

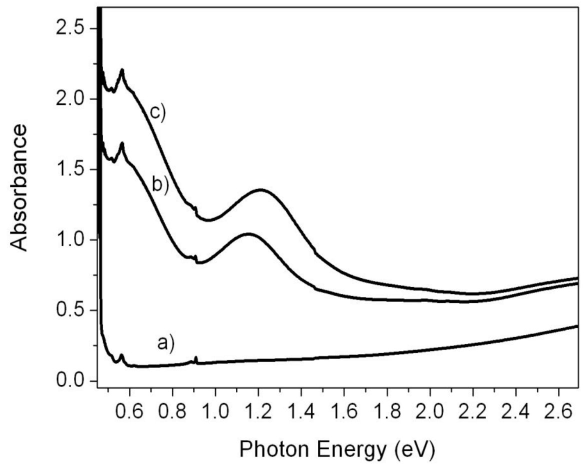
$$\varepsilon_m = 1.625$$

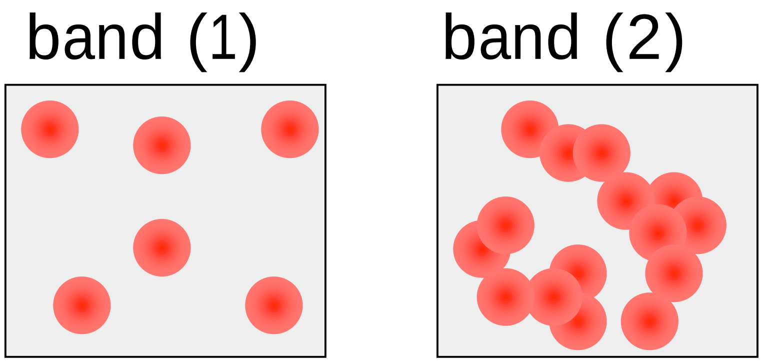


PG 17nm with Rb



PG 17nm with Cs





we apply Gans theory that describes the optical properties of randomly oriented spheroids with size R << λ

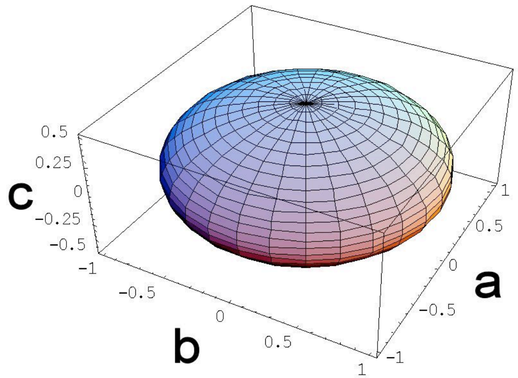
$$\sigma_{ext}(\omega) = \frac{\omega}{3c} \cdot V \cdot \varepsilon_m^{3/2} \cdot \sum_i \frac{\varepsilon_2(\omega)\left(1/P_i^2\right)}{\varepsilon_2(\omega)^2 + \left\{\varepsilon_1(\omega) + \varepsilon_m \frac{1-P_i}{P_i}\right\}^2}$$

$$P_c = \frac{1+e^2}{e^3} \cdot \left(e - \tan e^{-1}\right)$$

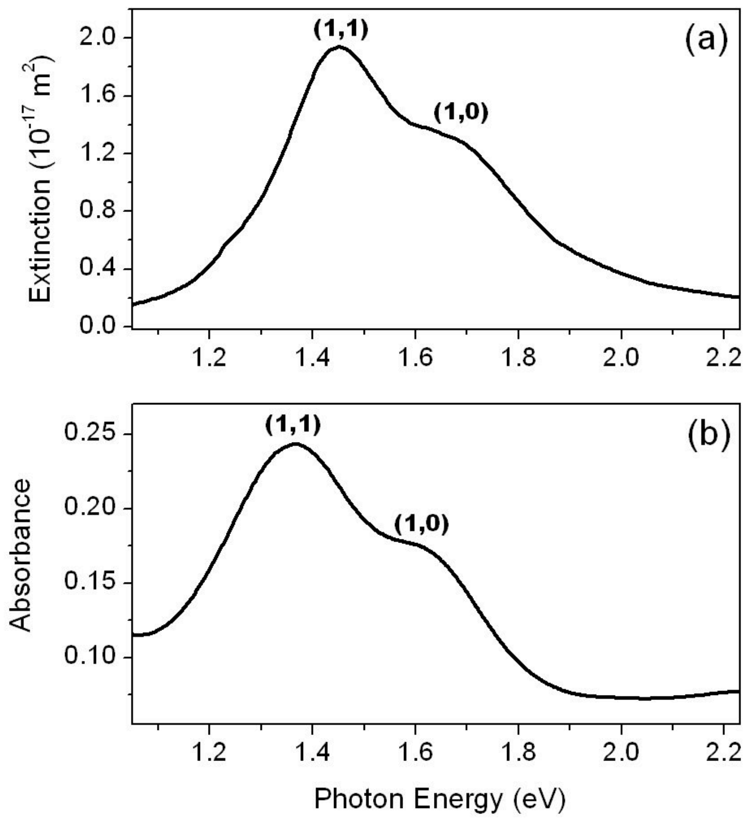
$$P_a = P_b = \frac{1}{2} \cdot (1 - P_c)$$

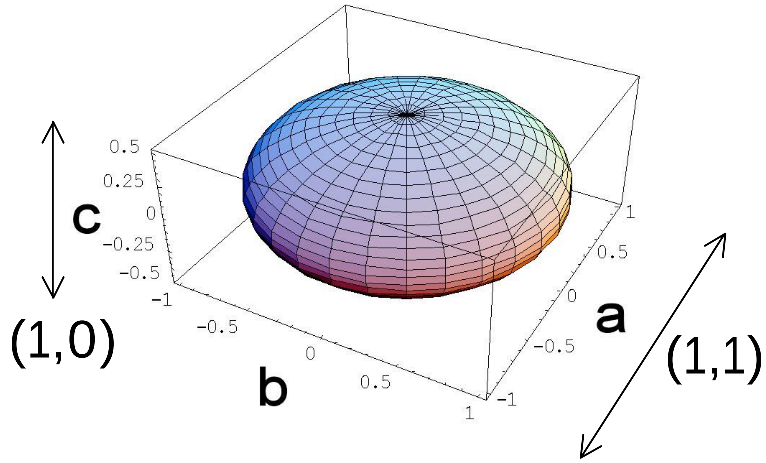
$$e = \sqrt{\frac{a^2}{c^2} - 1}$$

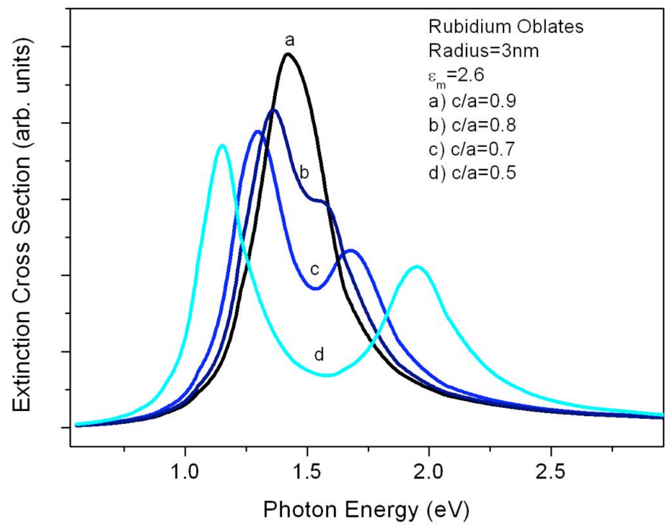
for oblate particles (c<a=b)



Rb/PG







R=3nm; c/a=0.8

Light controlled atomic dispensers - fast and clean

Atom delivery in nanostructures -
control of optical thicknes with light

Control of cluster formation in nanostructured materials

High vapor densities at room or lower temperatures

A. Burchianti, A. Bogi, C. Marinelli, E. Mariotti
CNISM and Physics Department, University of Siena, I-53100 Siena, Italy

C. Maibohm
Mads Clausen Institute, University of Southern Denmark, DK-6400 Sonderborg, Denmark

S.Sanguinetti
Physics Department, University of Pisa, I-56127 Pisa, Italy

S.N. Atutov, K. Nasyrov
Novosibirsk

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A. Bogi, C. Marinelli, A. Burchianti, F. Della Valle, E.Mariotti, S. Veronesi, G. Bevilacqua,