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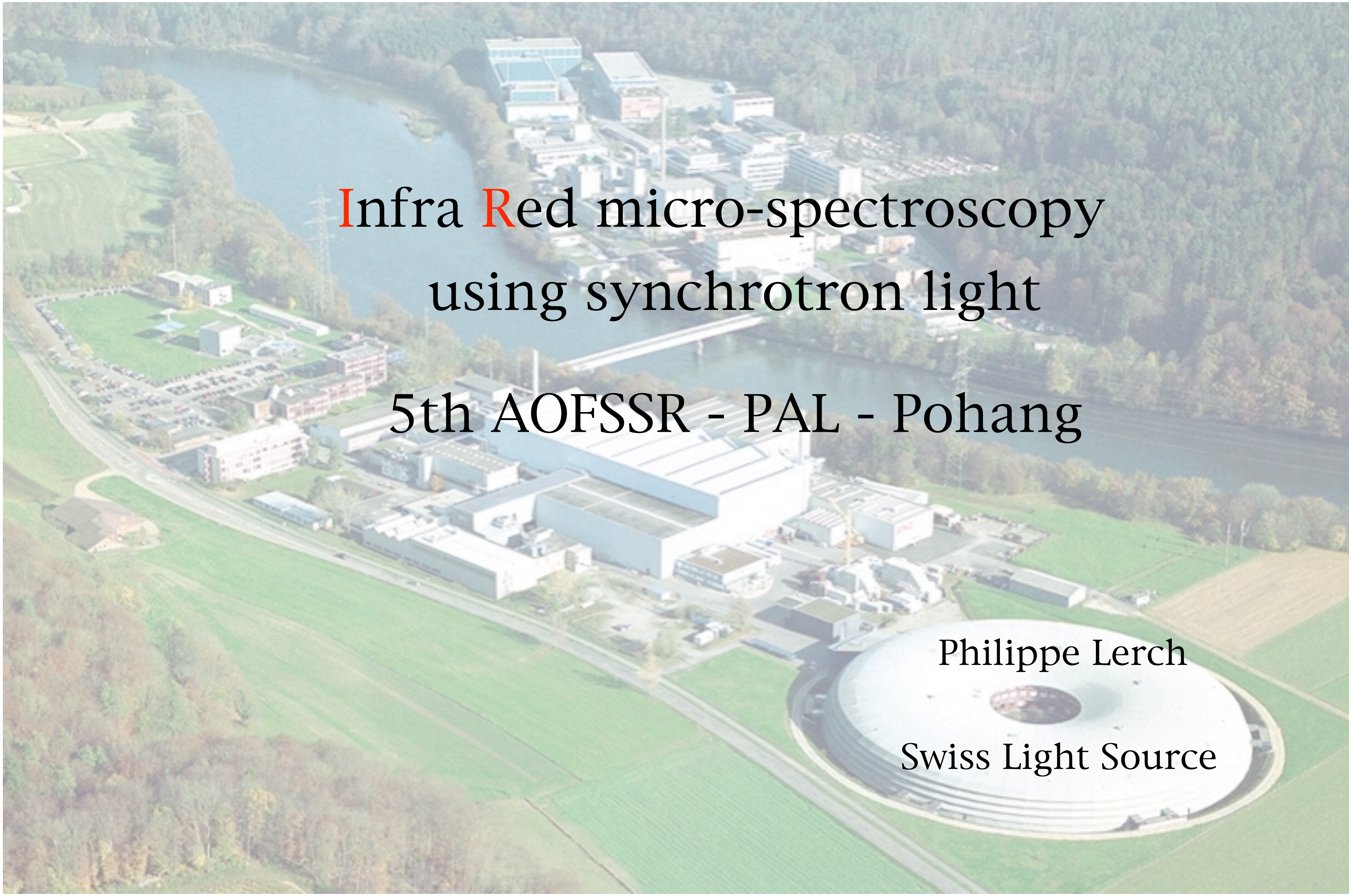


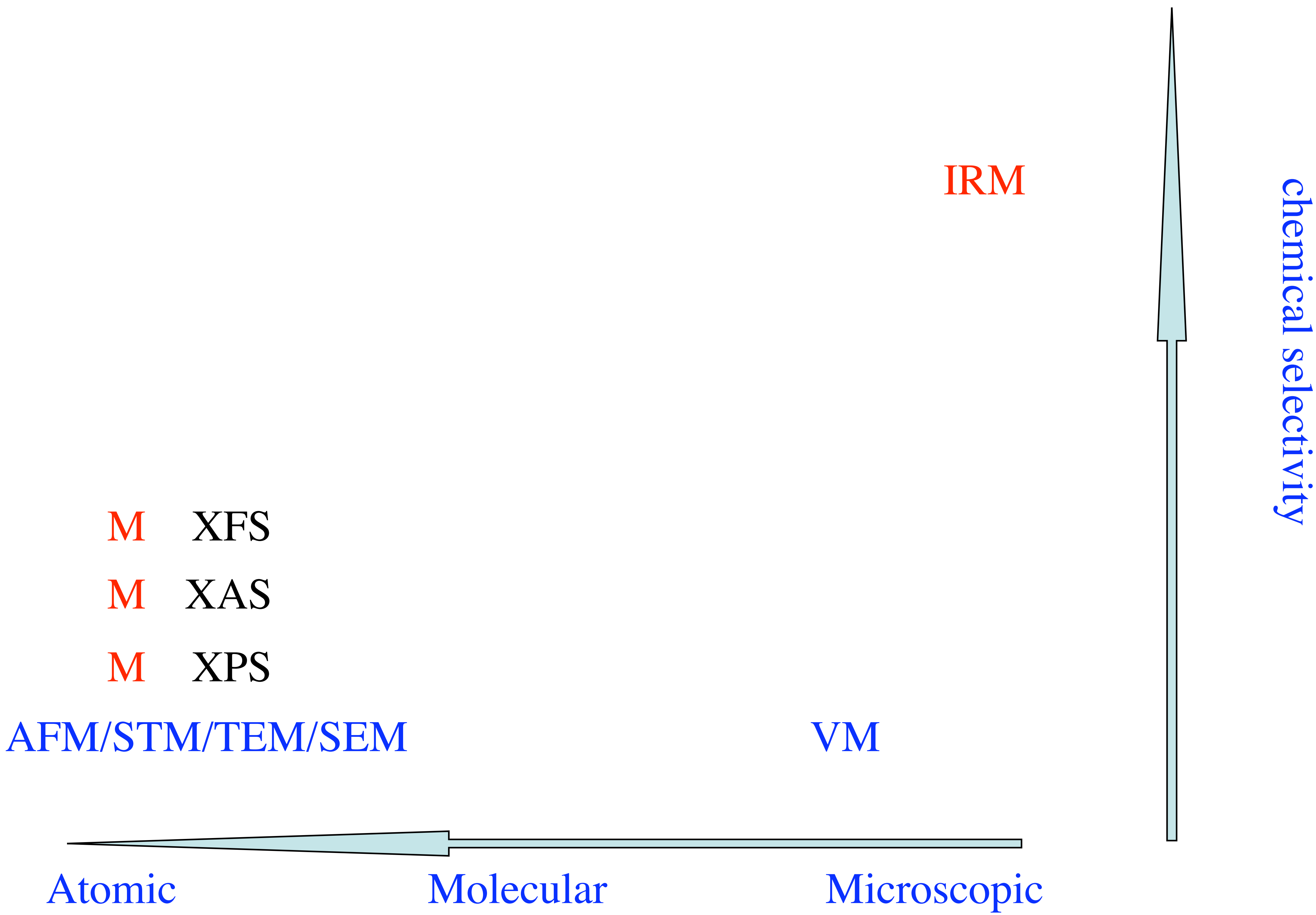
Infra Red micro-spectroscopy using synchrotron light

5th AOFSSR - PAL - Pohang

Philippe Lerch

Swiss Light Source

- sources and methods
- some examples


IRM
chemical selectivity
M XFS
M XAS
M XPS
AFM/STM/TEM/SEM
VM
Atomic
Molecular
Microscopic

!! MIR: thermal source has more total flux !!

SR is a pulsed source, and has more FIR flux

high brillance

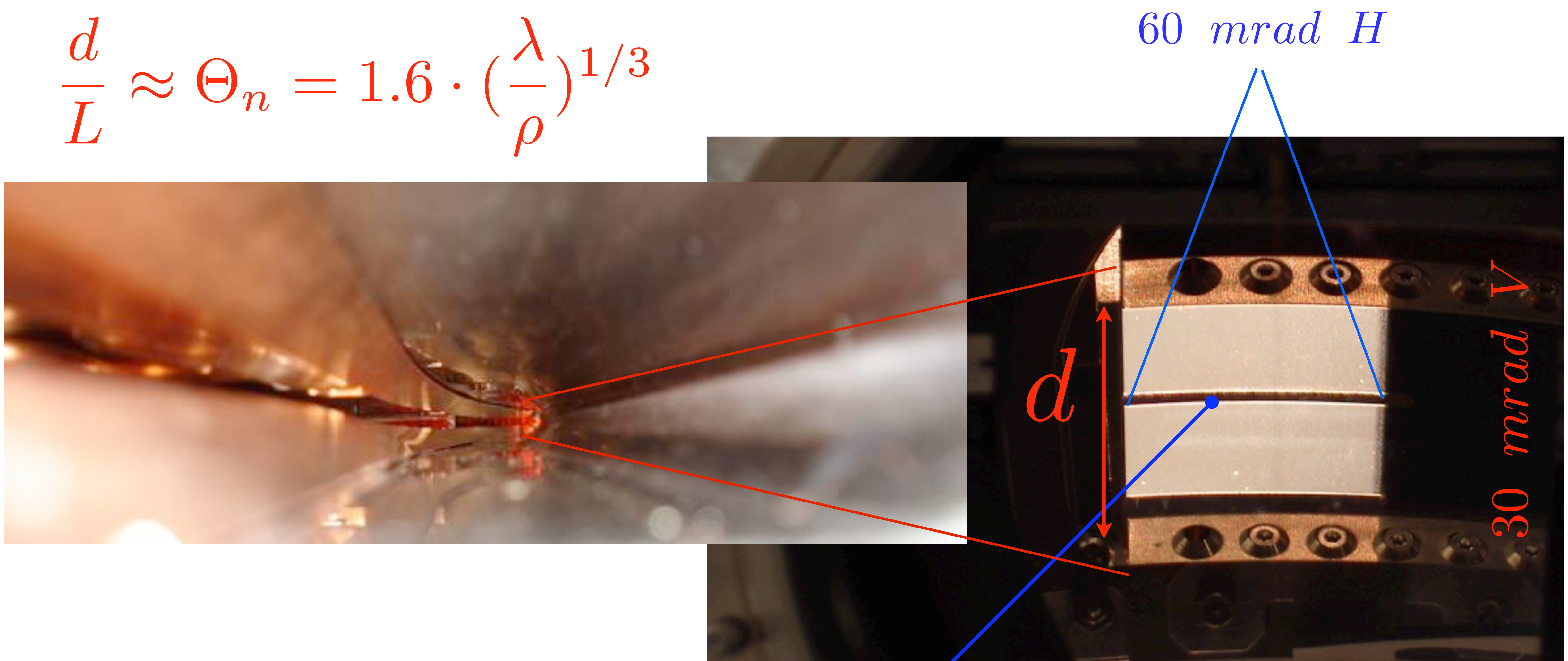
required for small samples

low brillance

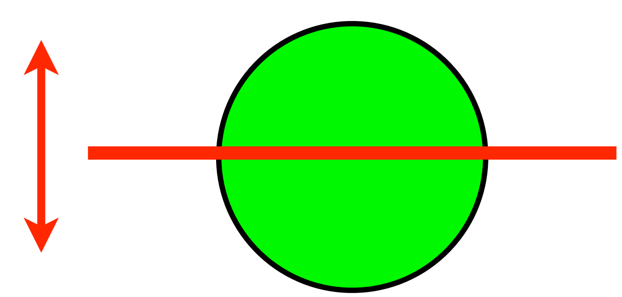
OK for large samples

small sample

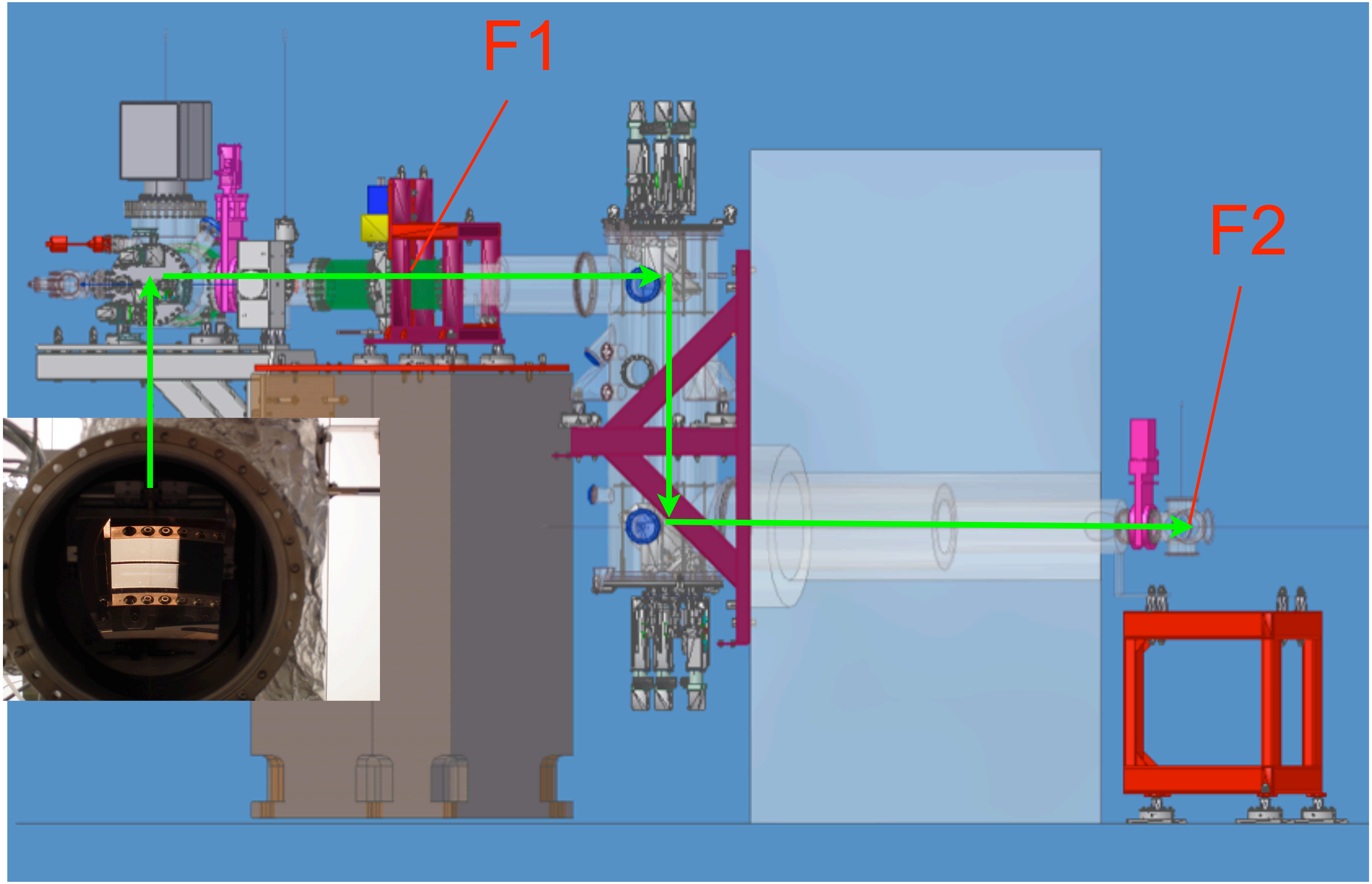
$$\frac{d}{L} \approx \Theta_n = 1.6 \cdot (\frac{\lambda}{\rho})^{1/3}$$



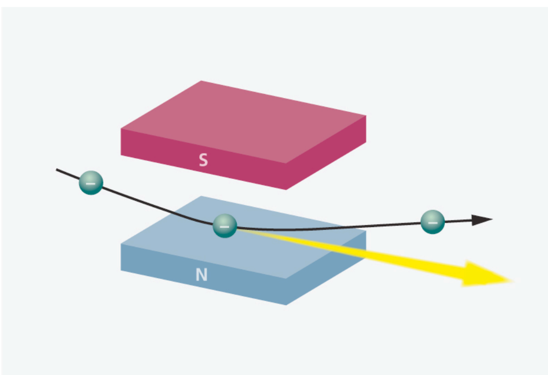
slot to avoid heat load
due to X-ray light



sensitive to vertical motion

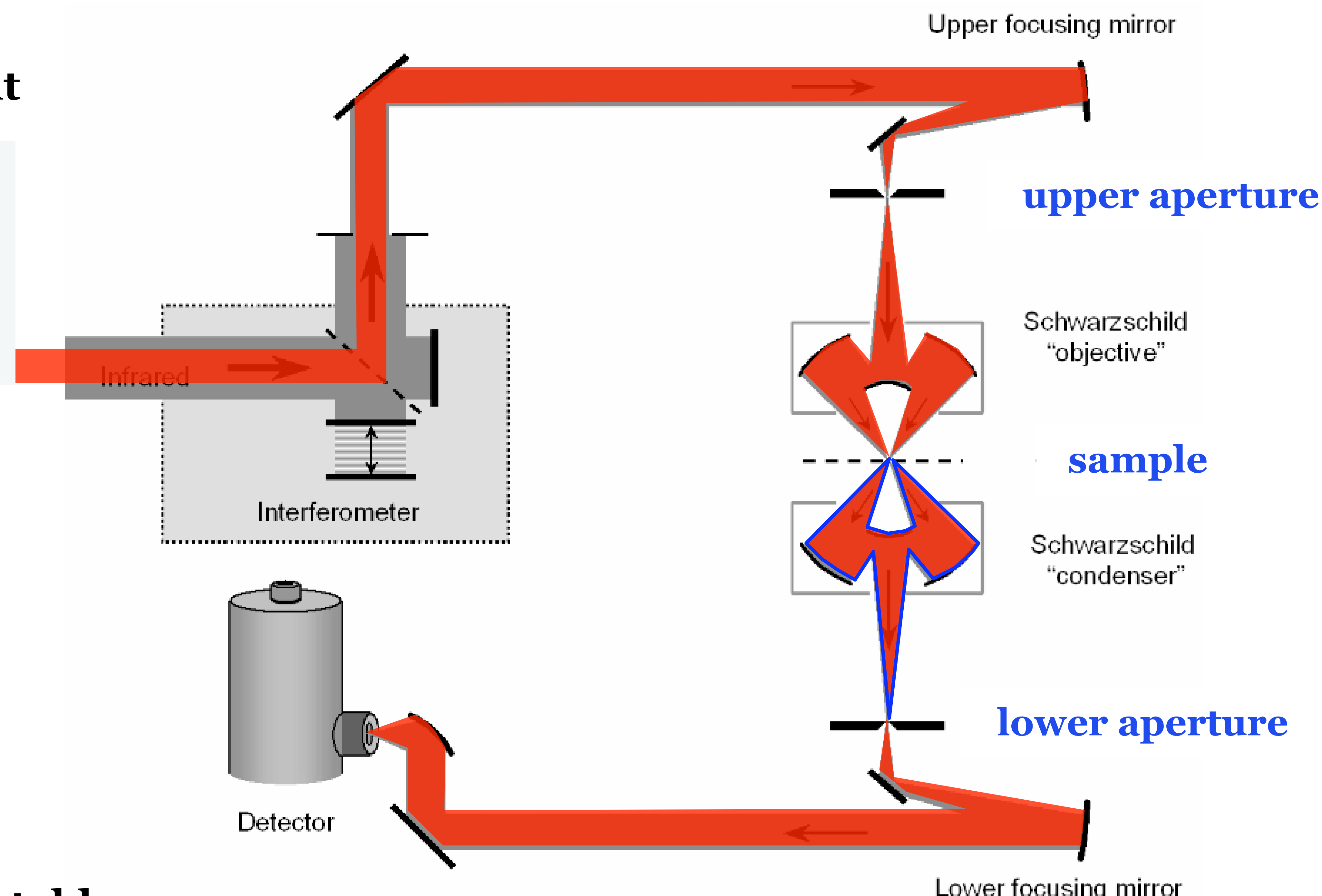

F1
F2

SR: very bright

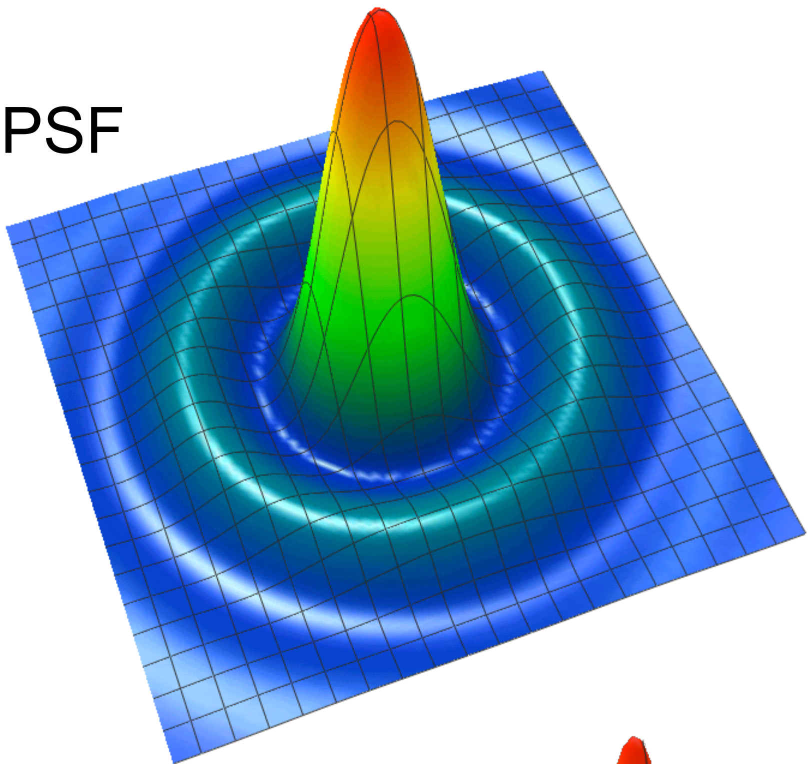


or

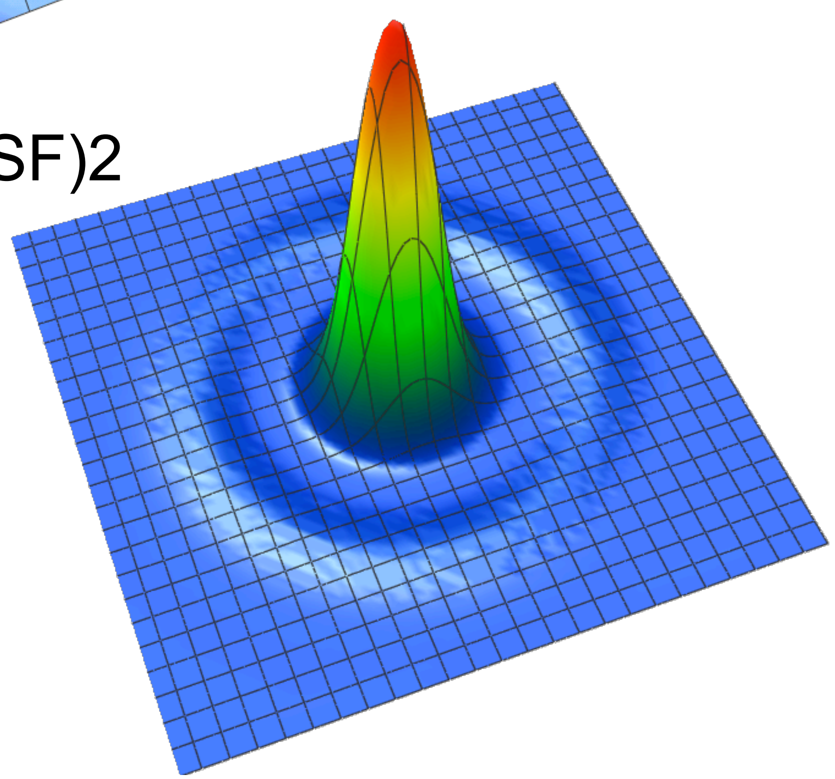
thermal: very stable

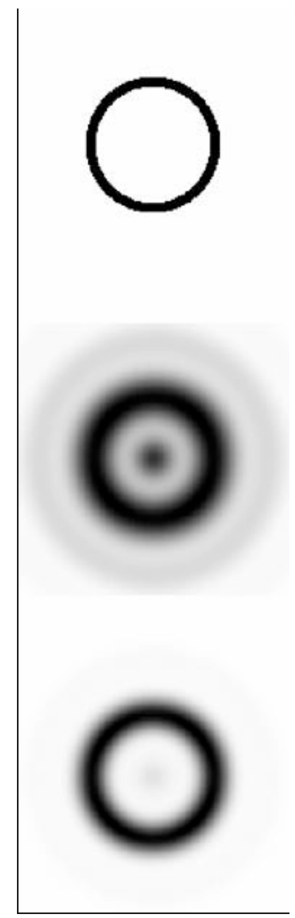


PSF



(PSF)2



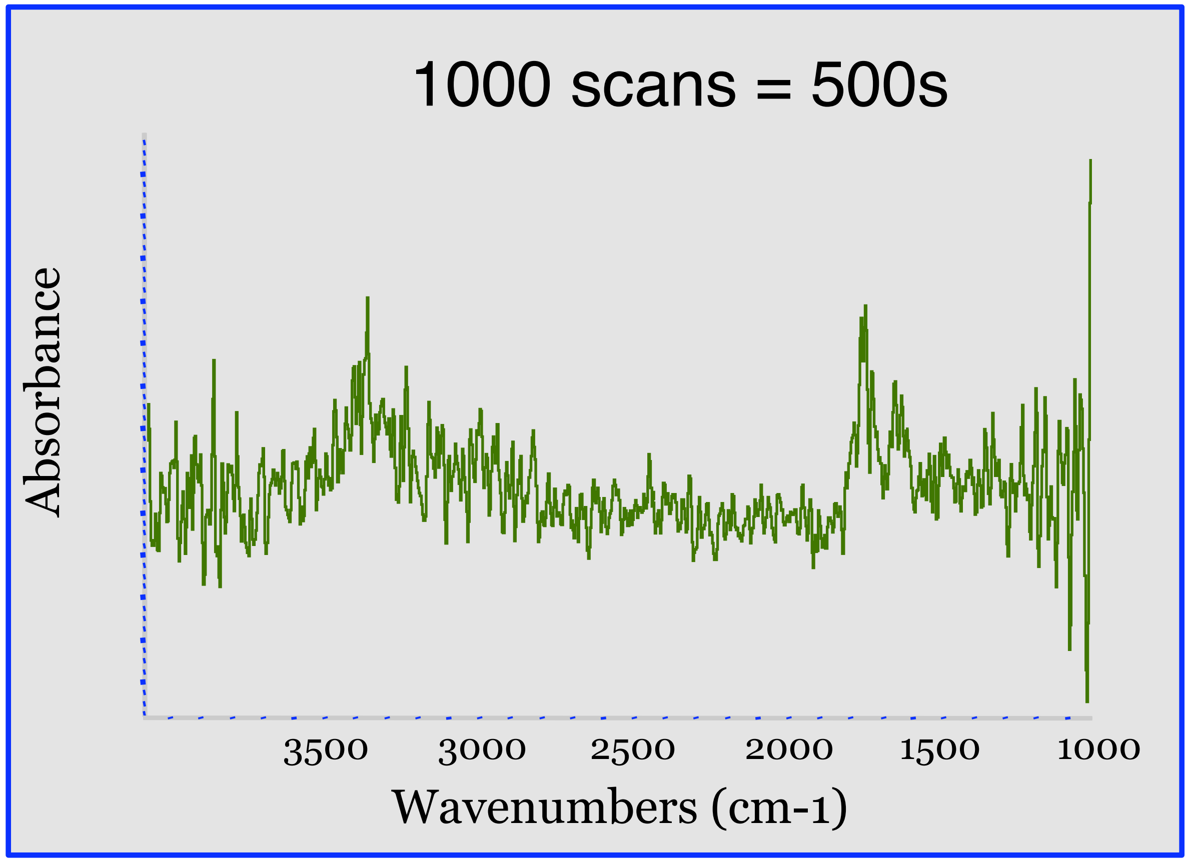


object

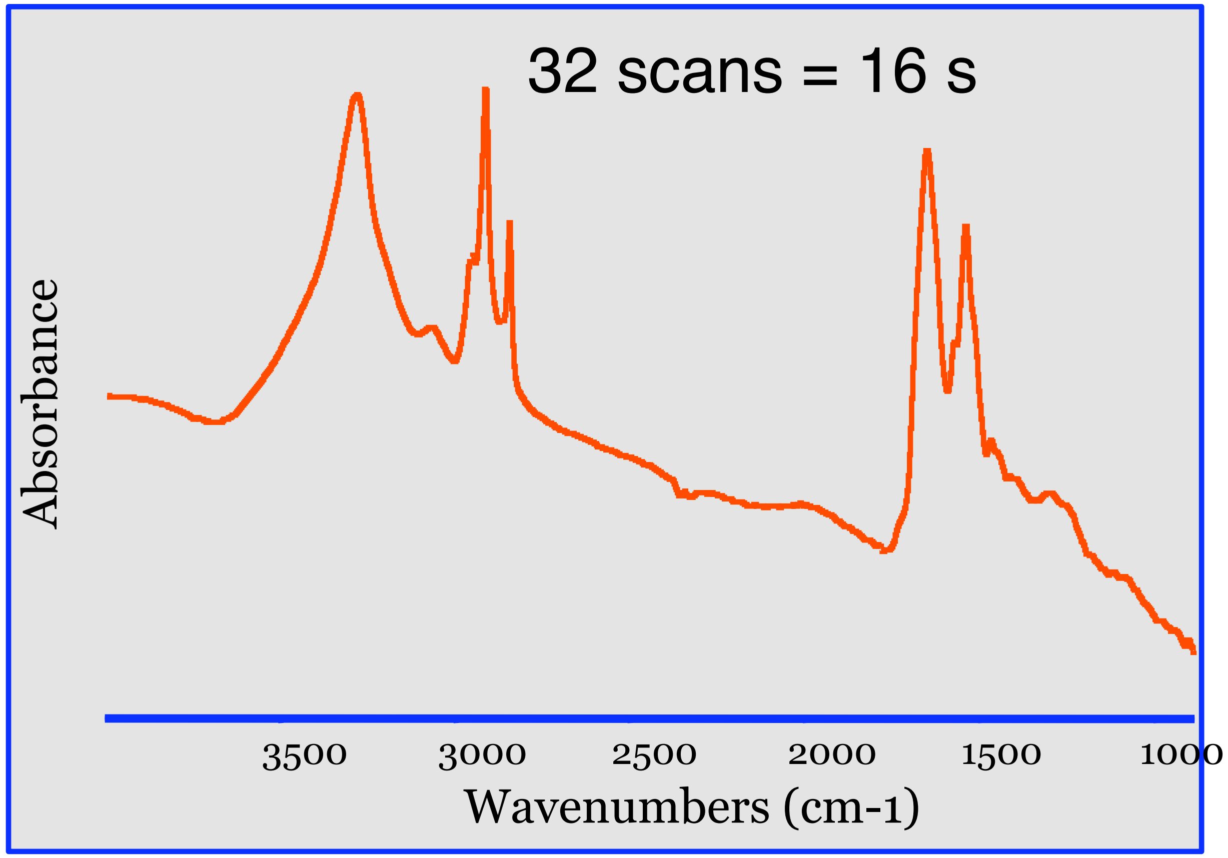
object **NOT** observed in confocal configuration

object observed in confocal configuration

With the globar source

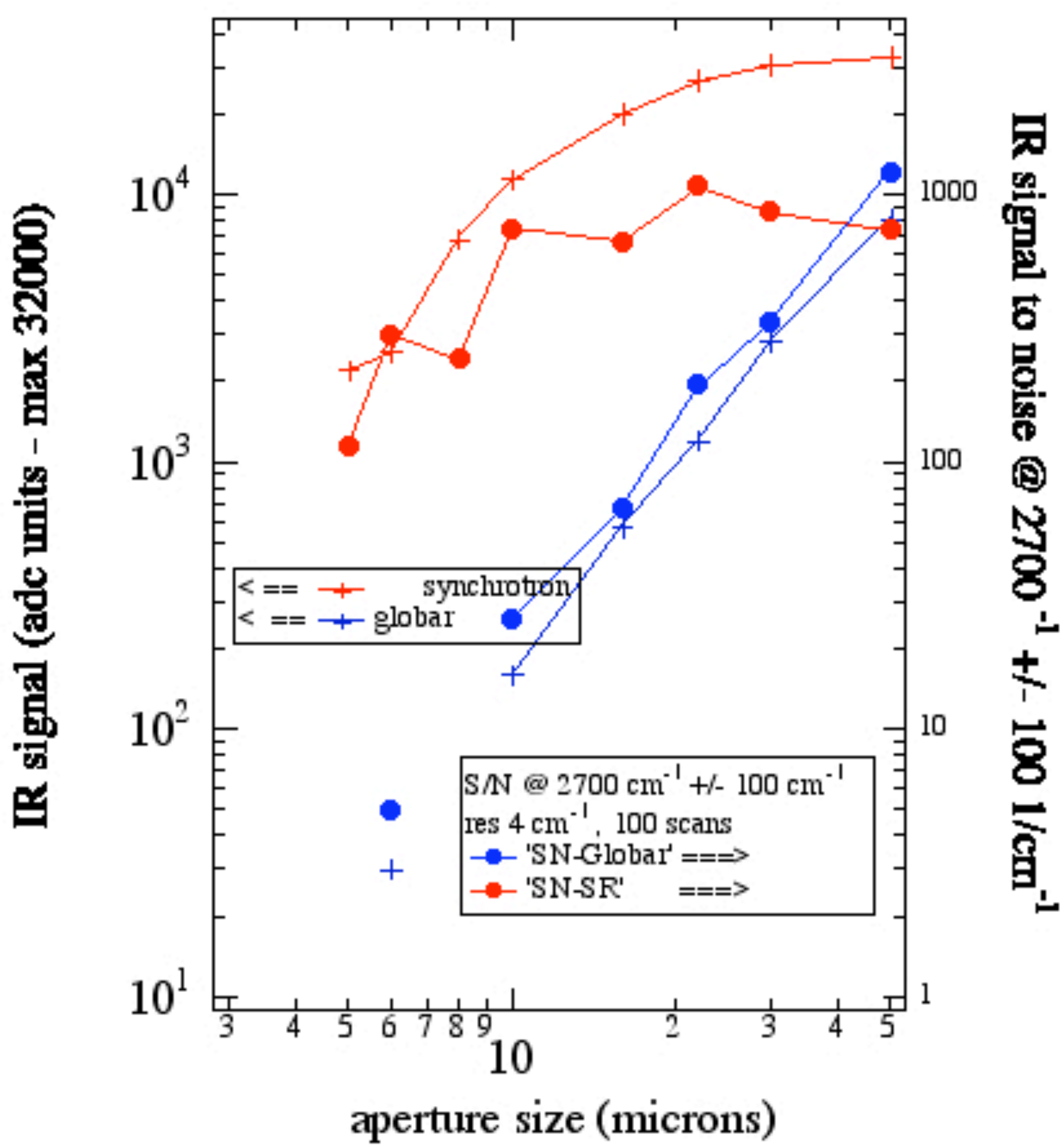


With the synchrotron source



6X6 μm^2 aperture

Figures from Paul Dumas, Soleil



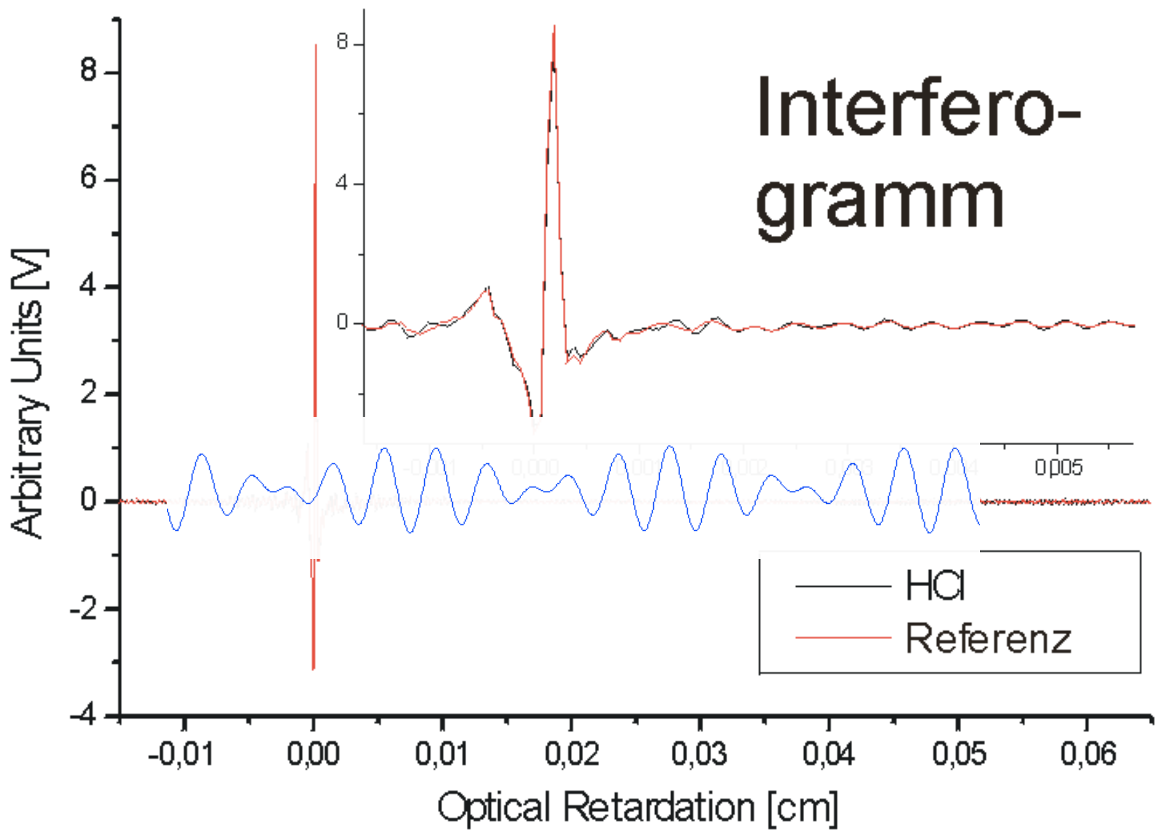
S/N @ 2700 1/cm - thermal

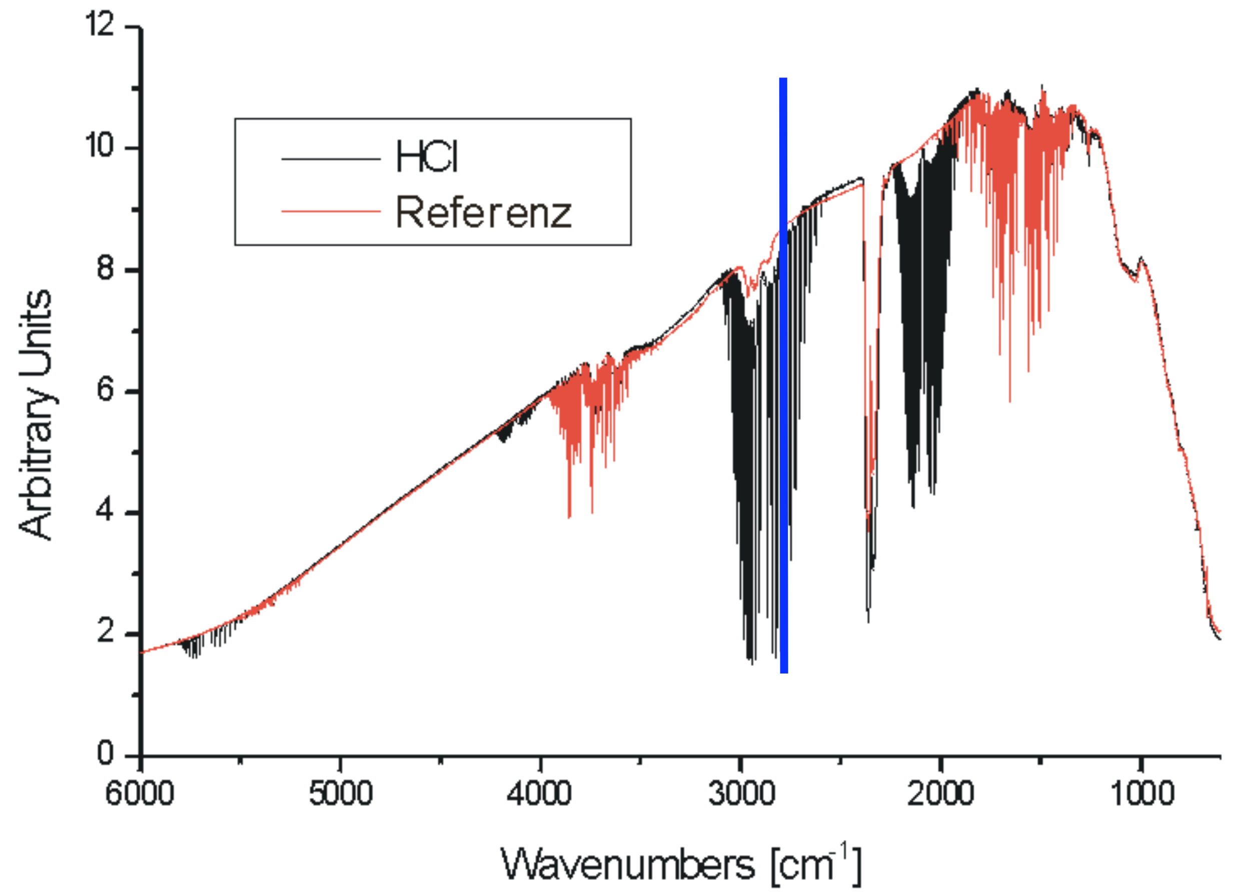
S/N @ 2700 1/cm - SR

there is a curve like that
for every wavelength !

spectral information coded
into ac signal (interferogram)

1 - 60 kHz





spurious intensity fluctuations added-up   appear as spectral artifacts

- sources and methods
- some examples

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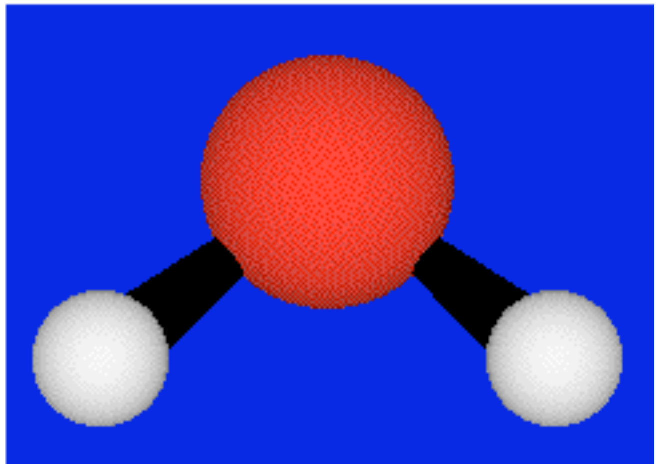
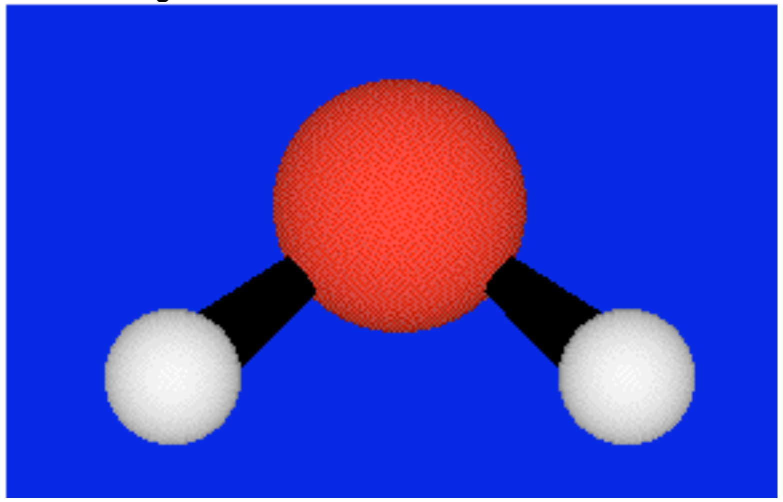
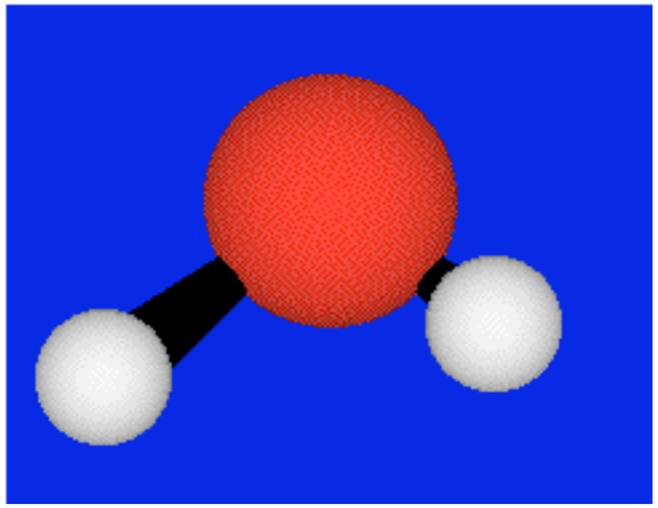
Symmetric stretch



Symmetric bend

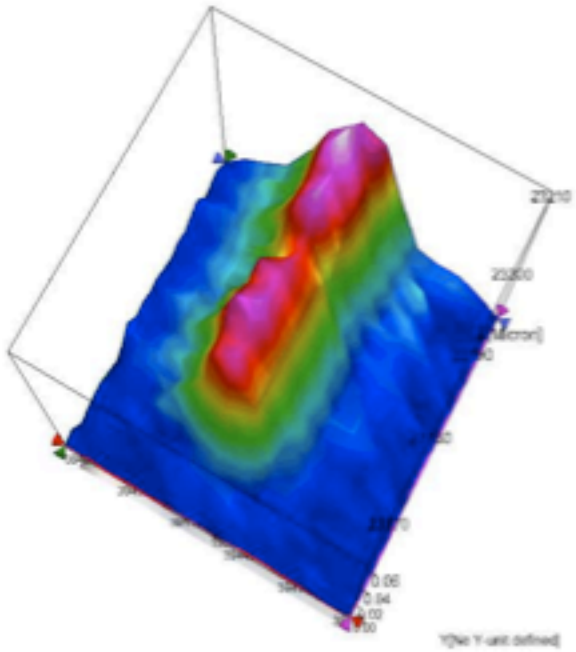


molecular probe



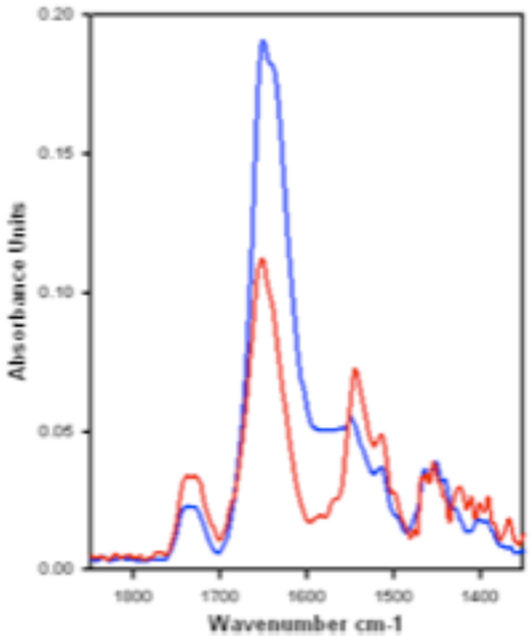
Asymmetric stretch

sub-cellular mapping rod cell



LIPID DISTRIBUTION:
absorbance at 2925 cm^{-1}

linear dichroism: info on molecular orientation vs membrane normal



Blue: parallel to rod axis
Red: perpendicular to rod axis

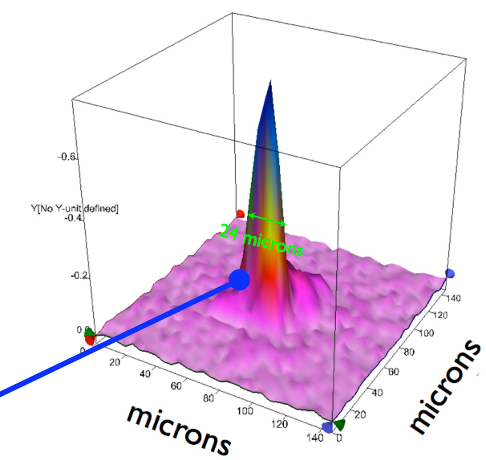
Rhodopsin α-helices inclination

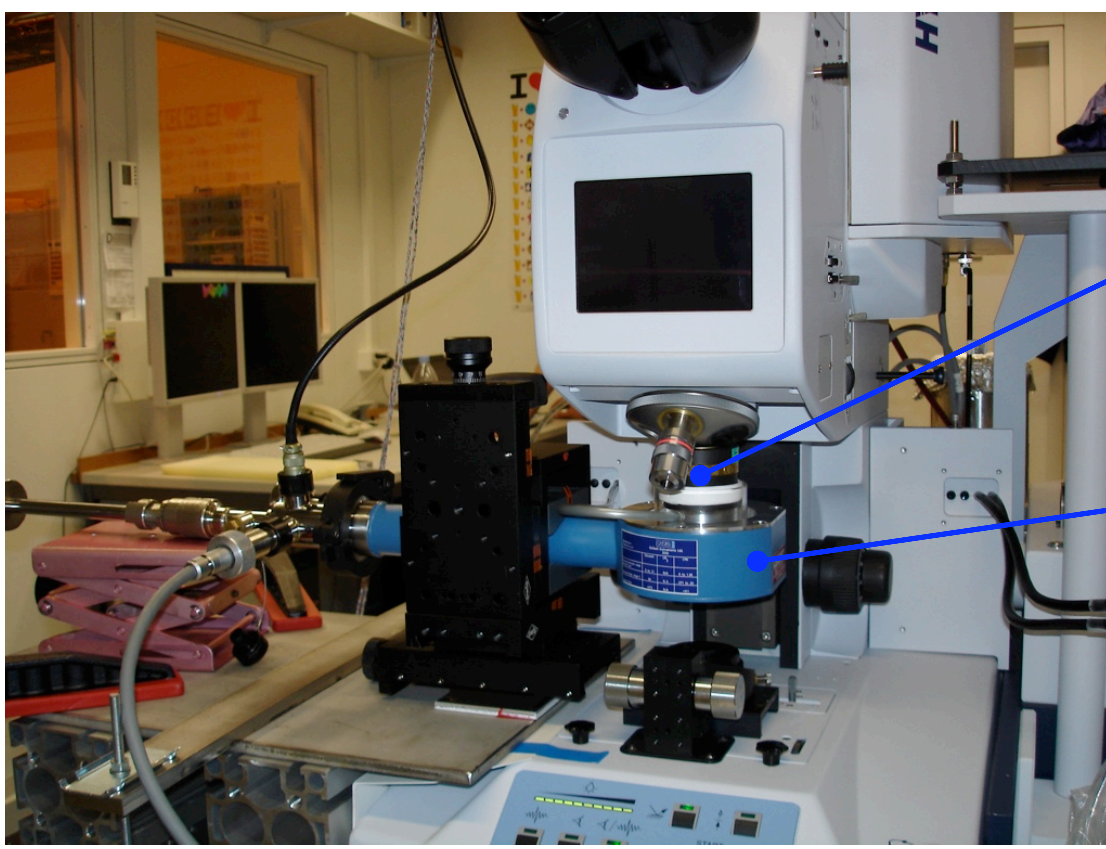
Micro-IR ⟨θ⟩ = 28°

XRD ⟨θ⟩ = 24°

L.Quaroni *et al*. ChemPhysChem, 2008, 9(10) 1380-1382

IR beam spot @ 8 microns





XY-table

4-300 K cryostat

DAC

in-situ P measurement

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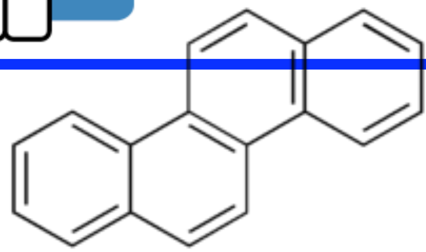
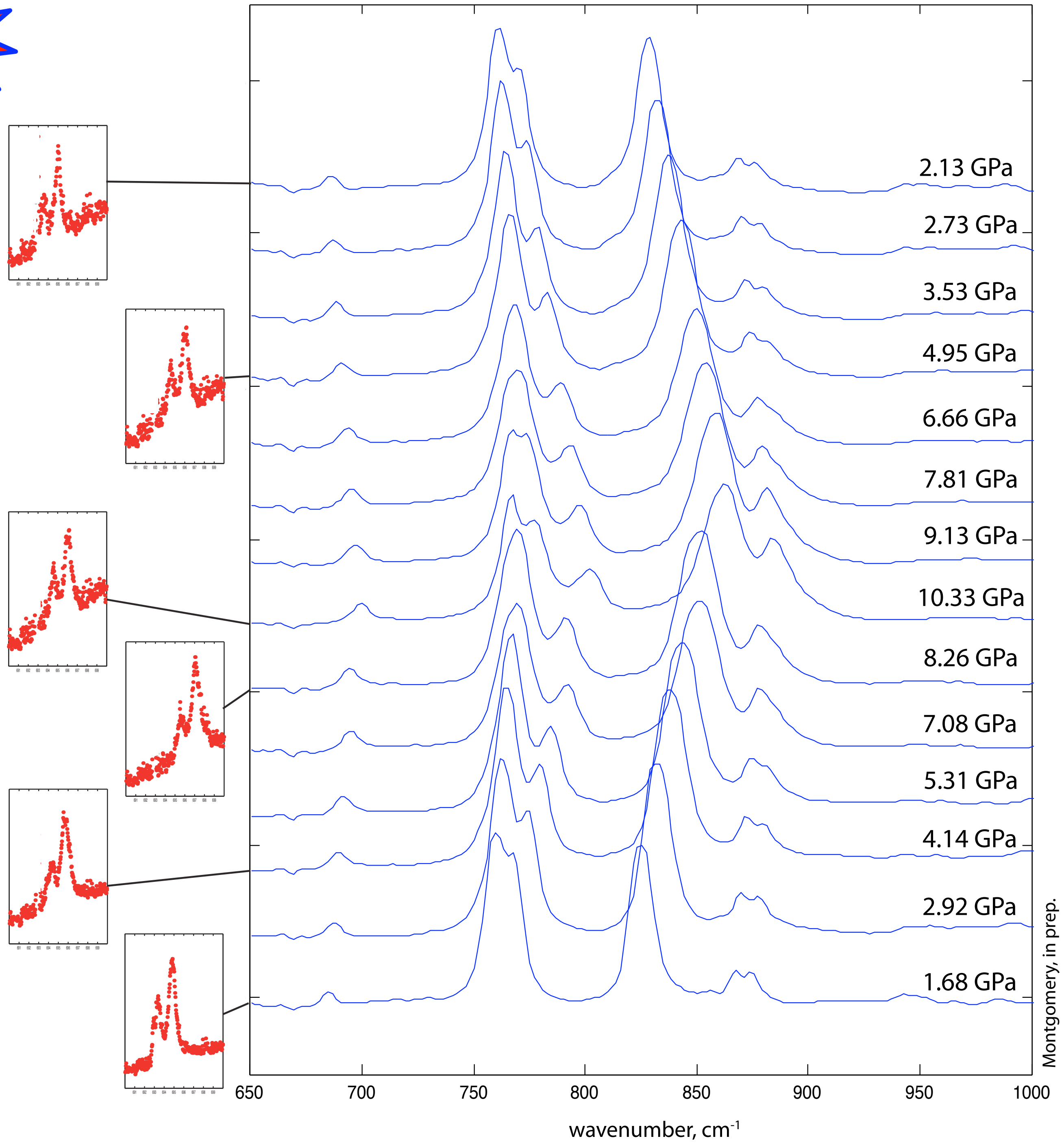
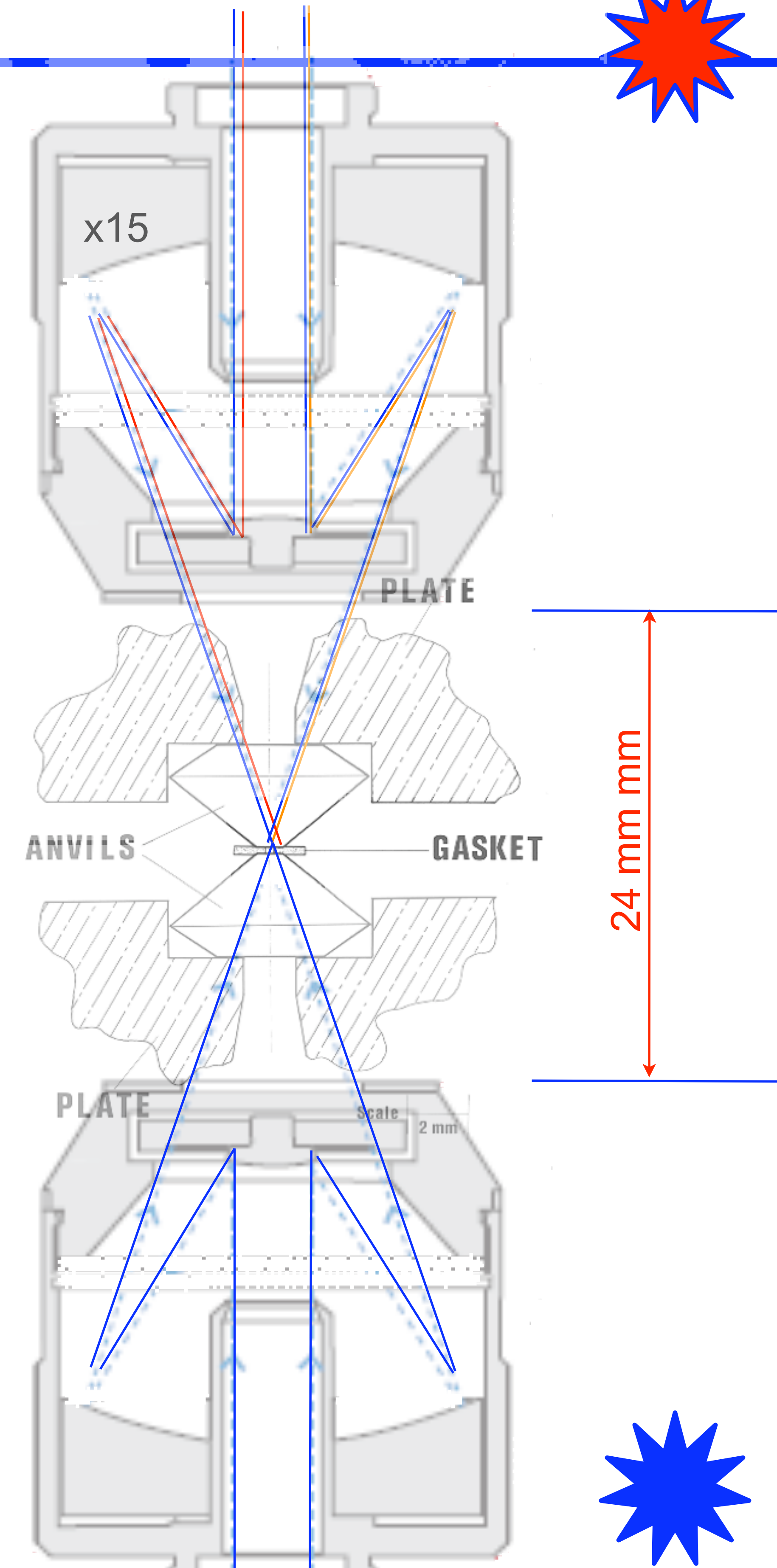


laser + IR from SR

Synchrotron-source FTIR of chrysene with in-situ pressure measurements, SLS X01DC May 2009





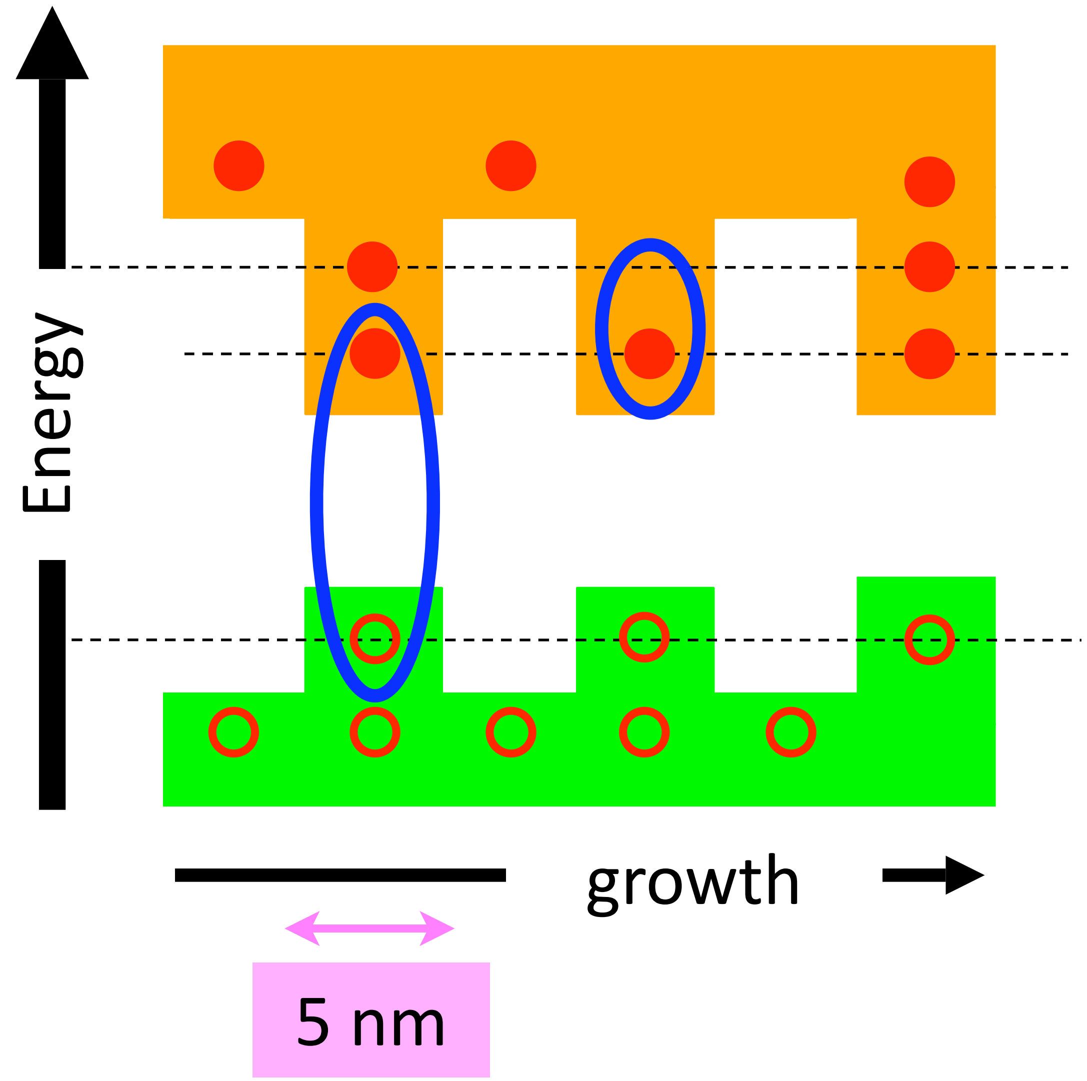
W. Montgomery *et al* Survival of primordial organic compounds during planetary accretion. Eos, Vol. 90, Number 52, 29 December 2009, Fall Meet. Suppl., Abstract P11A-1198.

quantum well transitions

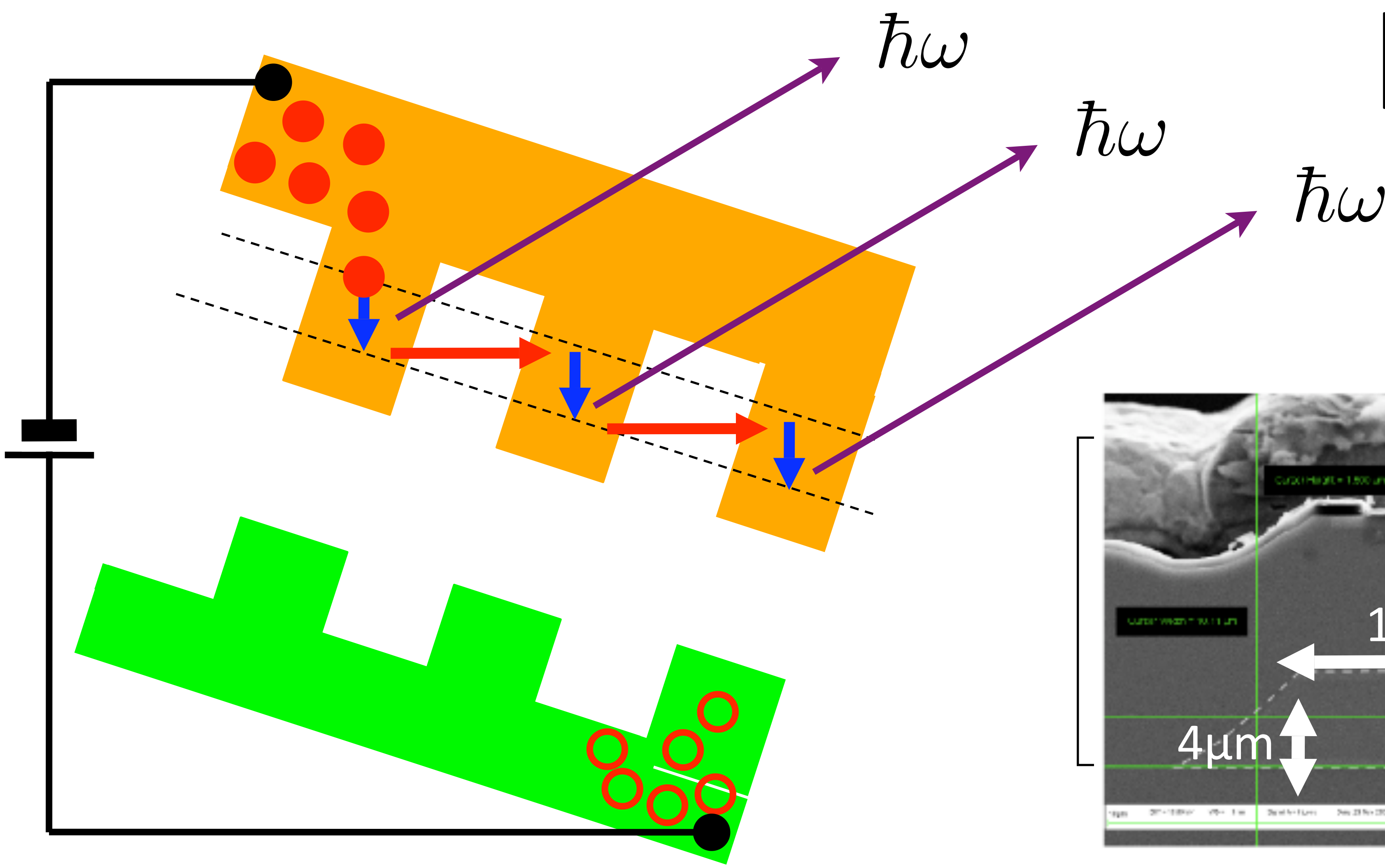
Relaxation into wells

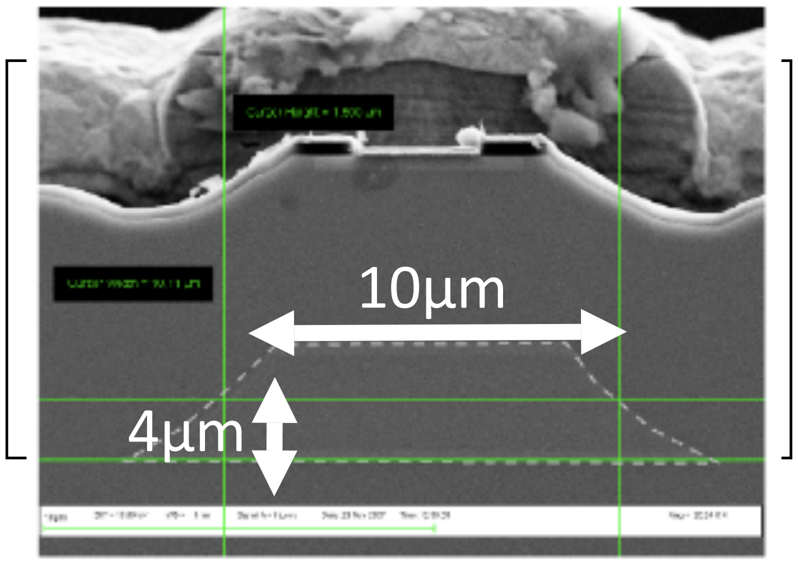
MIR transitions
<u>within</u> the well

NIR interband
transitions

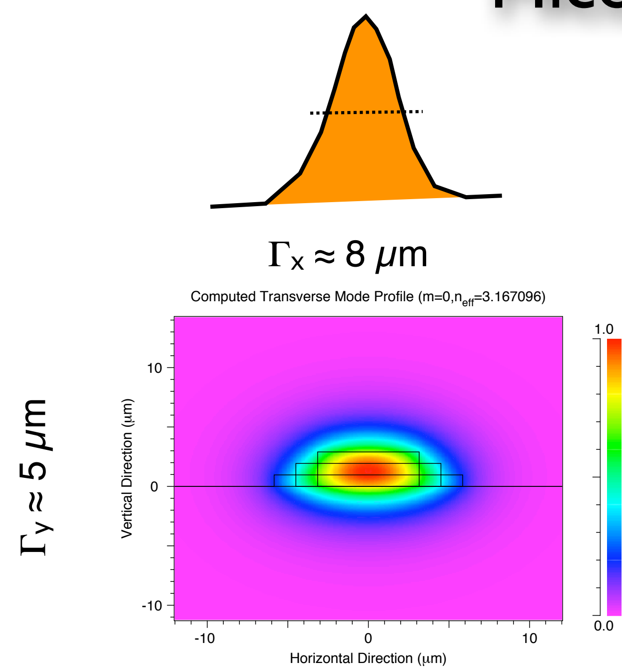


quantum cascade transitions

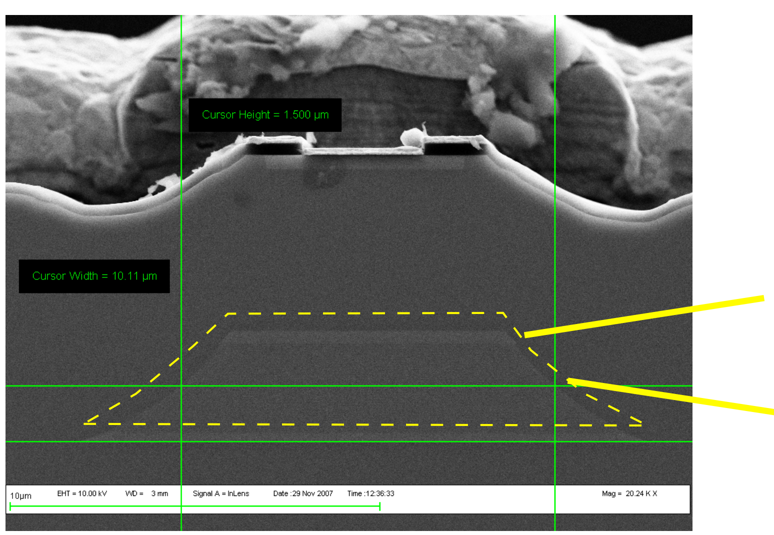


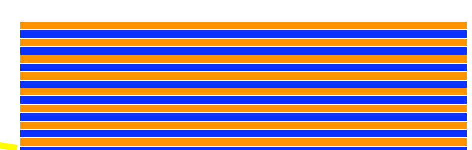


In-situ gain measurements of single mode quantum cascade laser
Micoscopy at the diffraction limit



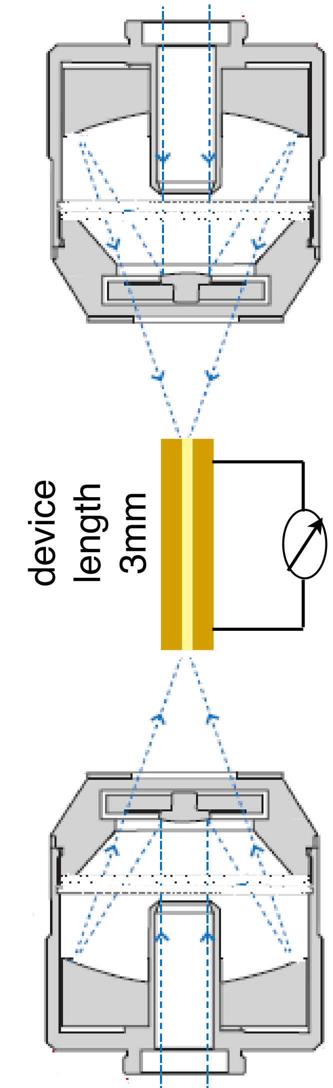
buried waveguide Quantum cascade laser





Principle:
edge to edge
transmission
through a single
transversal mode
laser cavity.

active laser material
InAlAs/InGaAs
multi quantum well



measurement
conditions:
0<I<2A
-5°C <T< 80°C

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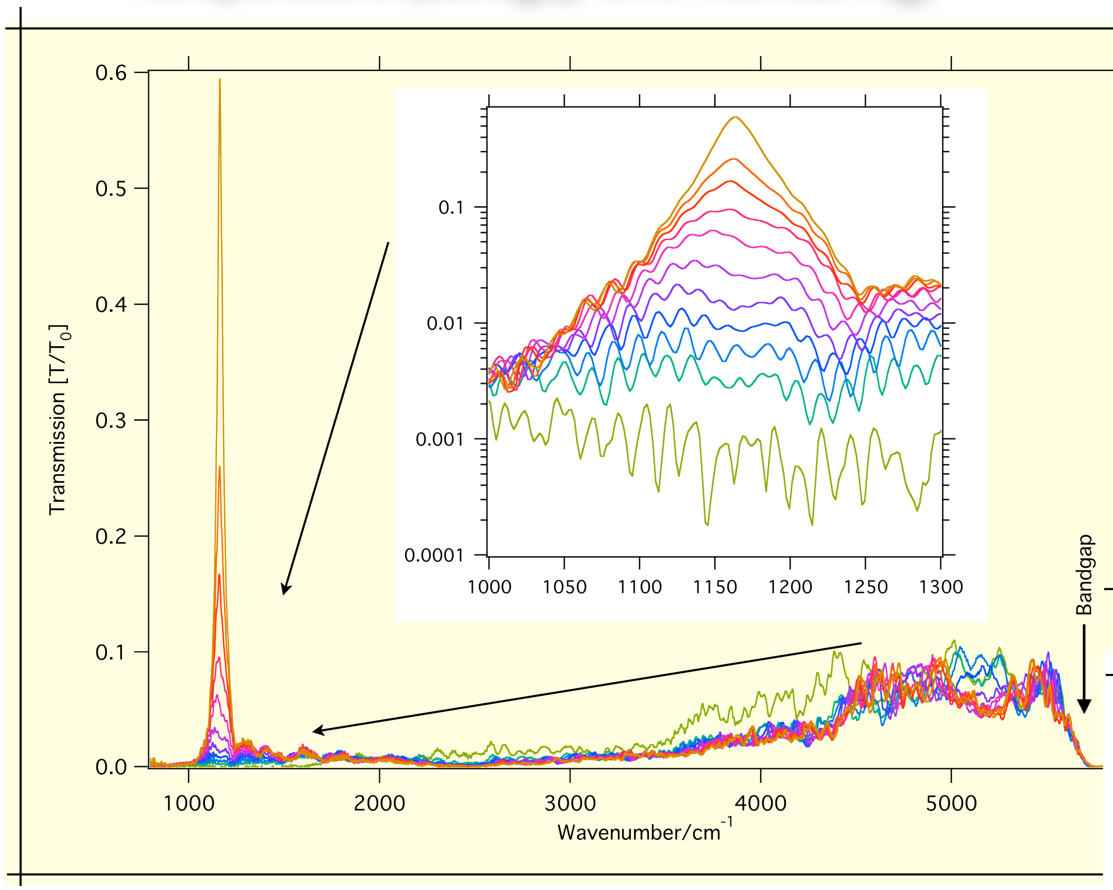
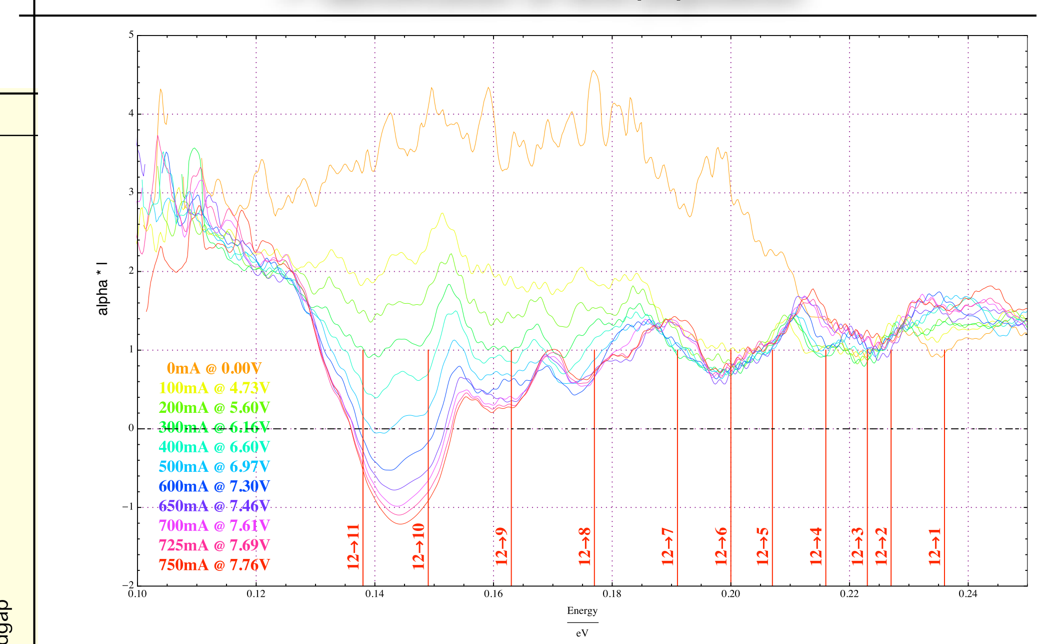
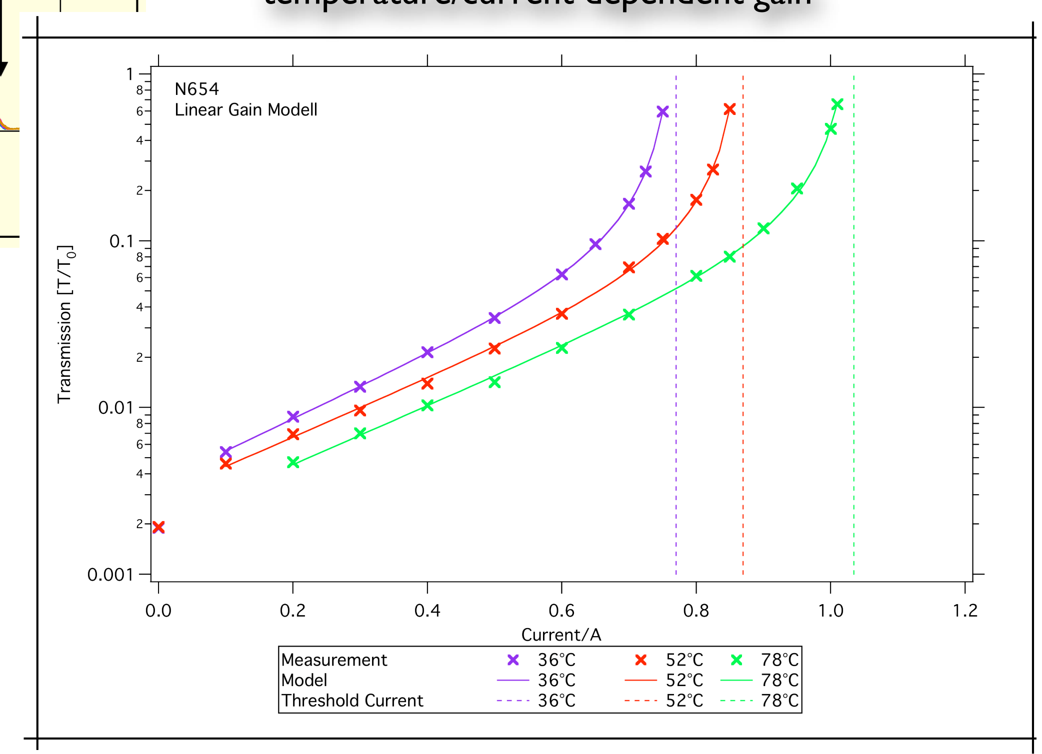
Transmission spectra taken at constant device temperature (bandgap shift monitoring)



experimental transmittance converted to gain/loss spectra -> identification of level population



temperature/current dependent gain



motivation:
Quantum cascade lasers (QCL) are interesting for many applications in medical diagnostics, environmental survey, and security screening etc. -> "fingerprinting" spectra.

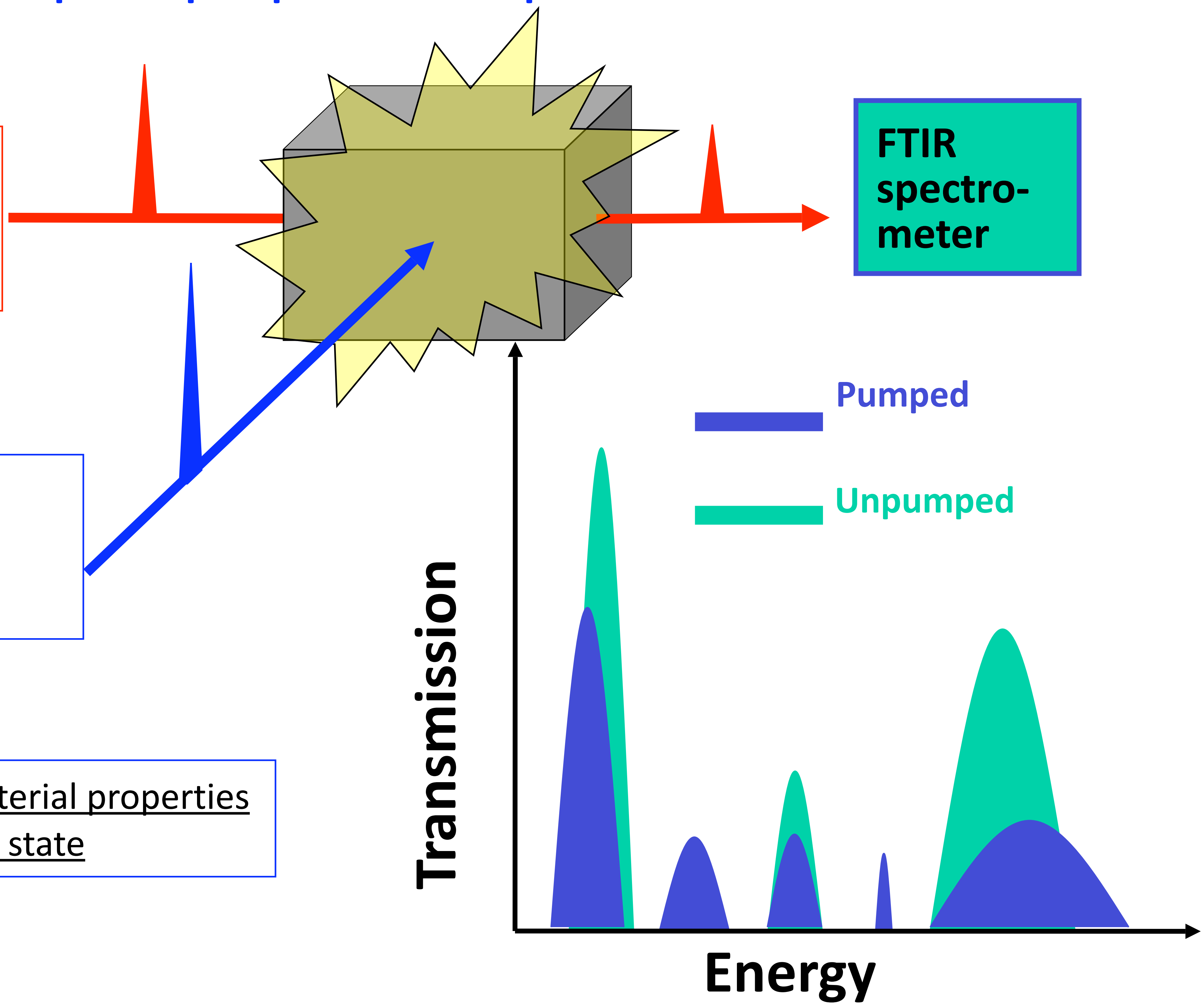
goal:
improving performance of QCL for continuos operation at RT with high power -> of particular interest for medical diagnostics, environmental survey, and security screening.

data: P. Friedli *et al*, to be published

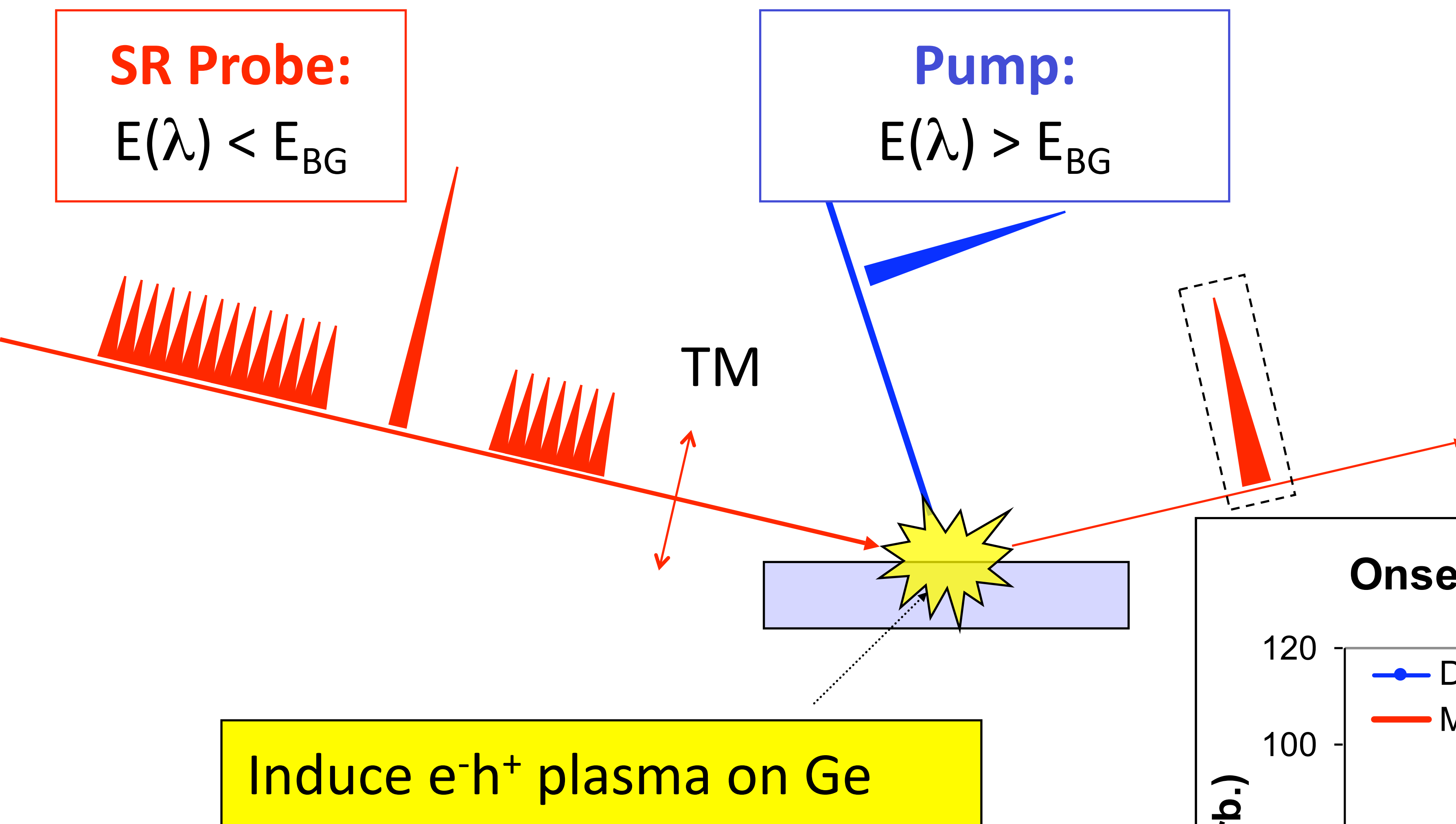
pump&probe experiment

Probe (100ps)
Broadband SRIR
Visible-20μm

Pump (100ps)
Tuneable Laser
1.6-16μm : 500-5μJ



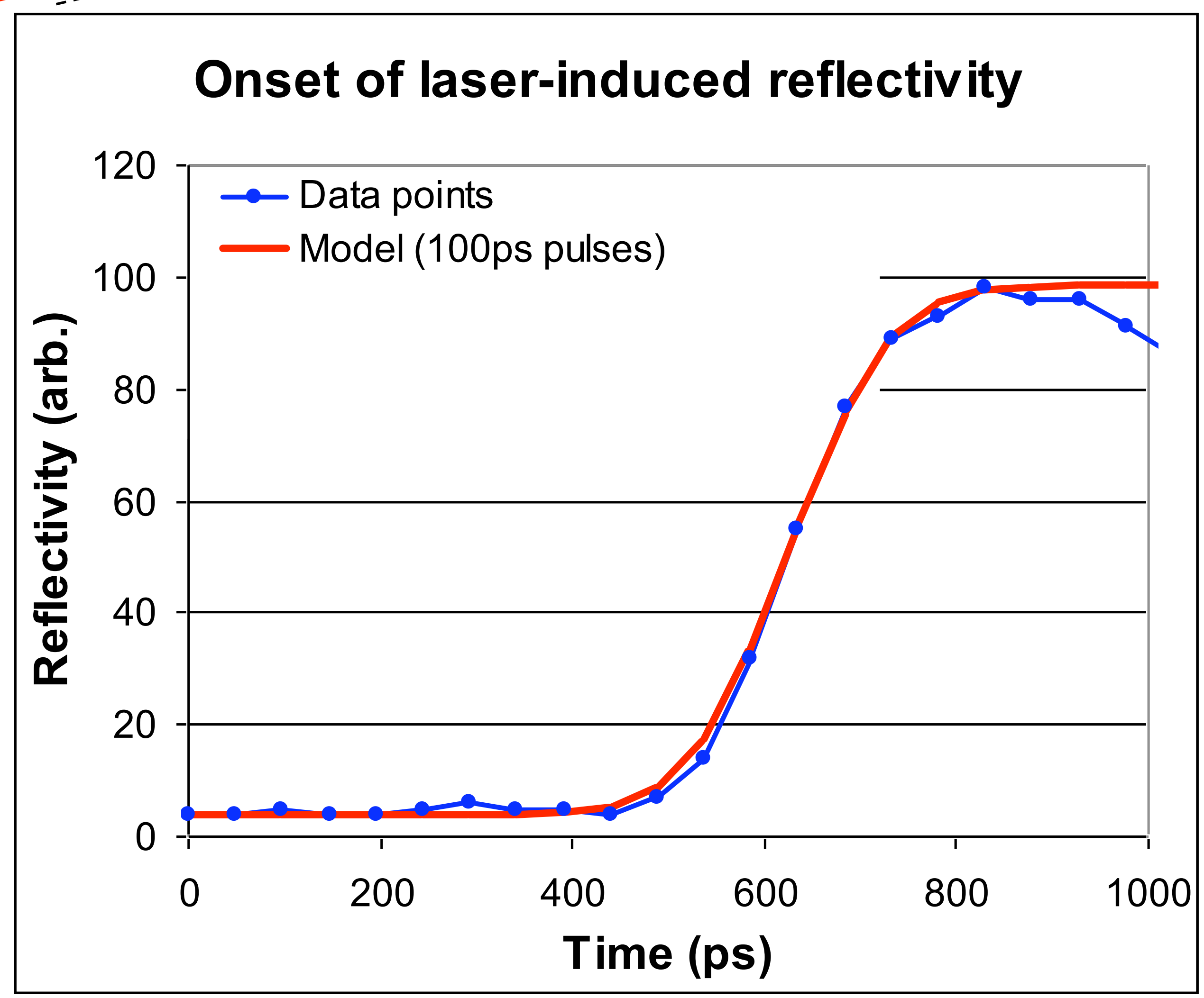
Resolve changes to material properties in its excited state



Brewster angle

TM reflectance

FTIR



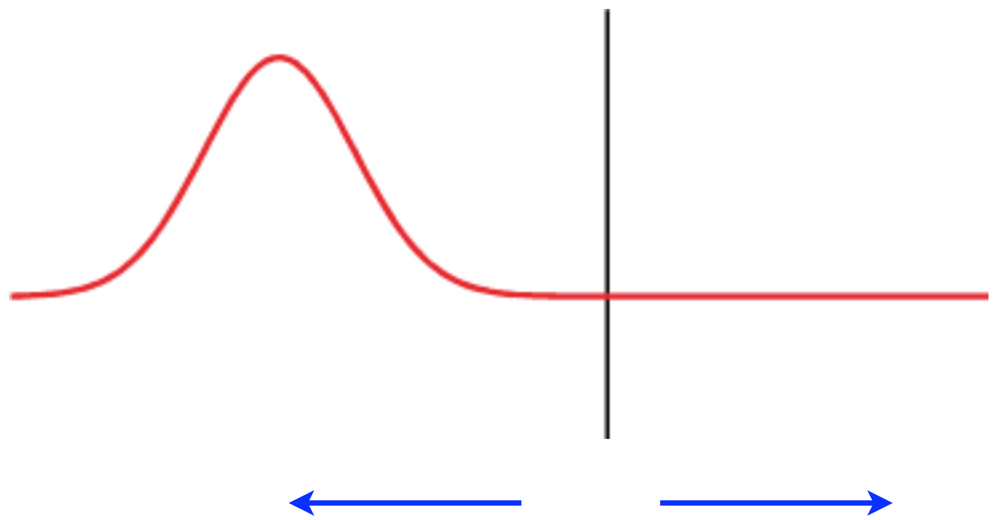
Unpumped: low-reflectance

Pumped: high-reflectance

L. Carroll *et al*, to be published

interaction light & matter

vacuum



$$N(\omega) = n(\omega) + i\kappa(\omega)$$

$$\vec{E}_{inc} = \vec{E}_R - \vec{E}_T$$

$$\vec{H}_{inc} + \vec{H}_R = \vec{H}_T$$

normal incidence

$$r_c = \frac{E_R}{E_{inc}} = \frac{N(\omega) - 1}{N(\omega) + 1}$$

$$R = r_c r_c^* = \frac{(n(\omega) - 1)^2 + \kappa^2(\omega)}{(n(\omega) + 1)^2 + \kappa^2(\omega)}$$

$n(\omega)$ and $\kappa(\omega)$ related by KK-relations

model dielectric function

↓

non magnetic !

$$\sqrt{\epsilon(\omega)} = N(\omega)$$

↑

exp reflectivity R

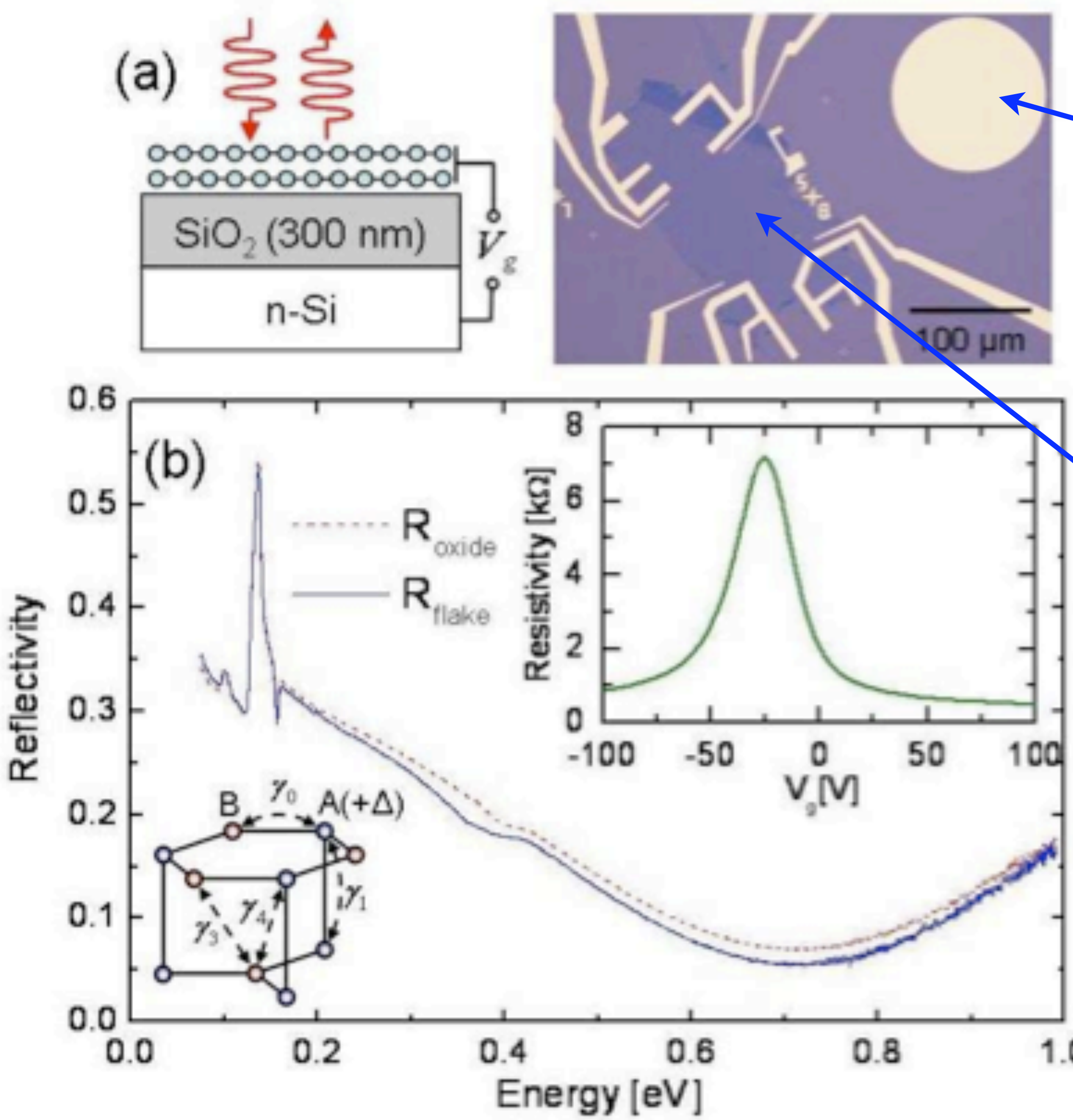


FIG. 1: (a) Schematic view and a micrograph of the used bilayer graphene device. (b) Infrared reflectance of graphene flake (blue solid line) and of bare substrate (red dotted line) (taken at T = 10 K and V_g = +100 V). Left inset: Bernal stacking of bilayer graphene and relevant hopping terms, right inset: resistivity at 10 K as a function of the gate voltage.

Au as in-situ reference

visible on SiO2: 2-3 layers

Phys. Rev. B 79, 115441 (2009)

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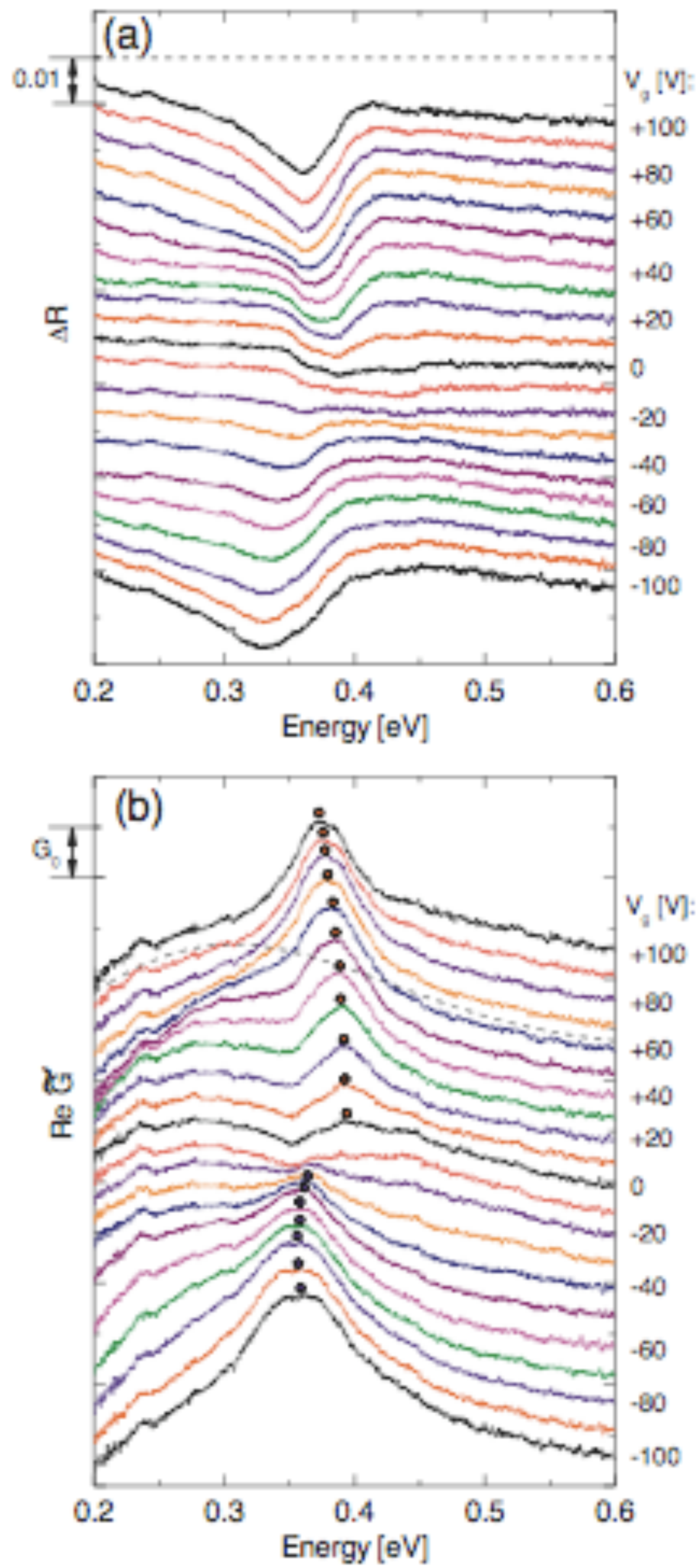
Phys. Rev. B 79, 115441 (2009)

curves are shifted for clarity



reflectivity change $\Delta R(\omega)$ @ 10 K

varying V_g

KK inversion

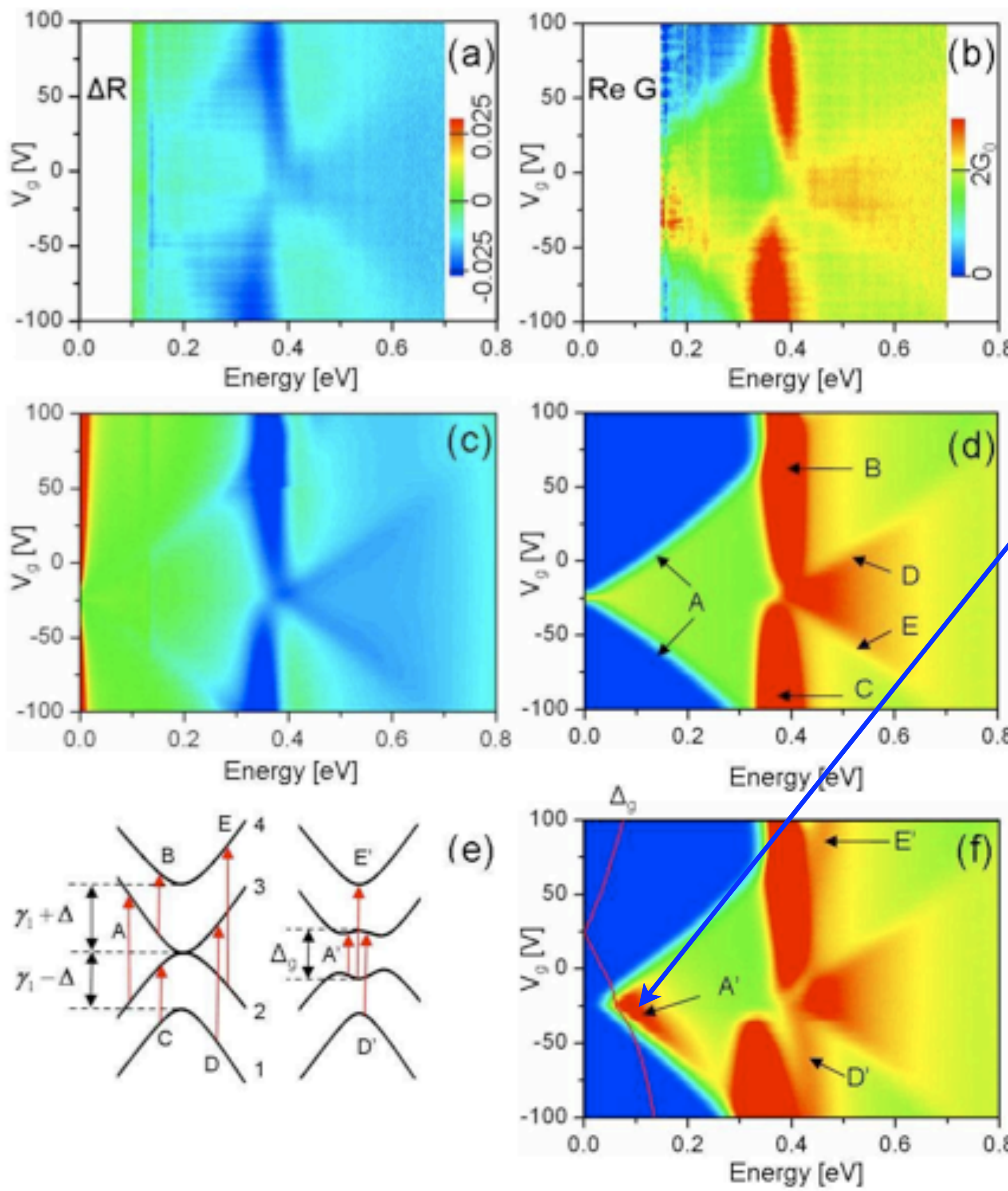
$G(\omega)$ sheet conductance

exp mod

$\Delta R(\omega)$

$G(\omega)$

Phys. Rev. B 79, 115441 (2009)



clearly not observed

story goes on:

Nature 459, 820 (2009)

PRL 103, 116804 (2009)

expected behavior if gap present for this model

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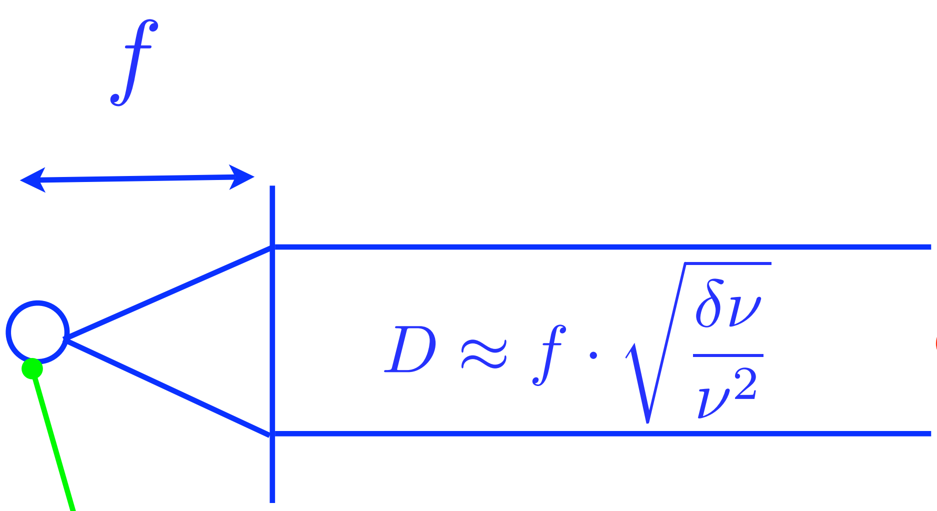
High resolution gas phase FIR spectroscopy



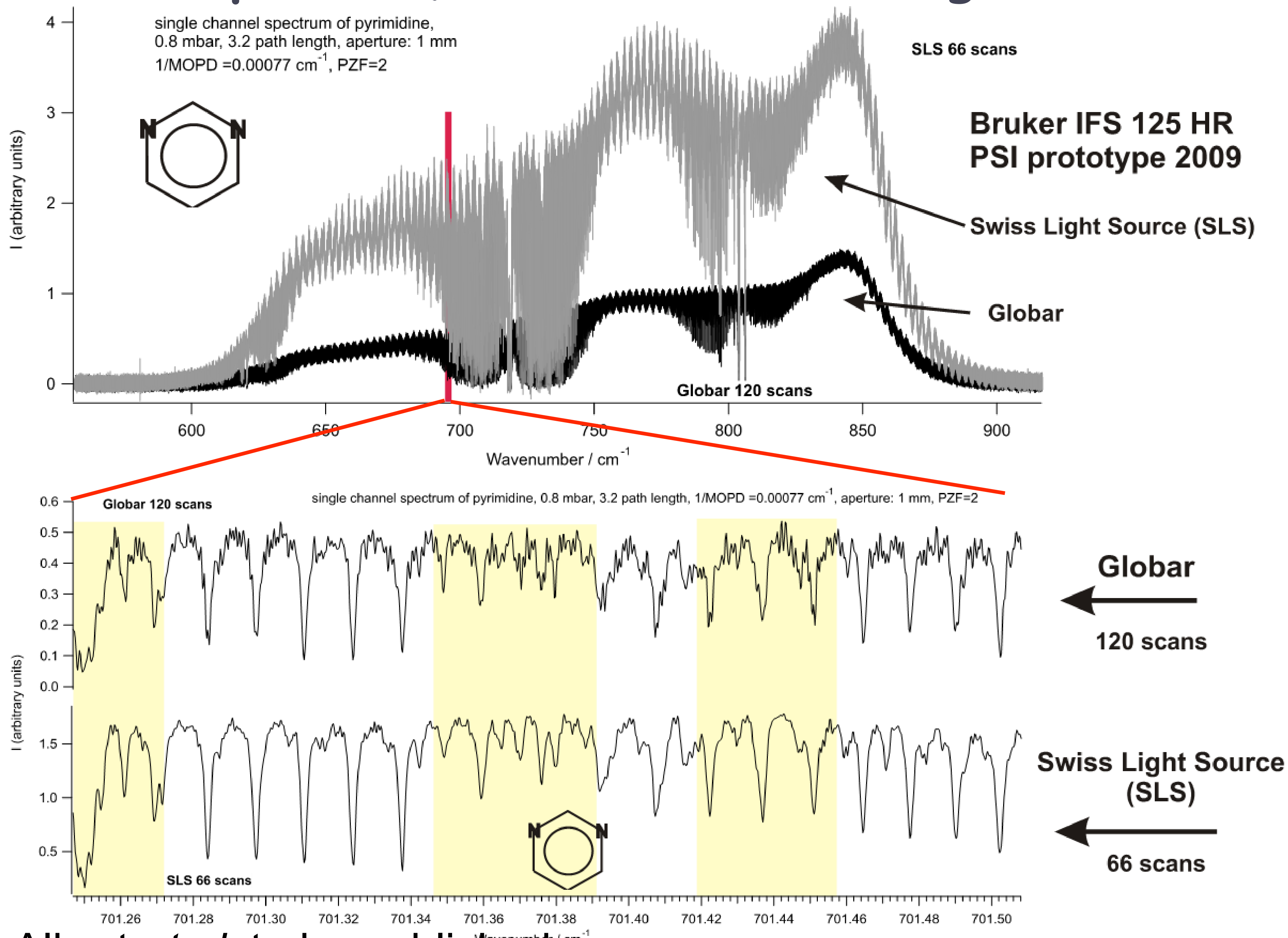
$$D \approx f \cdot \sqrt{\frac{\delta\nu}{\nu^2}}$$

$$\delta\nu \approx 10^{-3}$$

$$D = 0.8 \cdot mm$$

are PAH relevant to the unidentified interstellar bands question ?

Comparison of Bruker IFS 125 HR PSI prototype 2009 pyrimidine spectra (Globar and Swiss Light Source, SLS)



S. Albert *et al*, to be published

conclusions

make sure ALL things stay stable

use SR for small samples use thermal source when SR is down

SR useful for pump and probe experiment (nS)

IR probe is NON DESTRUCTIVE !

low energy excitations ... superconductor, semiconductor, devices ...

IR active molecular vibrations high resolution gas phase spectroscopy

high pressure @ high (low) temperature

... forensic, electrochemistry, life science ...

... cultural heritage ...

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고마워

thank you

多謝

ありがとう

ขอบคุณมาก