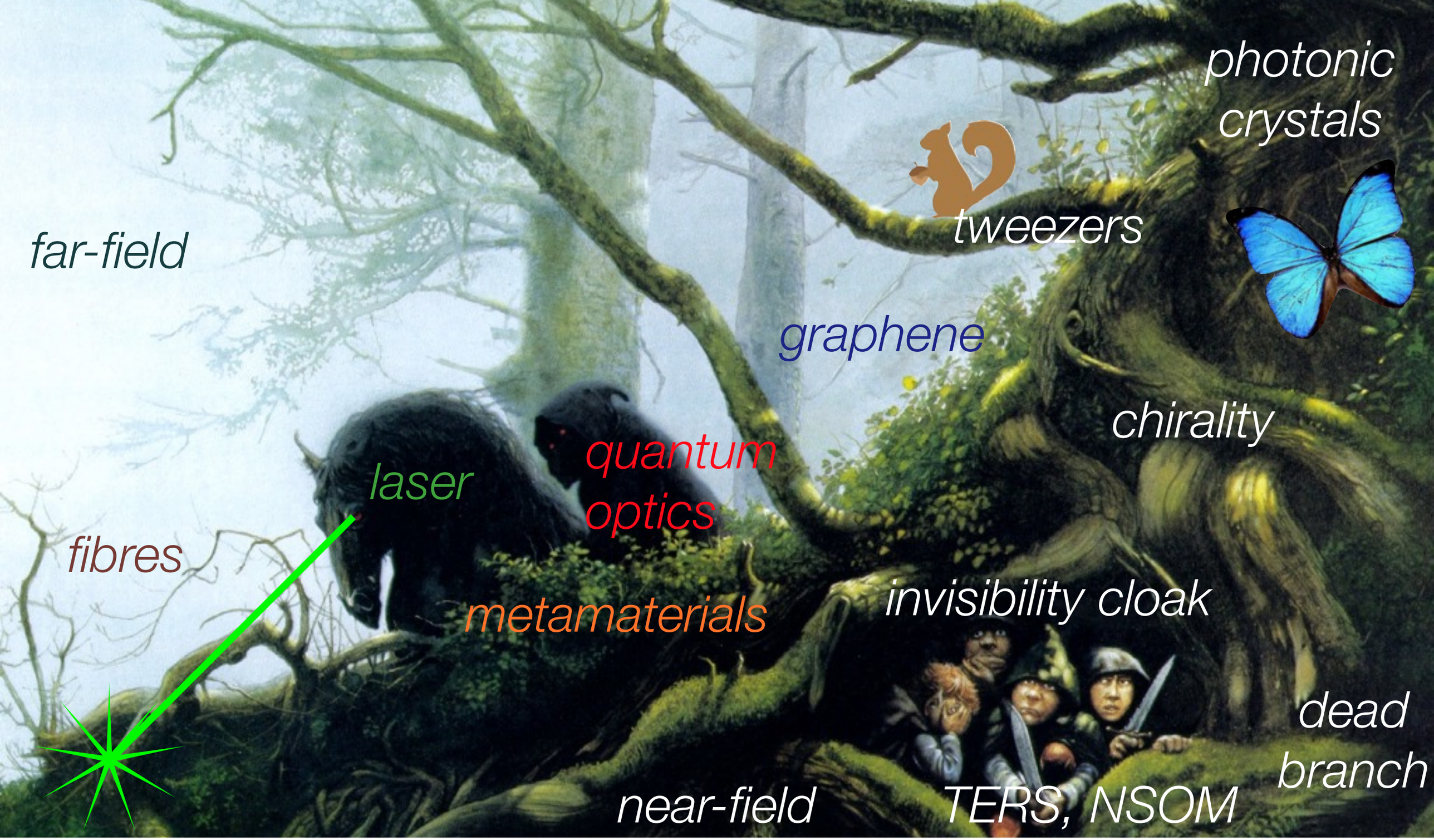
Optical antennas

Nano-optics and plasmonics

Baptiste Auguié

2015 bootcamp – Kaikoura



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"The antenna of a cell phone is used to concentrate the energy of incoming radiation onto a receiver chip with dimensions much smaller than the wavelength of the incoming radiation."

Lukas Novotny

The History of Near-field Optics

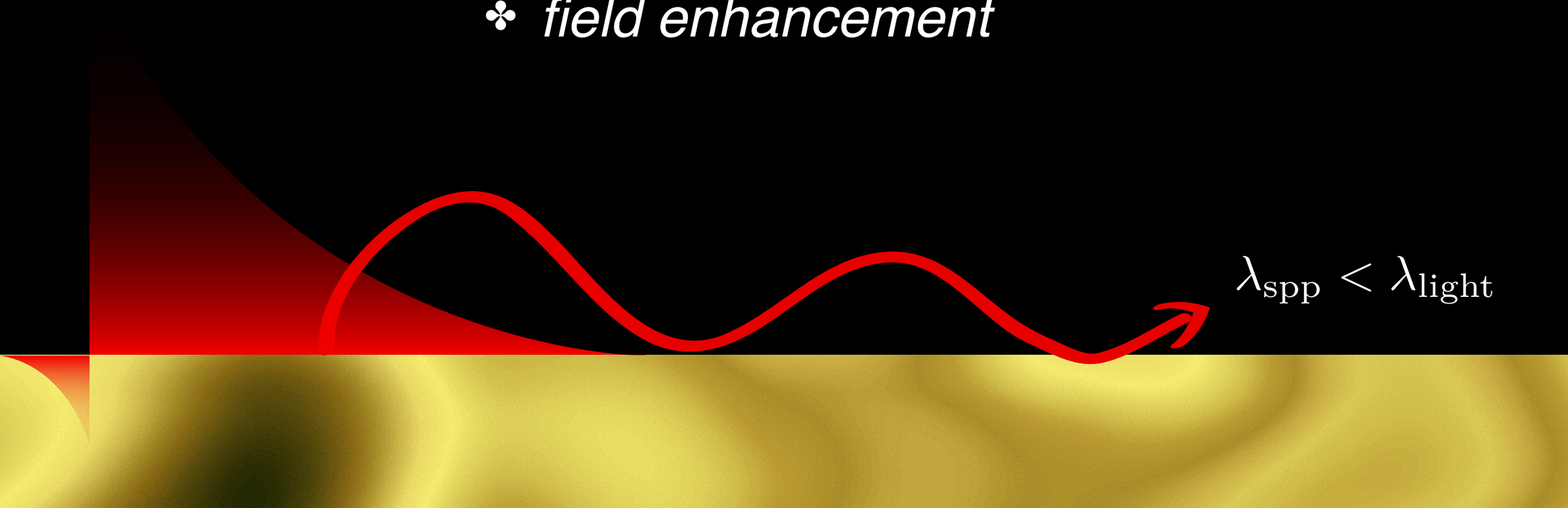
Lycurgus vase

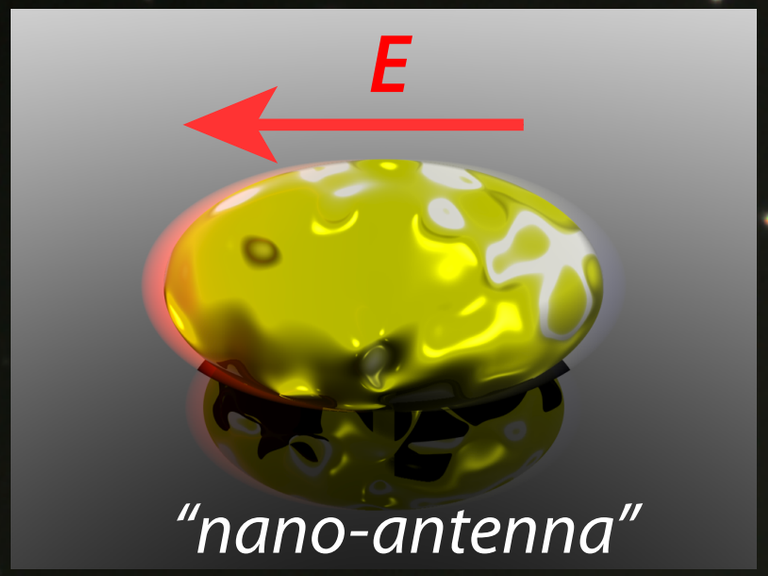
Why plasmonics?

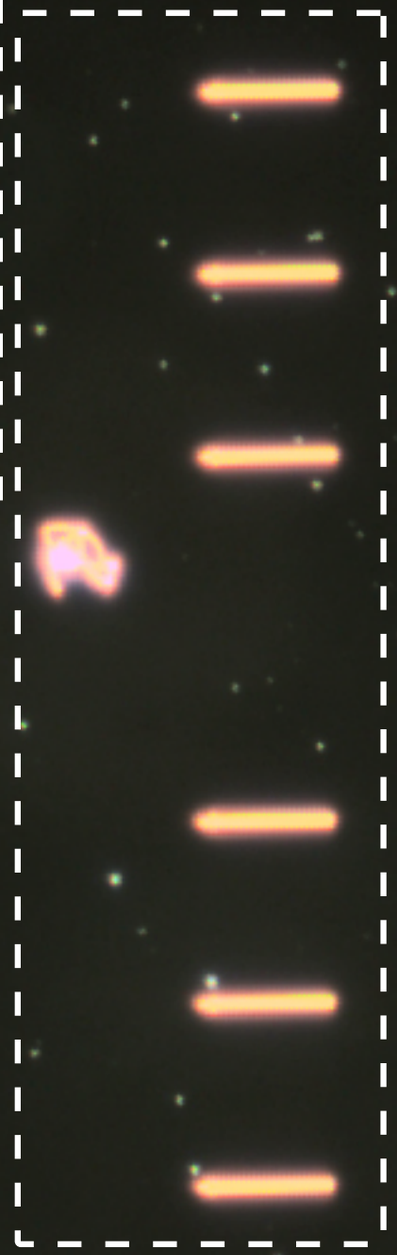
$$k = \frac{2\pi}{\lambda} = \sqrt{k_x^2 + k_z^2}$$

$$k_z \ imaginary \ \Rightarrow k_z^2 < 0$$

- *sub-wavelength optics*
- *field enhancement*

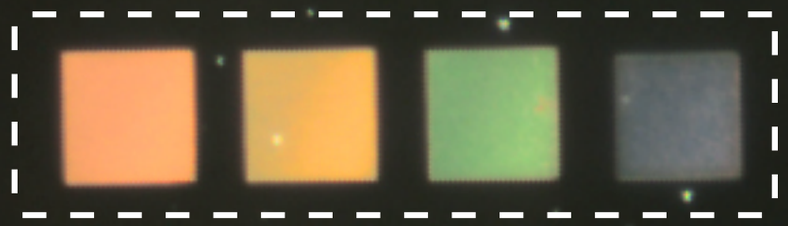






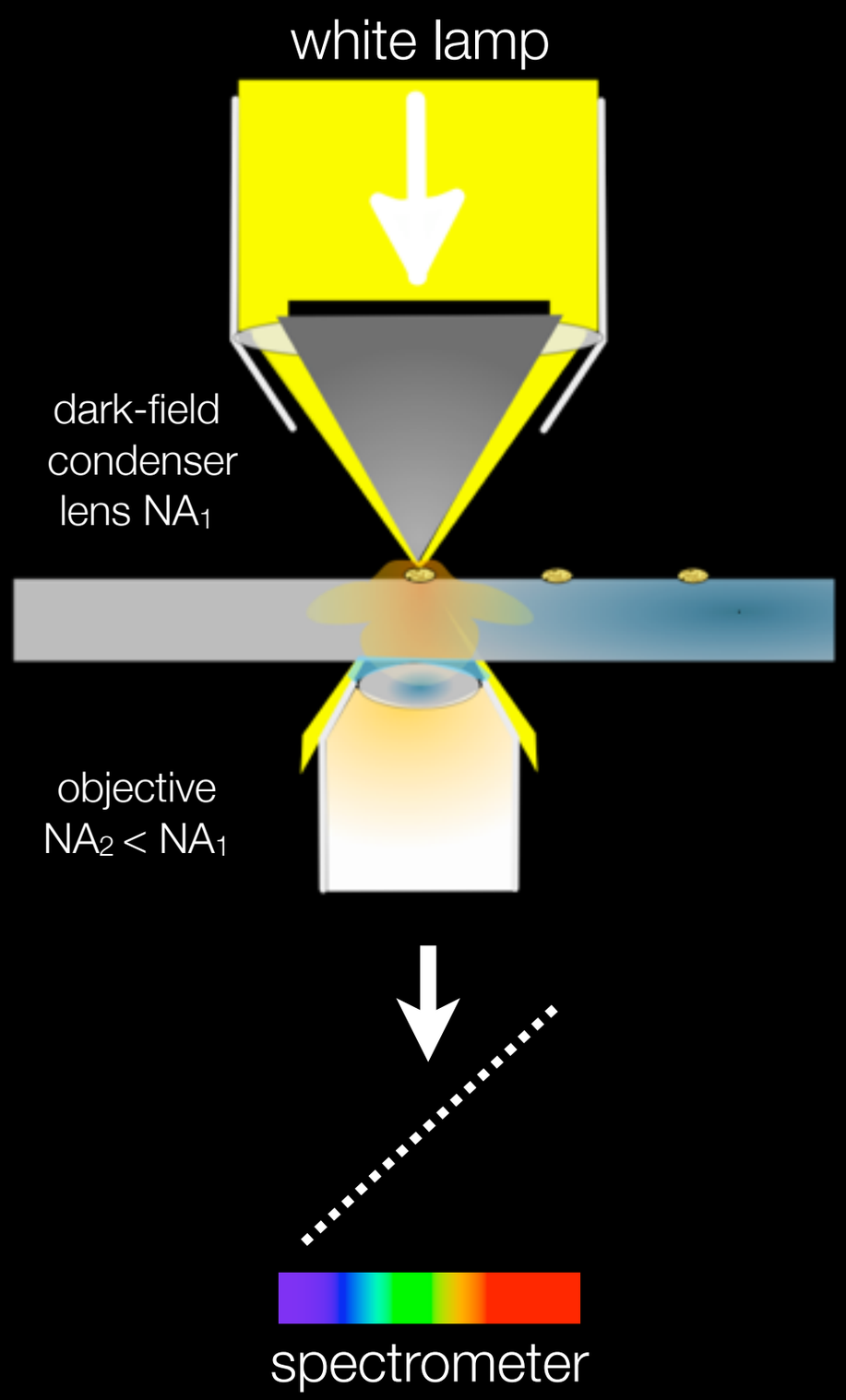
flake

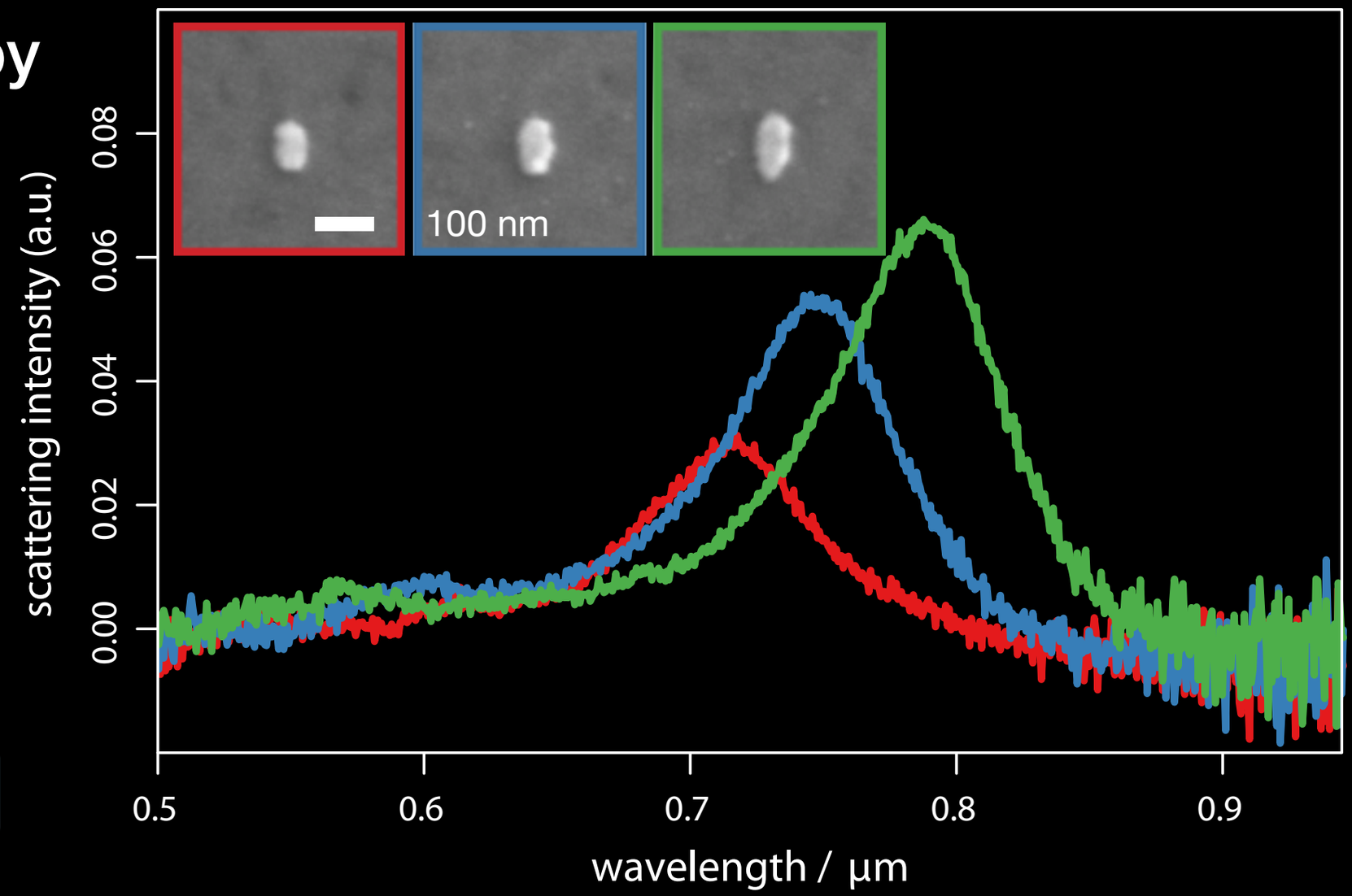
dust

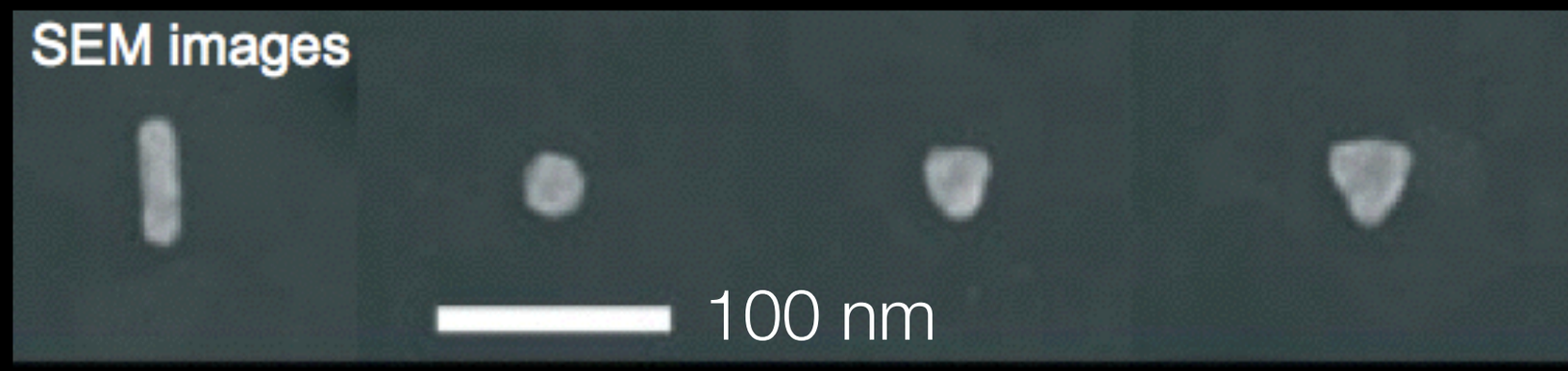


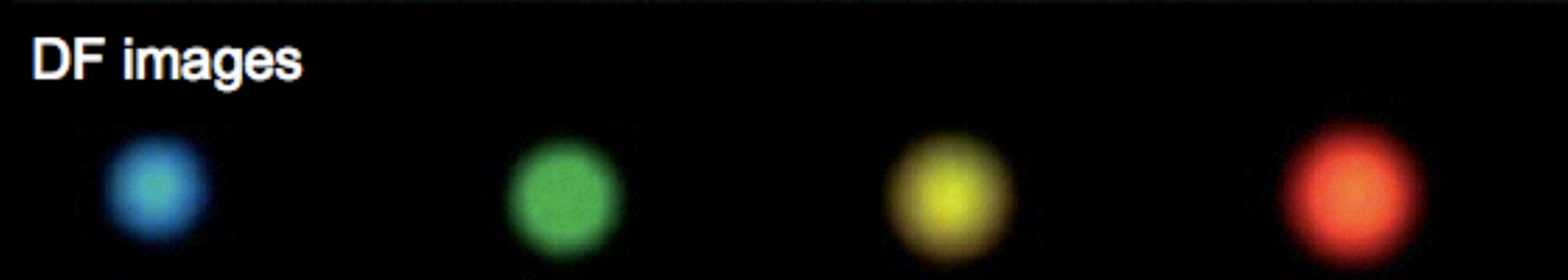
100µm

Dark-Field Spectroscopy



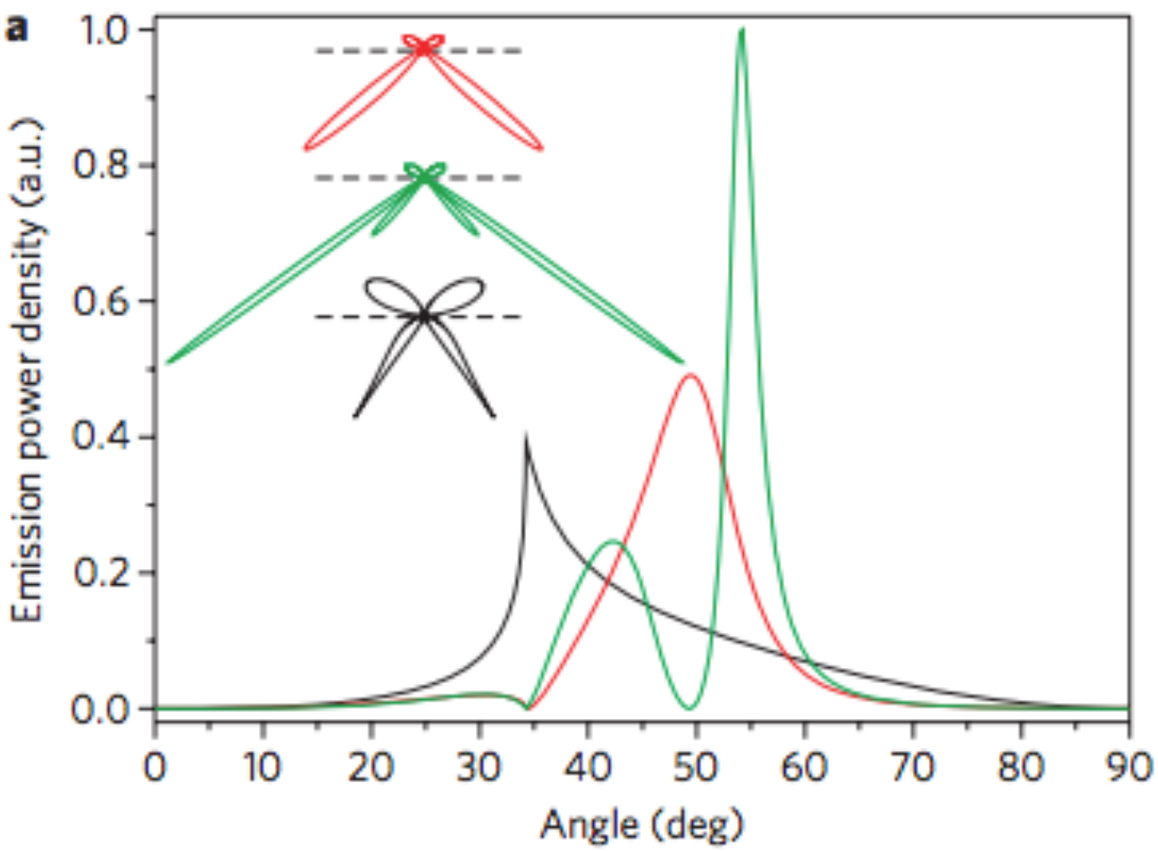


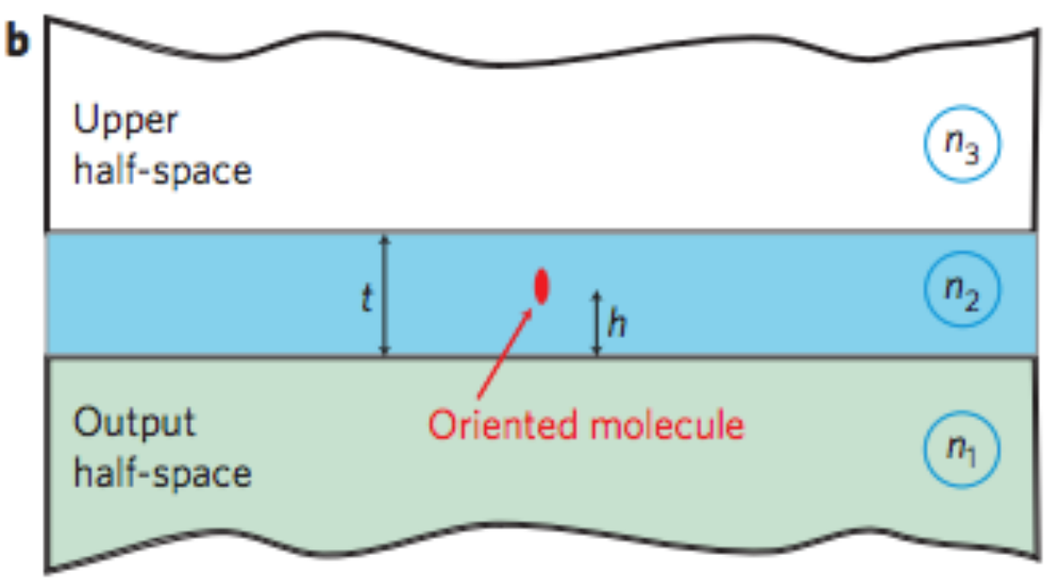




Planar "antennas"

Vahid Sandoghdar's group

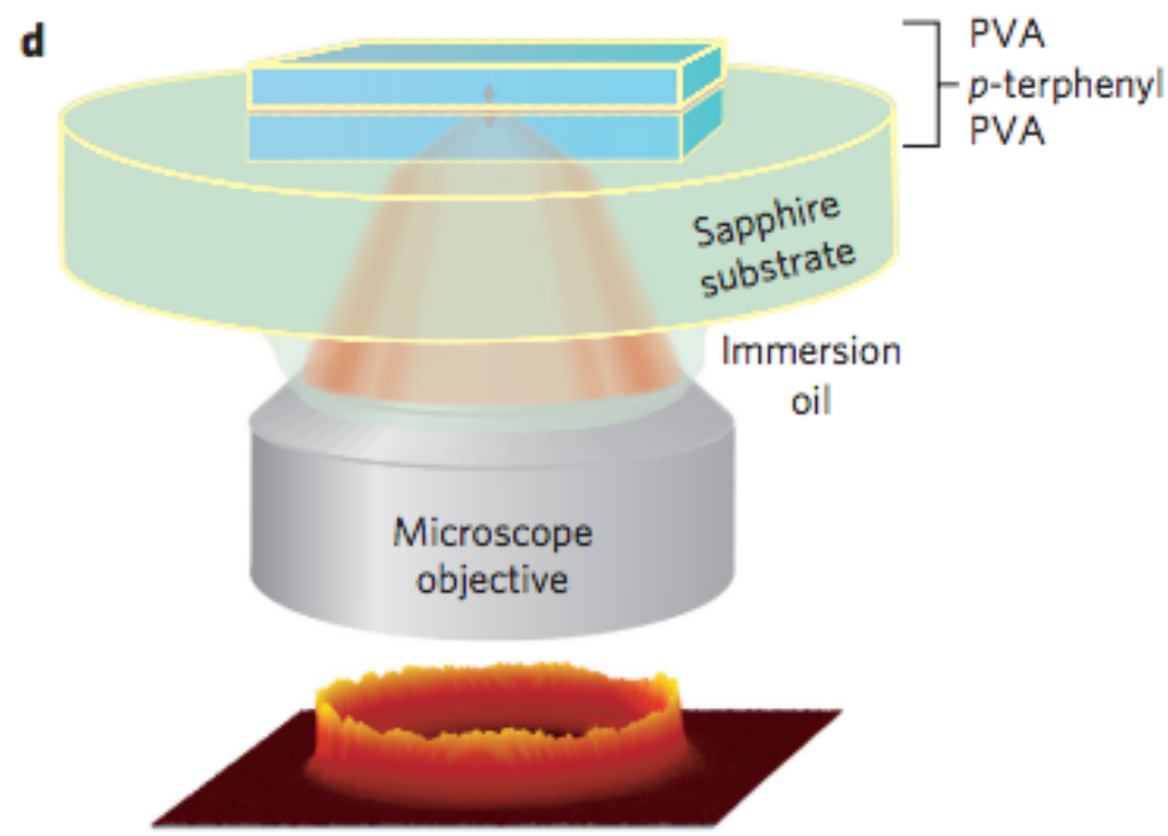


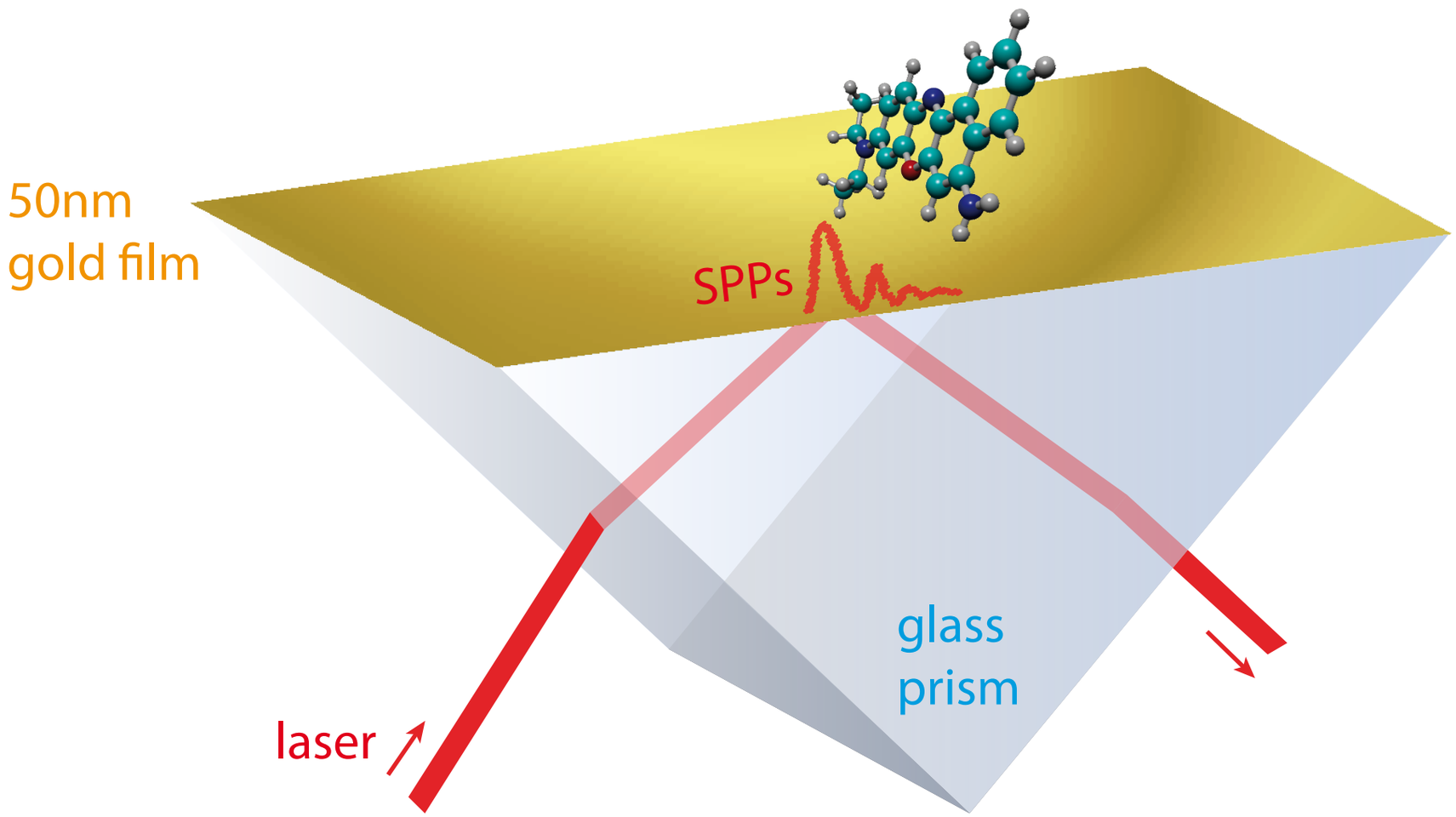


Controlling the Phase of a Light Beam with a Single Molecule
M. Pototschnig, Y. Chassagneux, J. Hwang, G. Zumofen, A. Renn, **V. Sandoghdar** Phys. Rev. Lett. 107, 063001 (2011)

A planar dielectric antenna for directional single-photon emission and near-unity collection efficiency
K. G. Lee, X. Chen, H. Eghlidi, P. Kukura, R. Lettow, A. Renn, **V. Sandoghdar**, S. Götzinger Nature Photonics 5, 166 (2011)

Single molecule imaging by optical absorption
M. Celebrano, P. Kukura, A. Renn, **V. Sandoghdar**
Nature Photonics 5, 95 (2011)

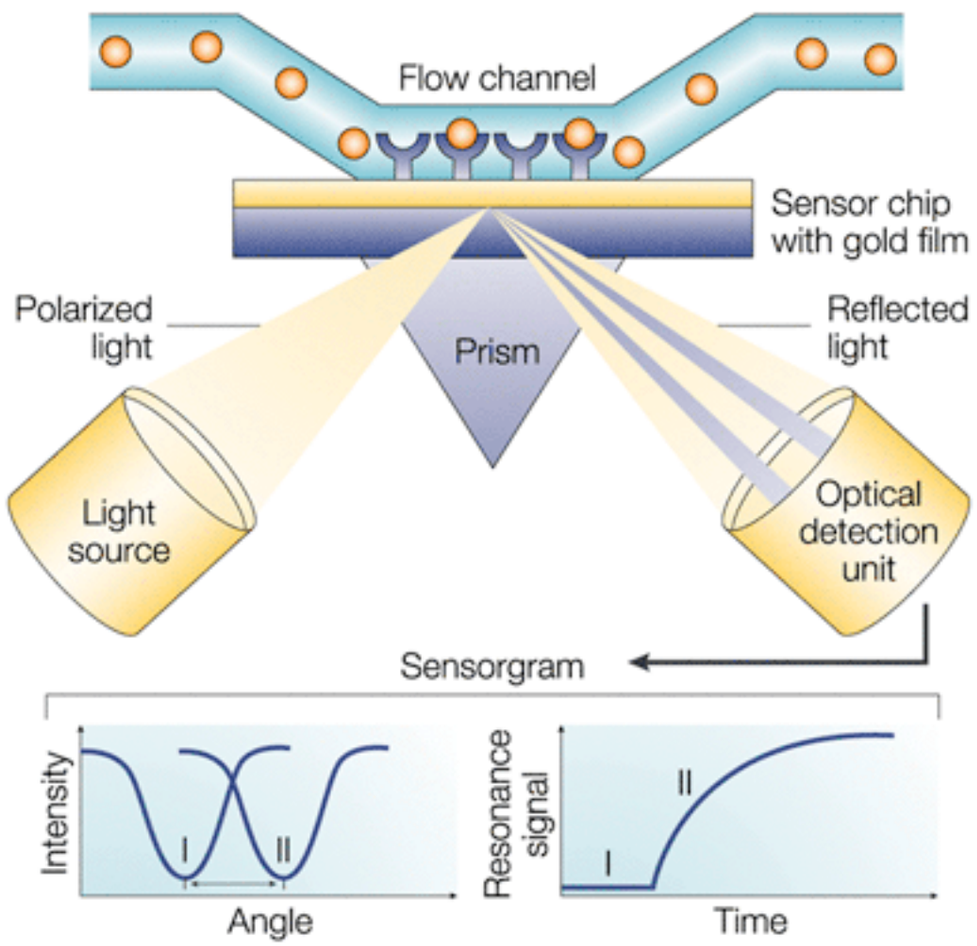


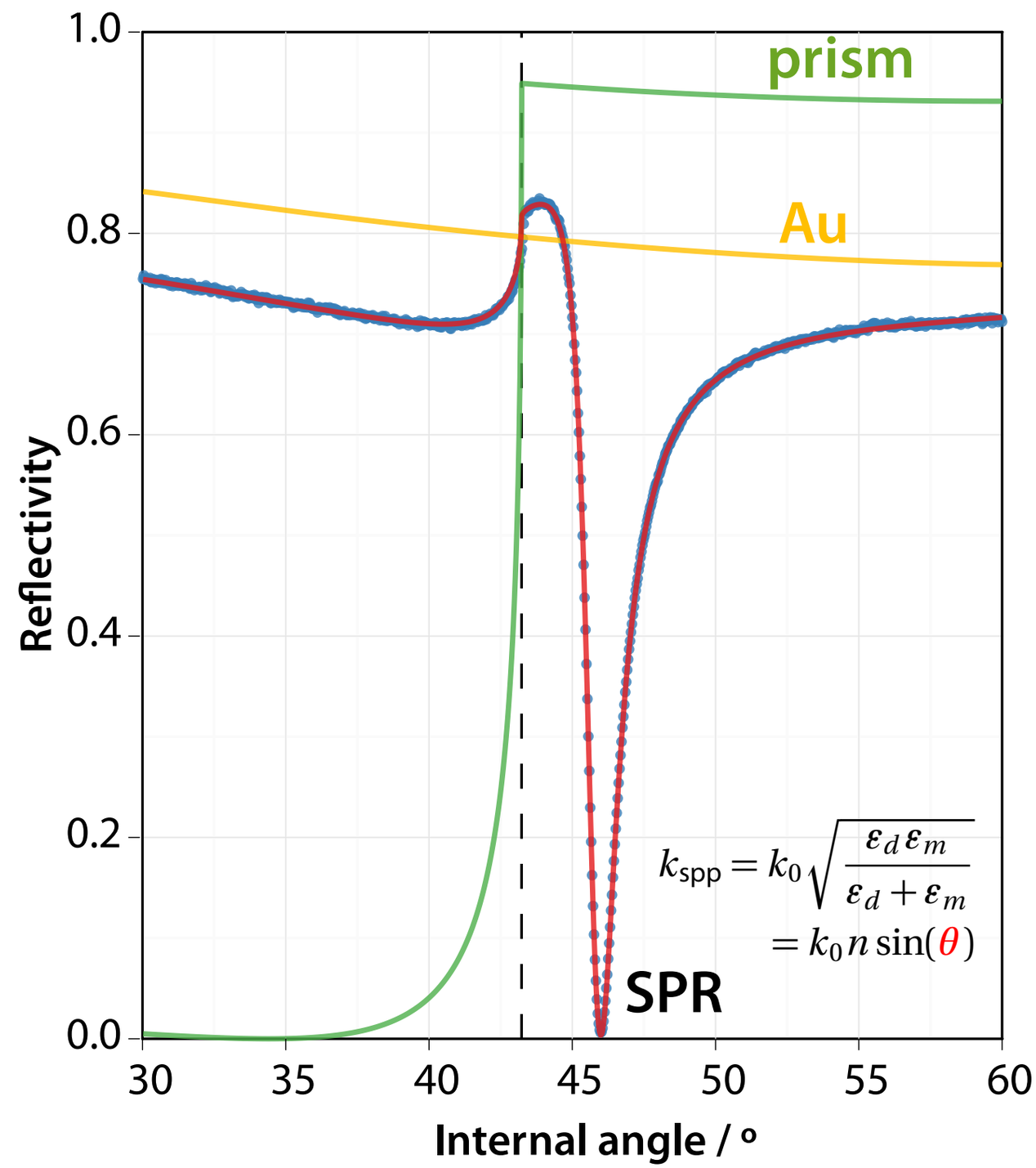


Surface Plasmon Resonance

Kretschmann style

Surface-plasmon resonance





Optical reciprocity

$$\mathbf{p}_1 \cdot \mathbf{E}_2 = \mathbf{p}_2 \cdot \mathbf{E}_1$$

$\mathbf{p}_1$

$\mathbf{p}_2$

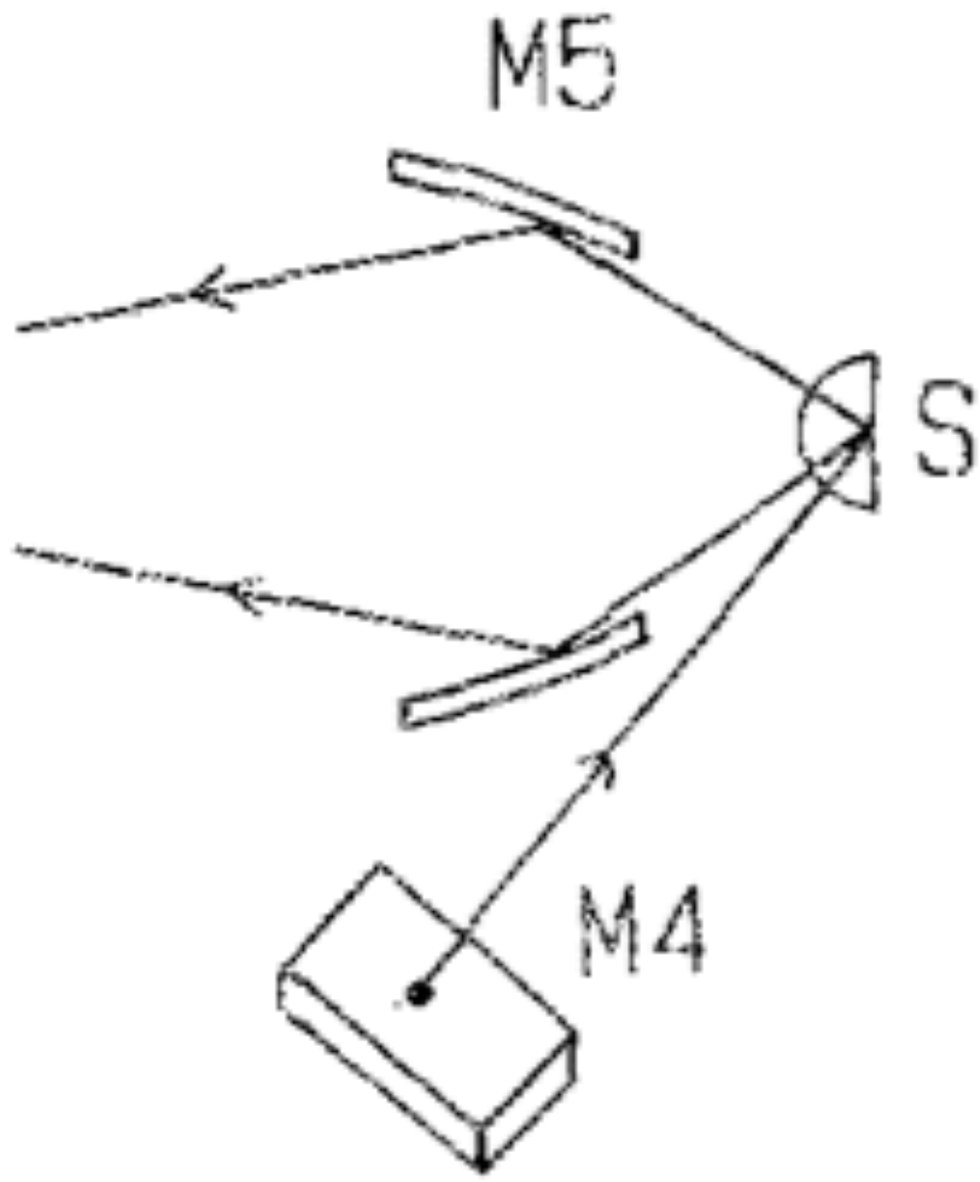
FAR-FIELD radiation linked
to NEAR-FIELD enhancement

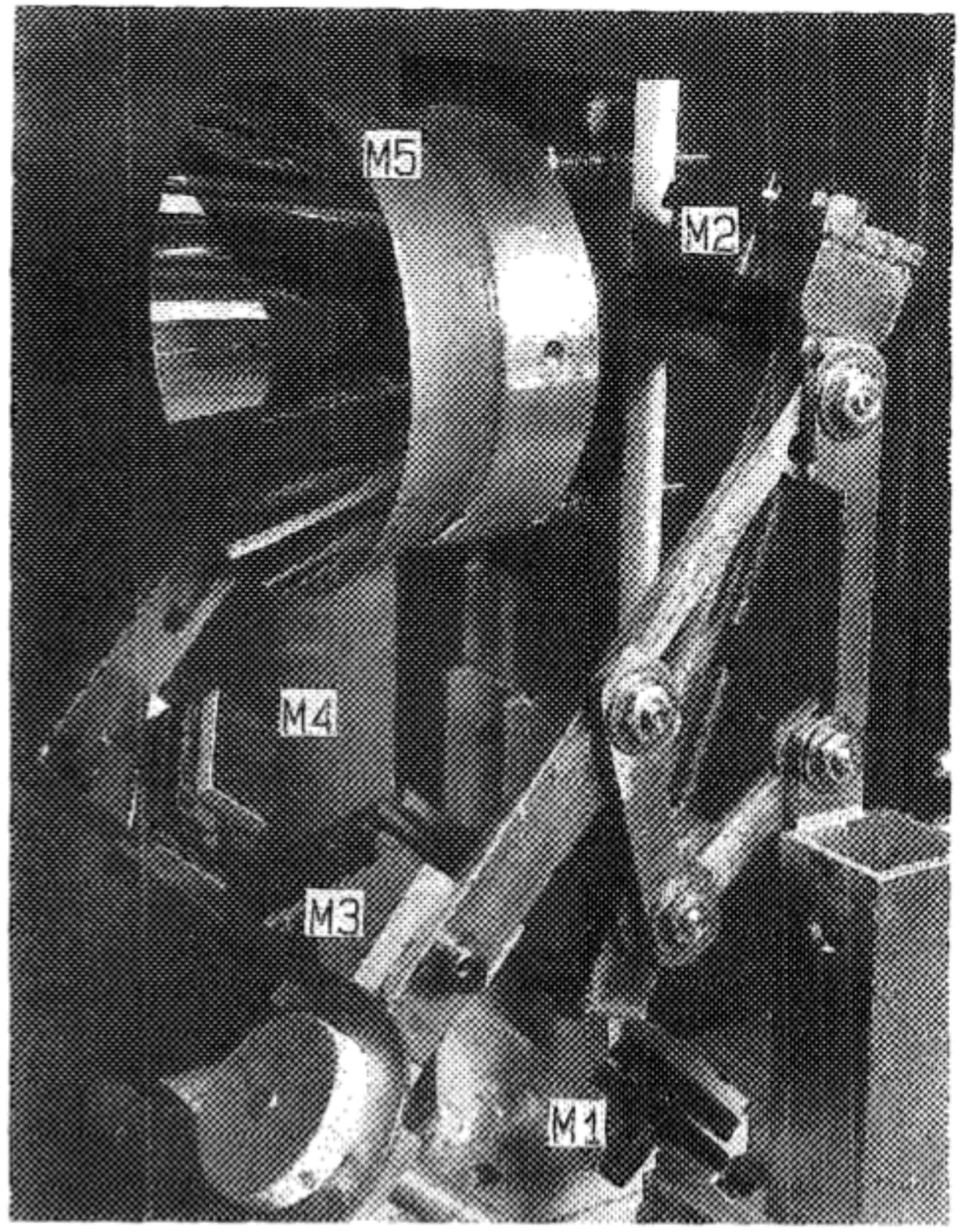
and vice versa

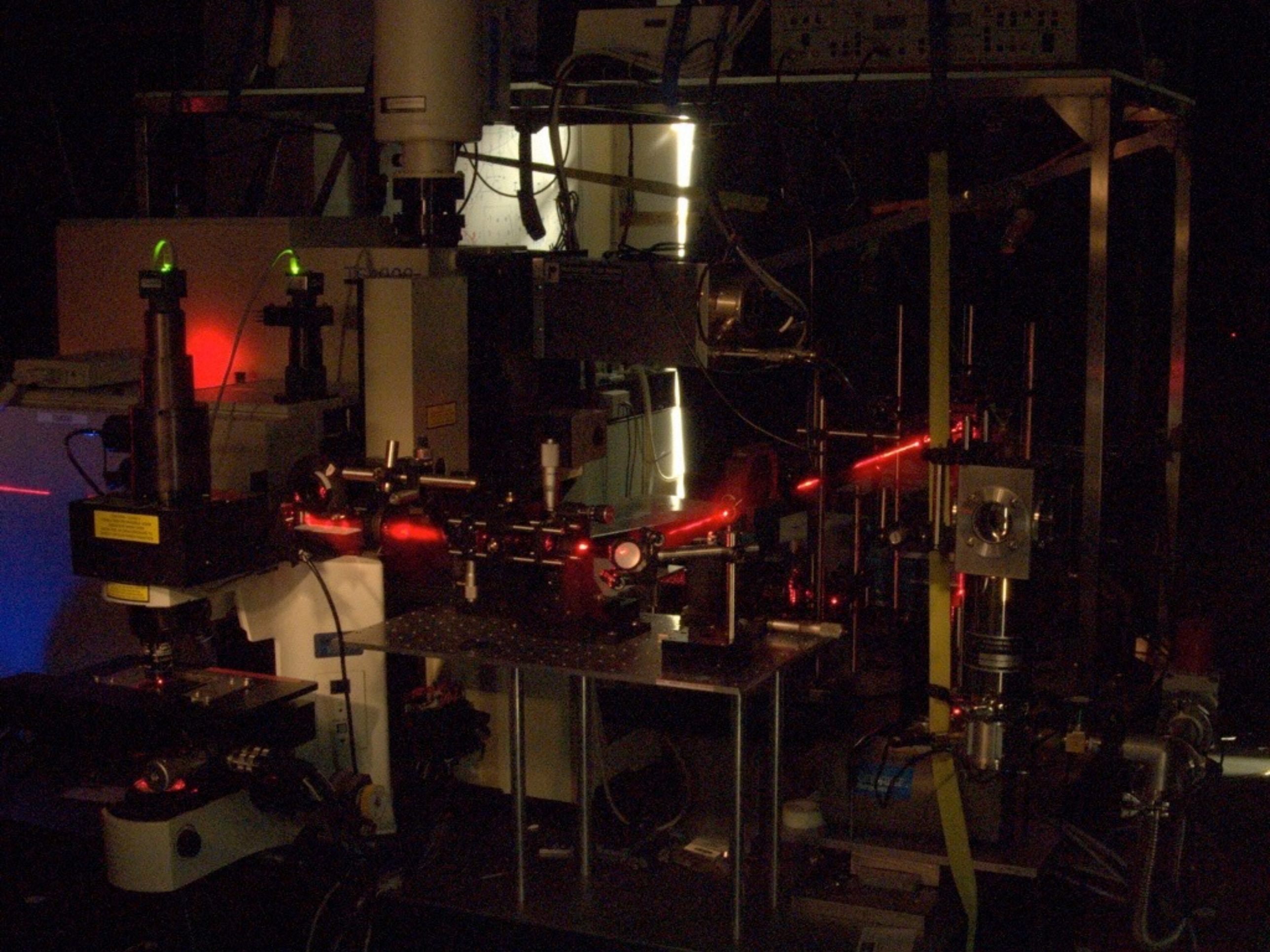
ONE RING TO RULE THEM ALL, ONE RING TO FIND THEM

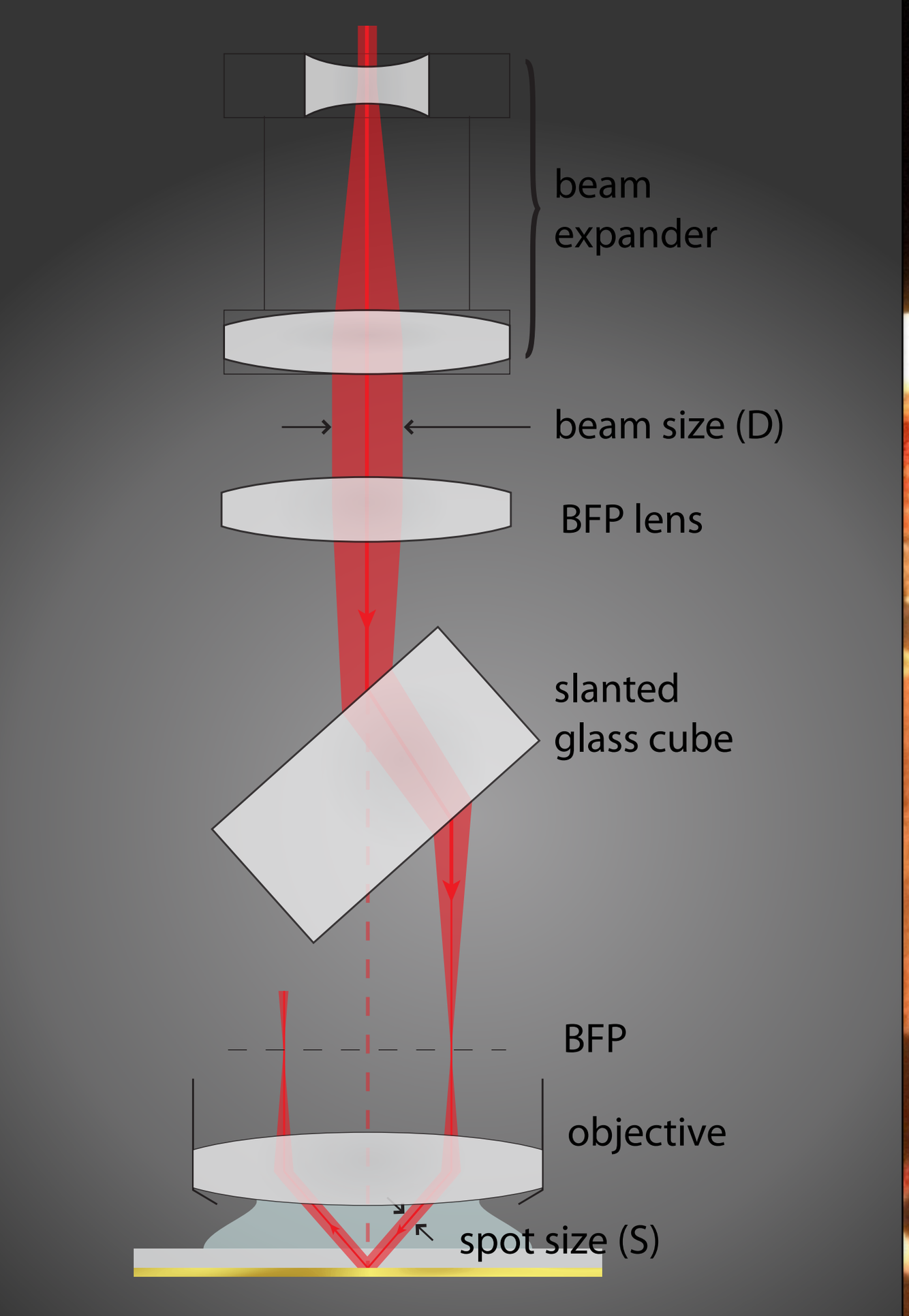
ONE RING TO BRING THEM ALL

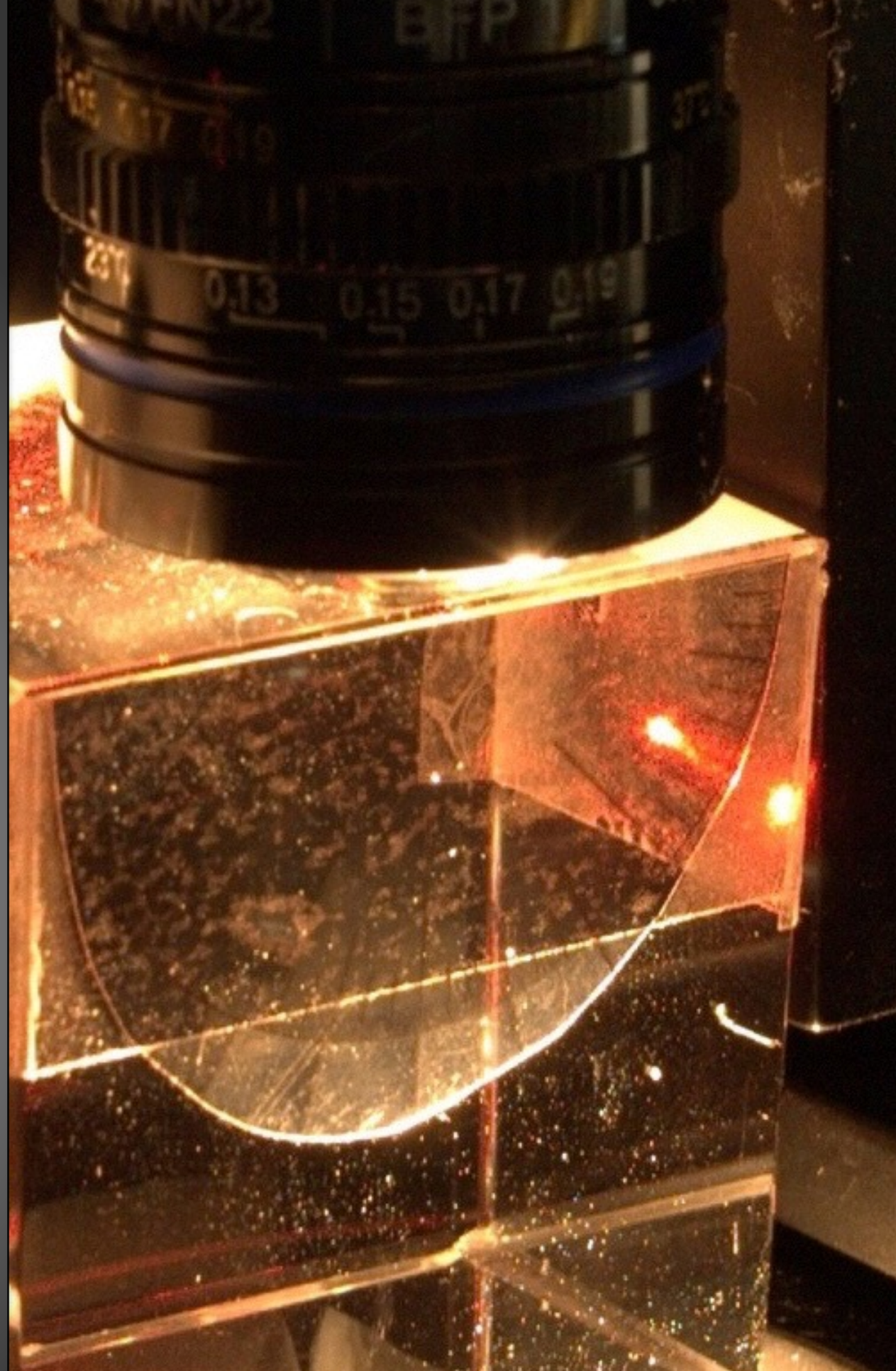
AND IN THE DARKNESS BIND THEM


M5
S
M4

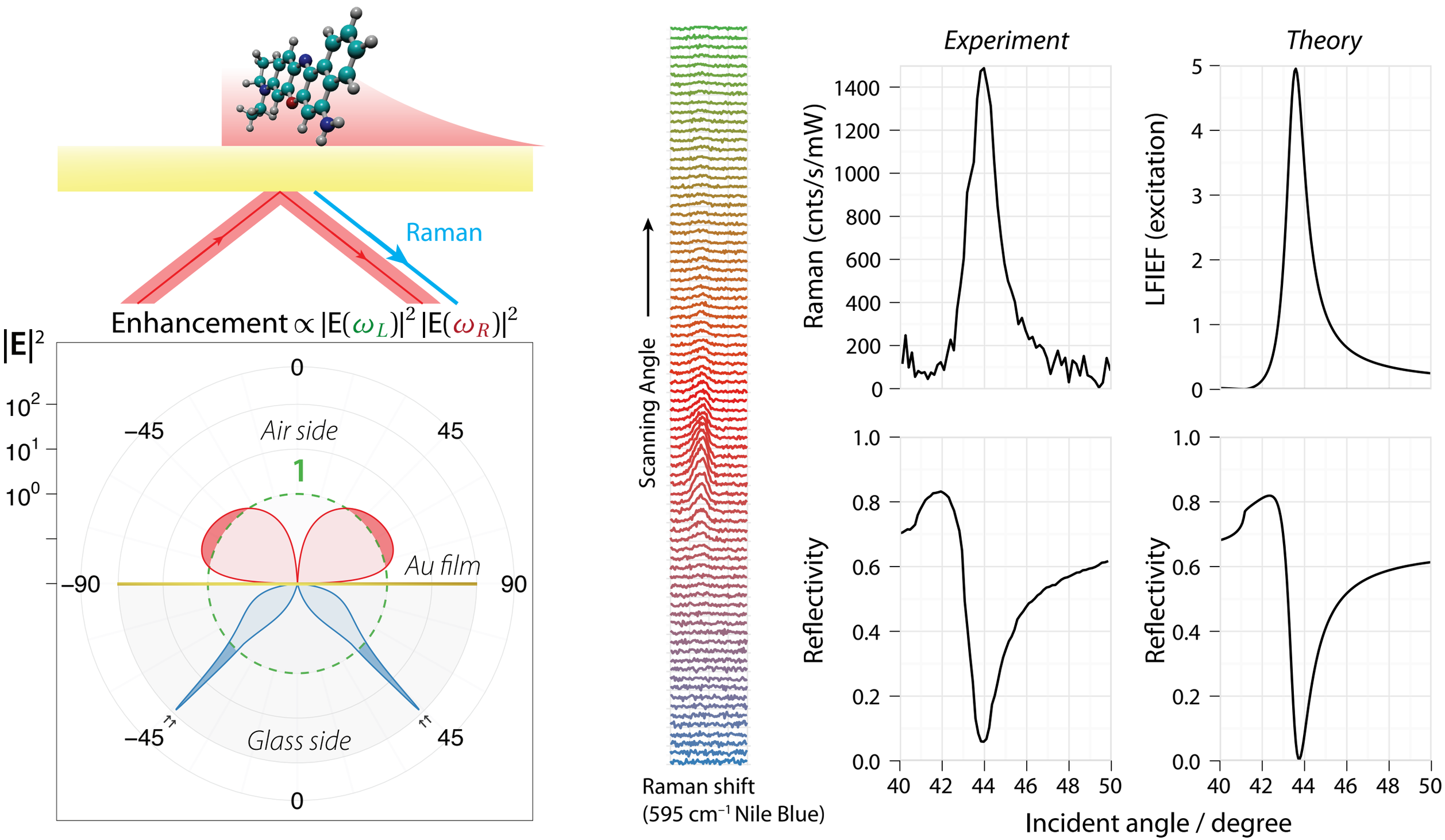

M5
M2
M4
M3
M1

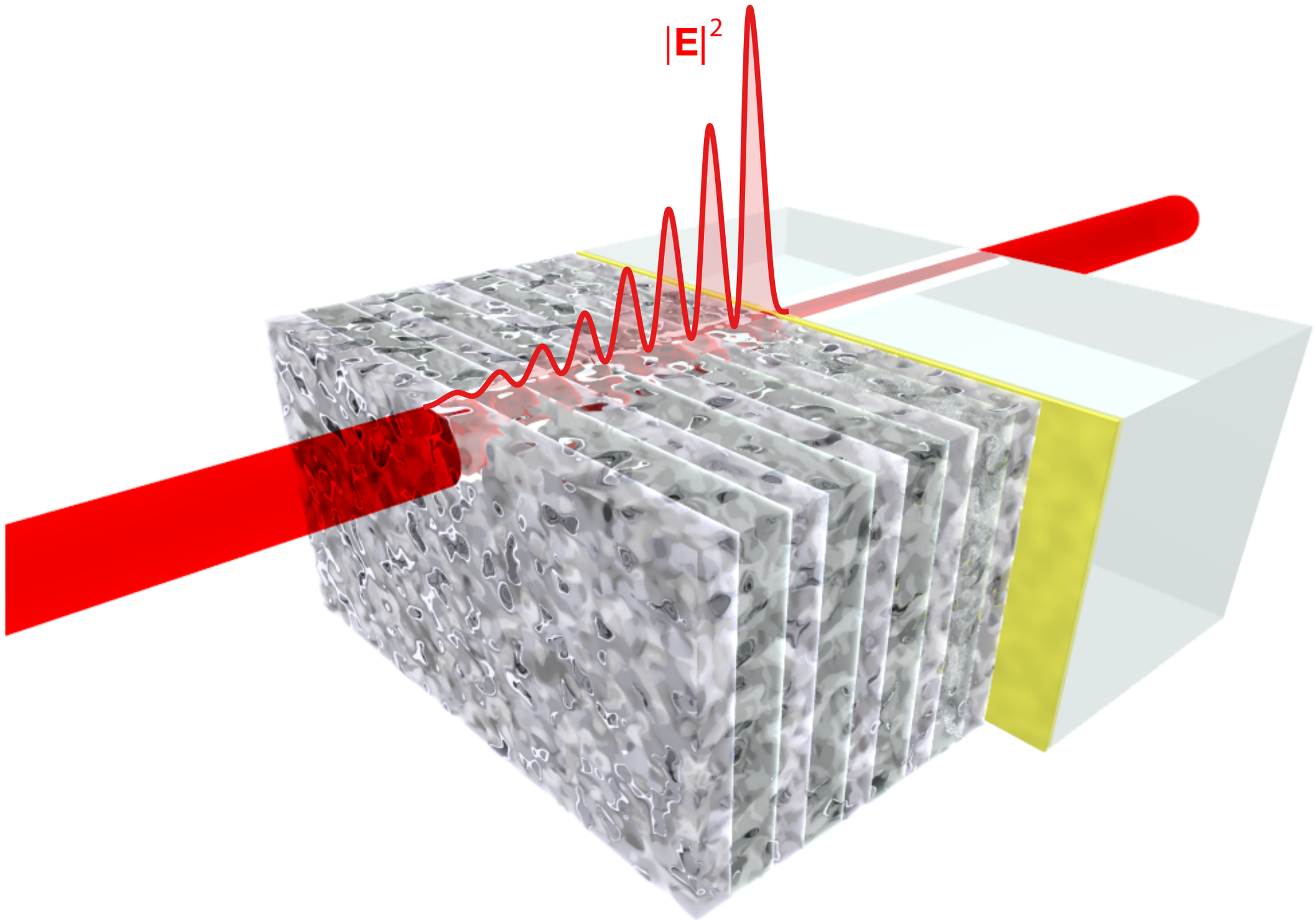



beam
expander
beam size (D)
BFP lens
slanted
glass cube
BFP
objective
spot size (S)


BFP
0.13
0.15
0.17
0.19

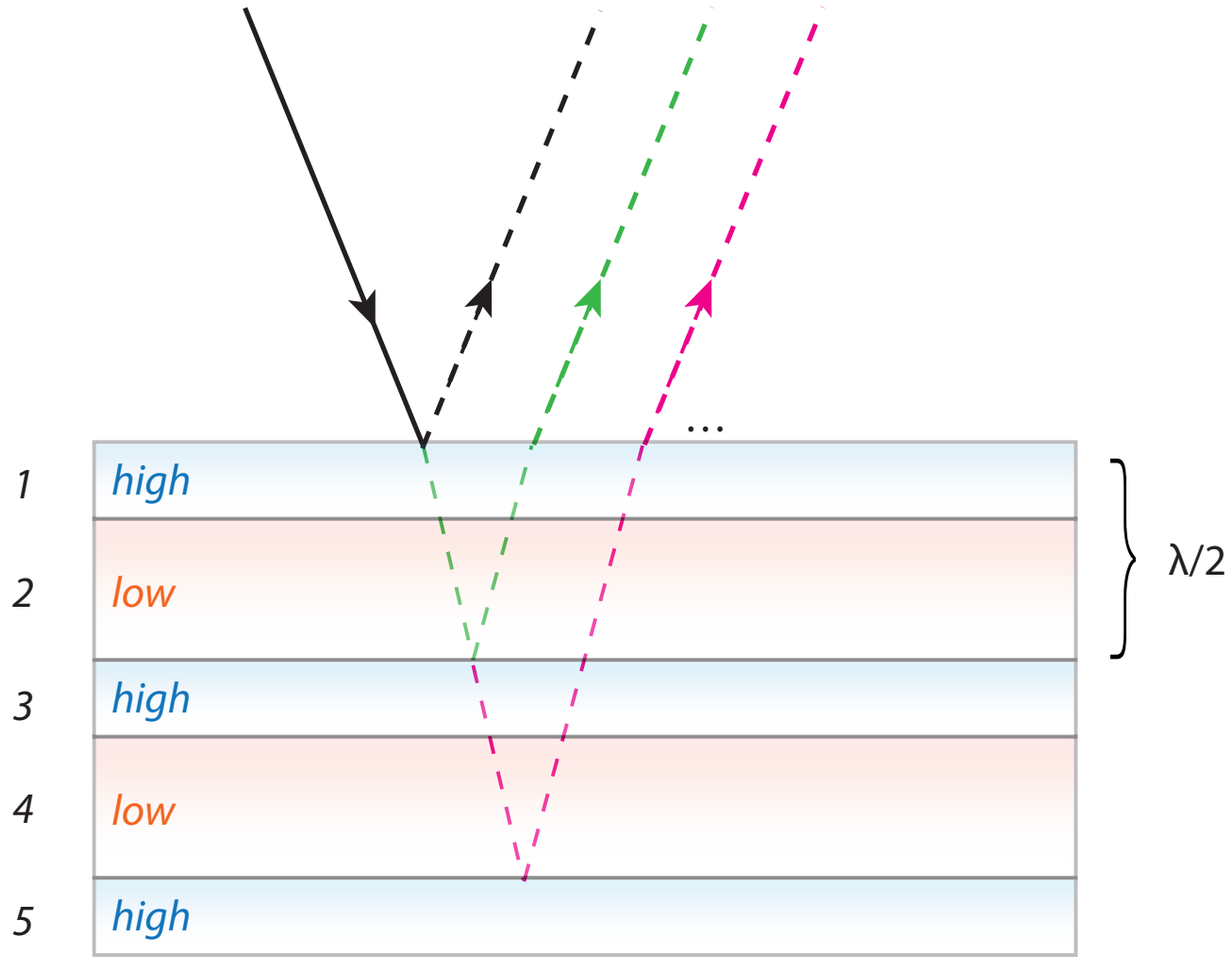
SERS on a flat metal film

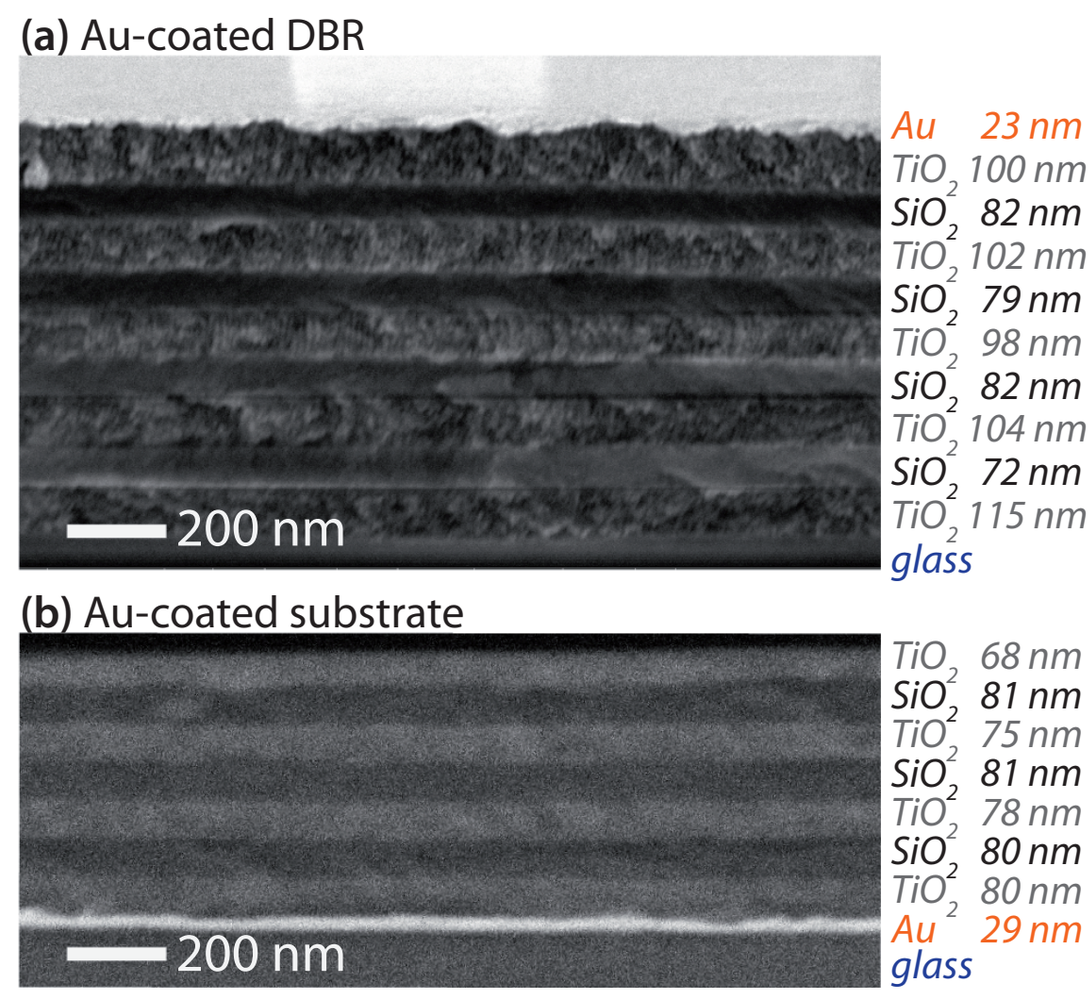


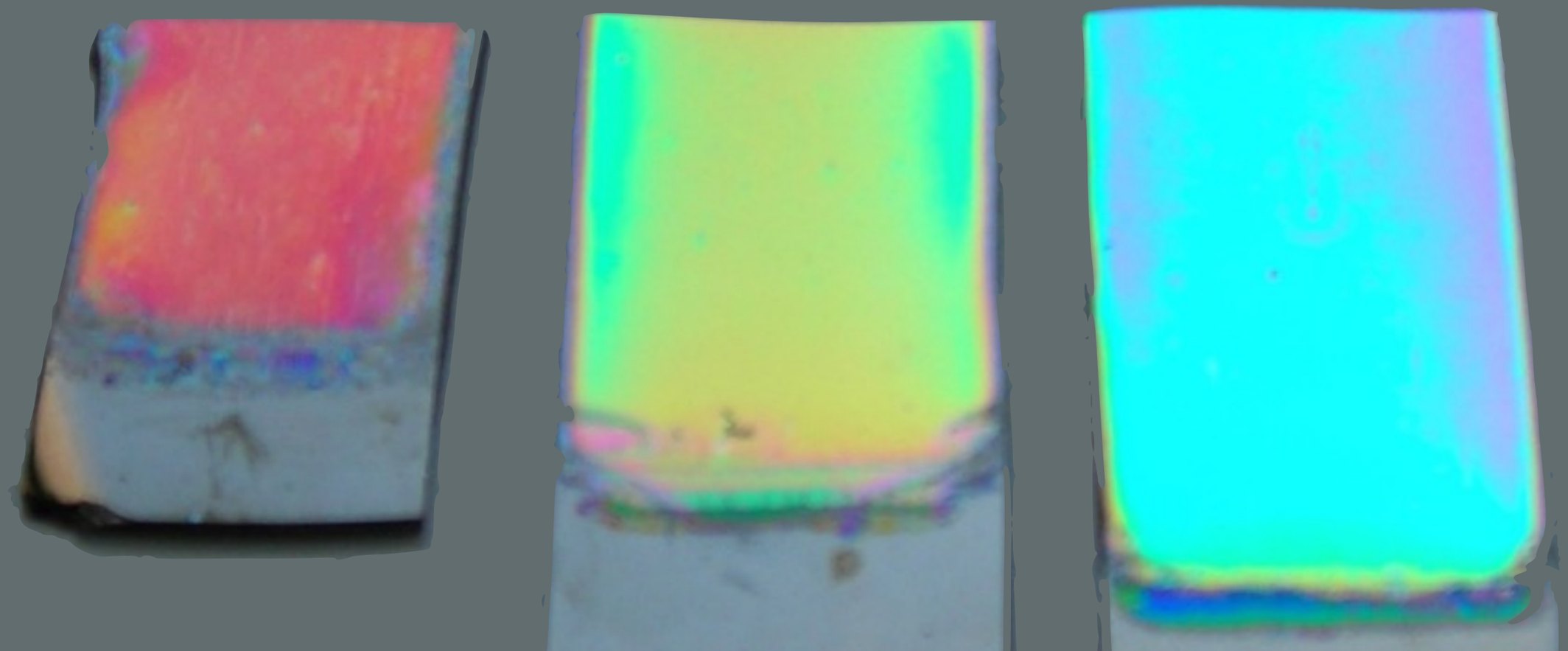


What in the world are

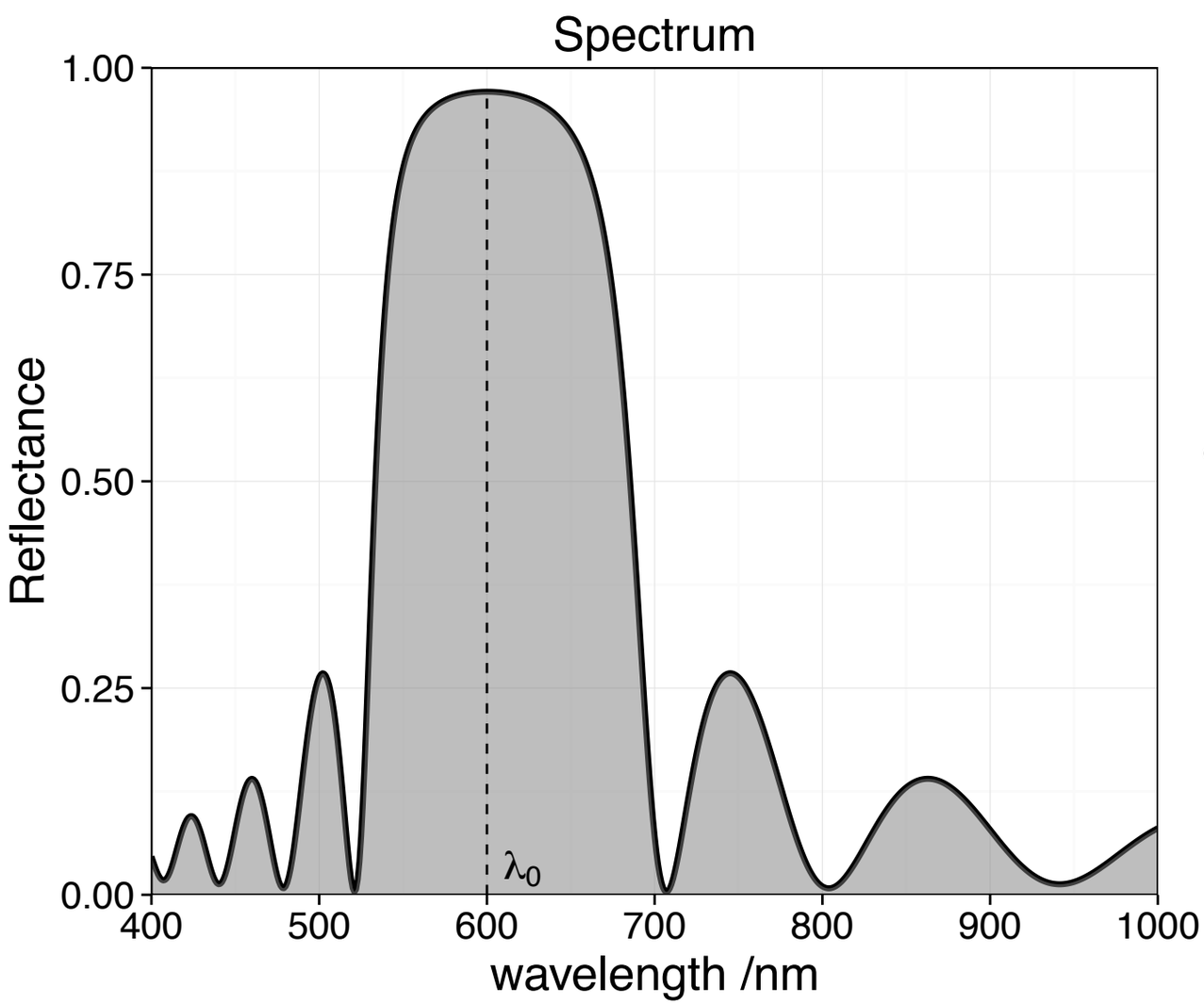
Tamm plasmons ?

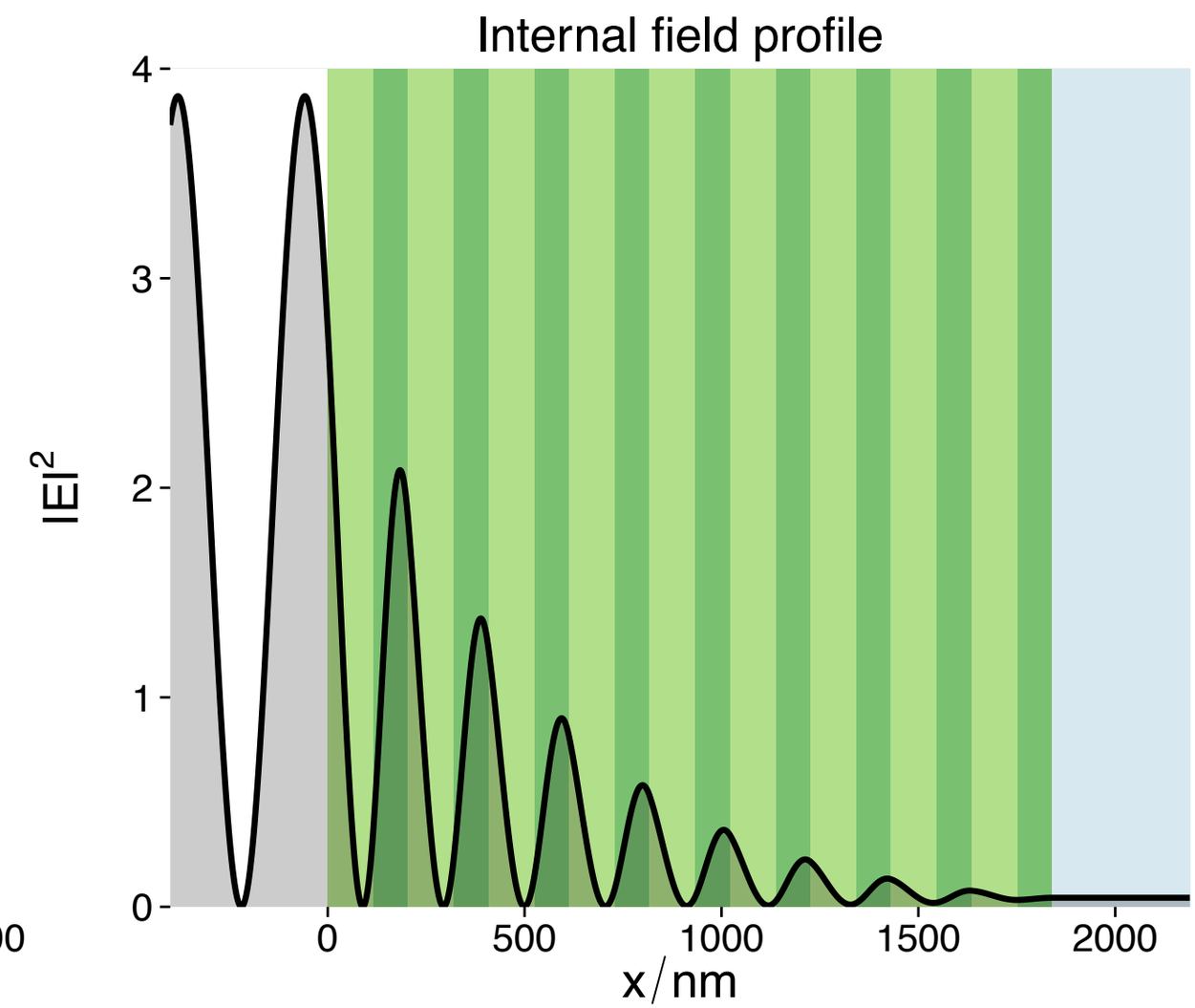

1
high
2
low
3
high
4
low
5
high
...
λ/2


(a) Au-coated DBR
200 nm
Au 23 nm
TiO2 100 nm
SiO2 82 nm
TiO2 102 nm
SiO2 79 nm
TiO2 98 nm
SiO2 82 nm
TiO2 104 nm
SiO2 72 nm
TiO2 115 nm
glass
(b) Au-coated substrate
200 nm
TiO2 68 nm
SiO2 81 nm
TiO2 75 nm
SiO2 81 nm
TiO2 78 nm
SiO2 80 nm
TiO2 80 nm
Au 29 nm
glass

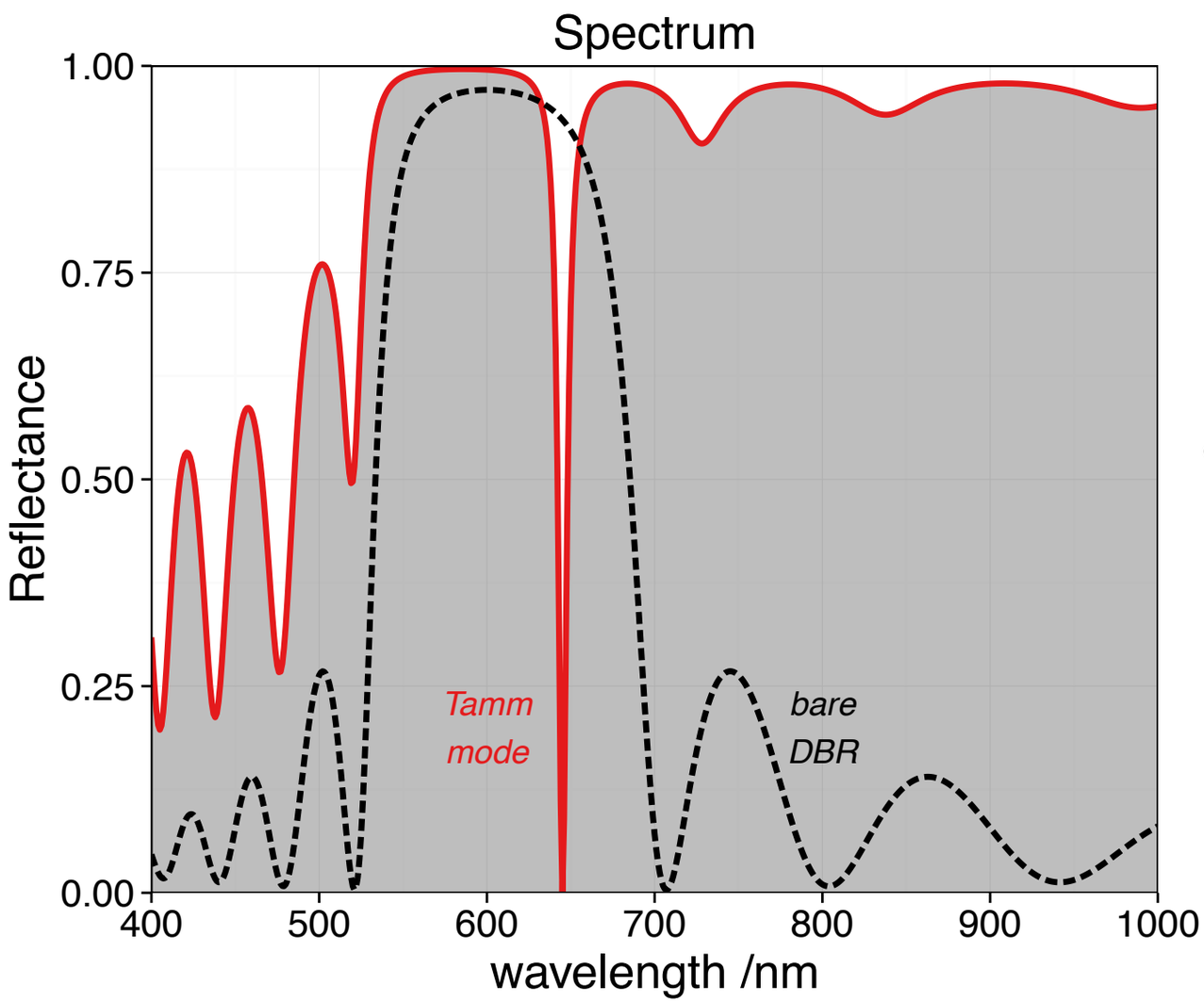


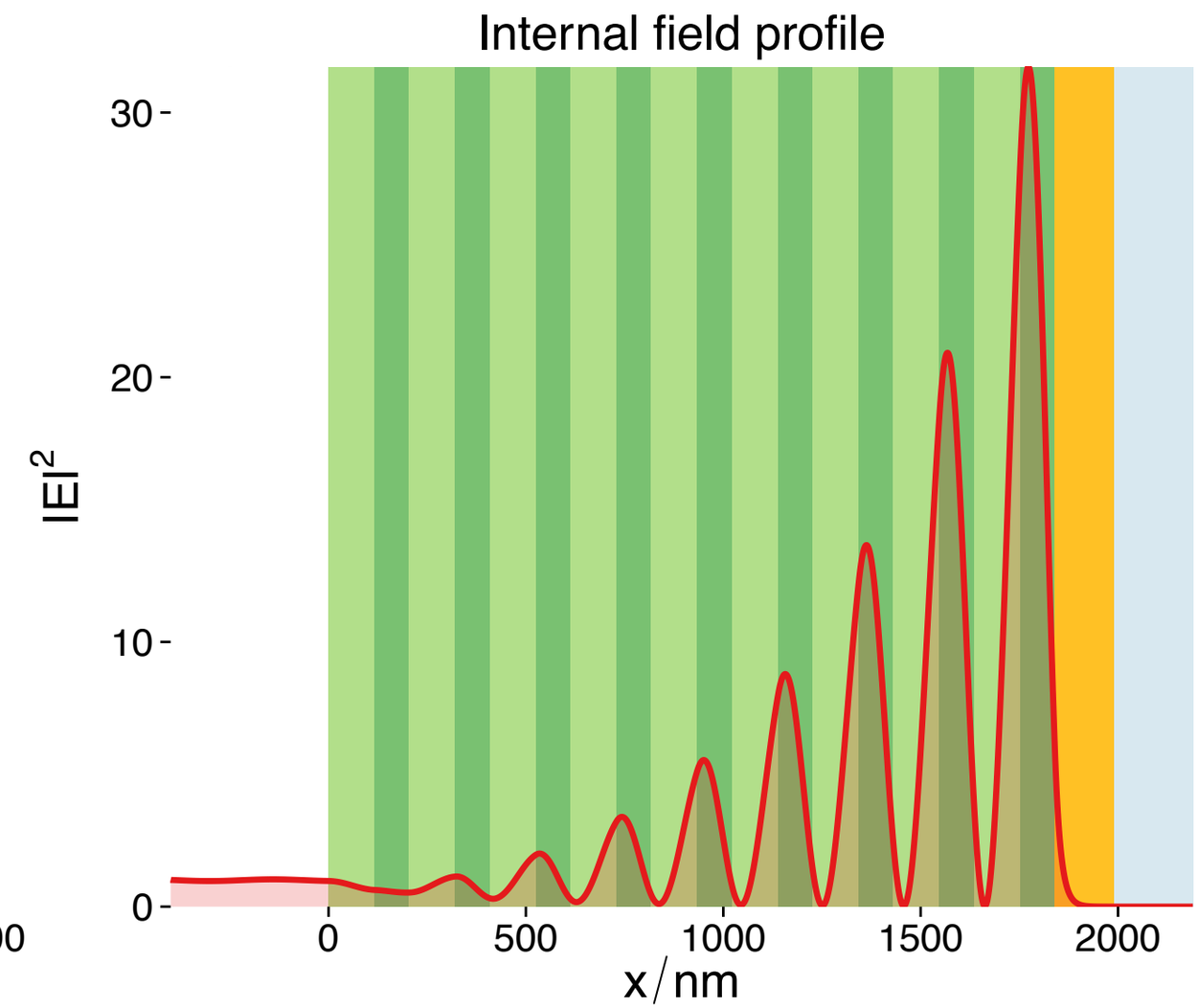
Distributed Bragg Reflector



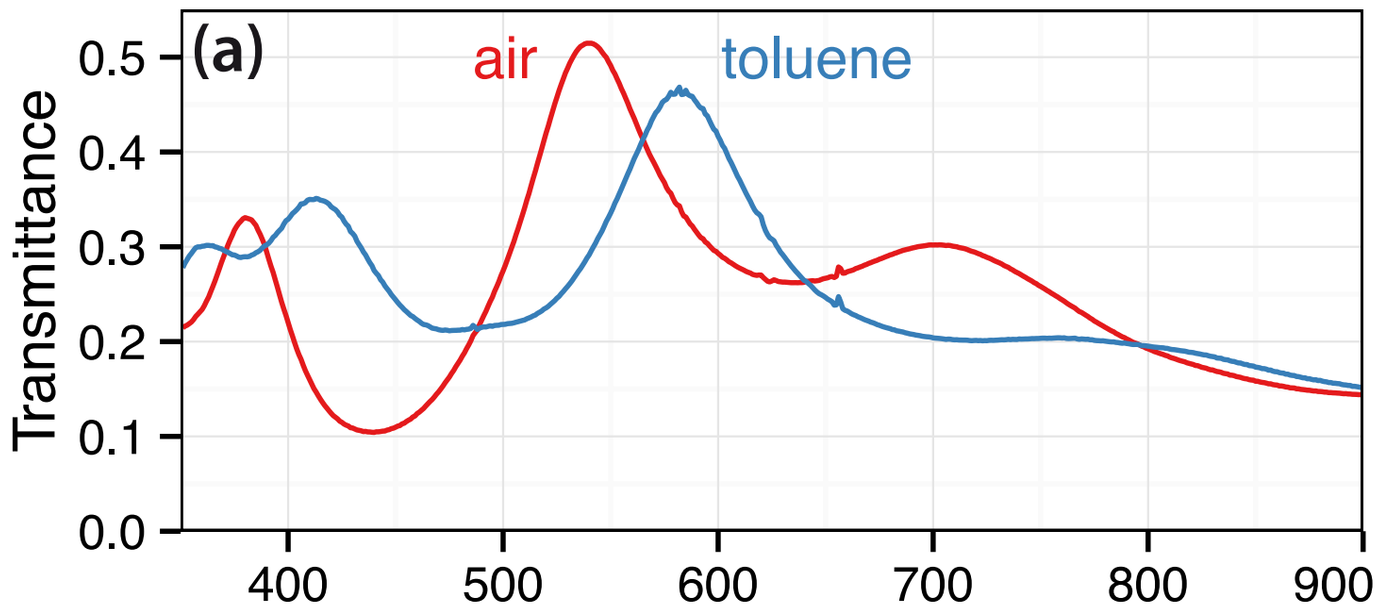


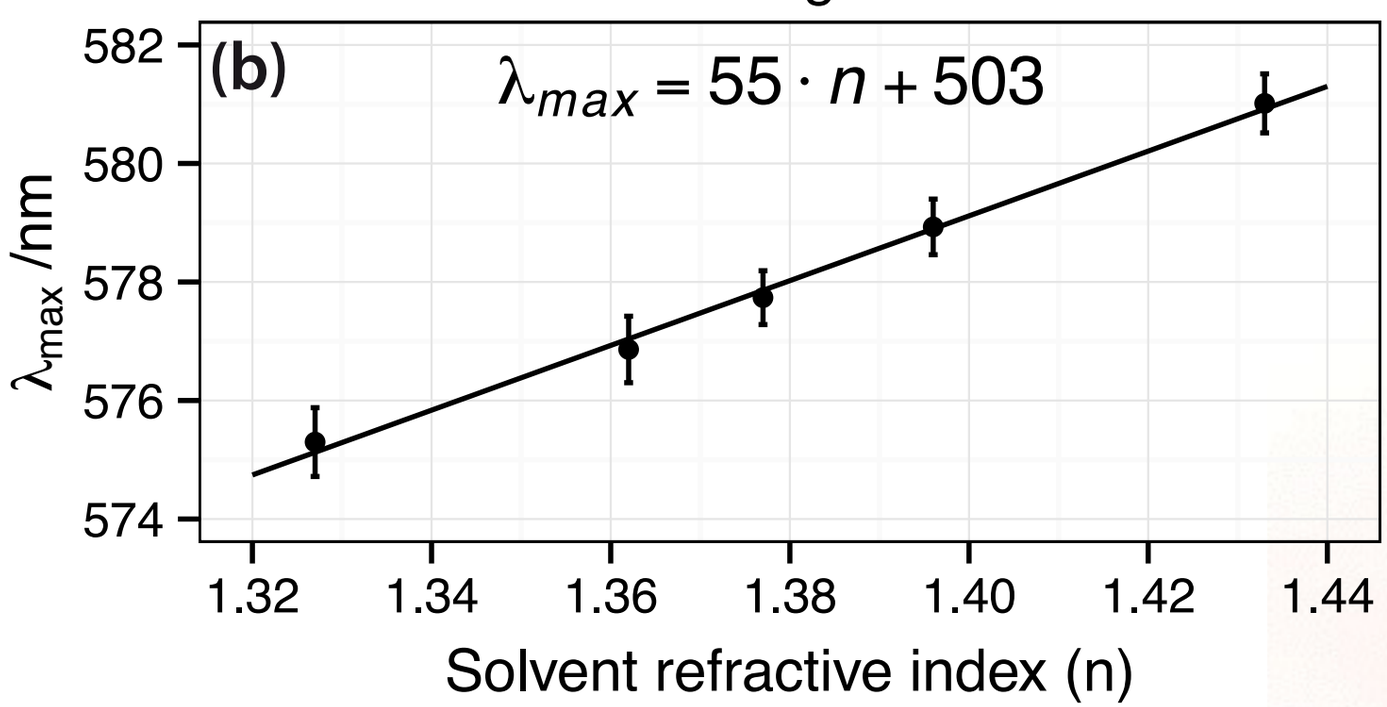
Adding a gold layer



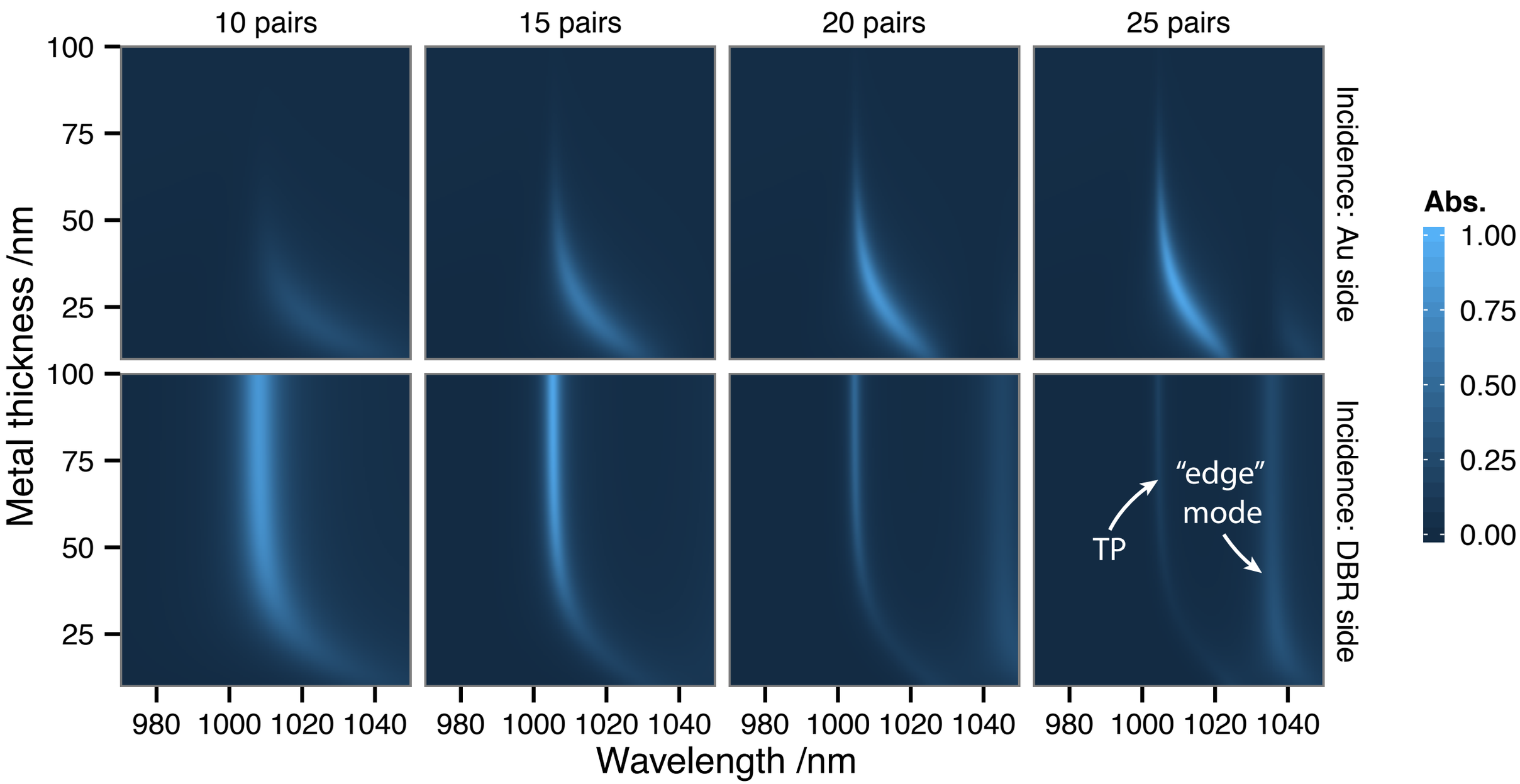


Icing on the cake – a refractive index sensor





Perfect absorber – *critical coupling*



More on critical coupling:

Colloquium: Unusual resonators: Plasmonics, metamaterials, and random media Rev. Mod. Phys. 80, 1201, 2008