Probing Polaritons in Low-dimensional Materials with Synchrotron Infrared Nanospectroscopy

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CNPEM Centro Nacional de Pesquisa em Energia e Materiais
MINISTÉRIO DA CIÊNCIA, TECNOLOGIA E INOVAÇÕES
PÁTRIA AMADA BRASIL GOVERNO FEDERAL


City of Campinas
State University
Of Campinas
LNNano
Laboratório Nacional
de Nanotecnologia
Old storage ring
(uvx)
LNBio
Laboratório Nacional
de Biociências
Shutdown
in 2019
Commissioning
phase
New storage ring
(Sirius)
LNLS
Laboratório Nacional
de Luz Síncrotron
sirius
lnbr
laboratório nacional de
biorrenováveis
CNPEM
Centro Nacional de Pesquisa
em Energia e Materiais
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PhD student

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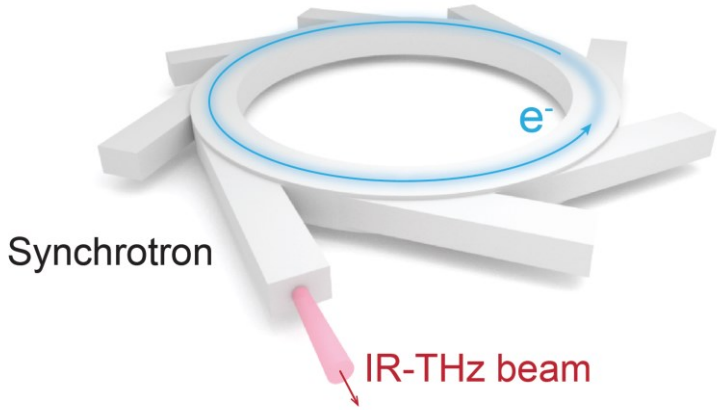
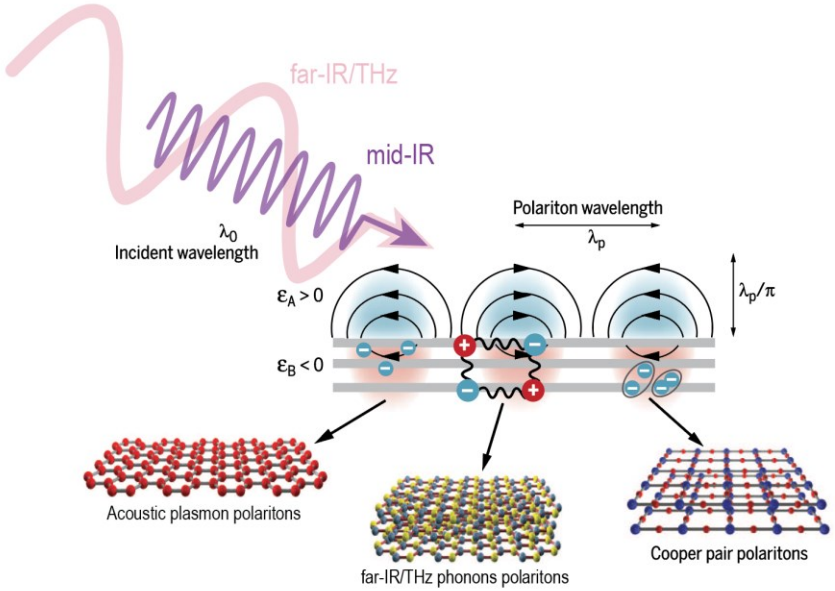
Outline

Synchrotron radiation and the ultrabroadband nanospectroscopy

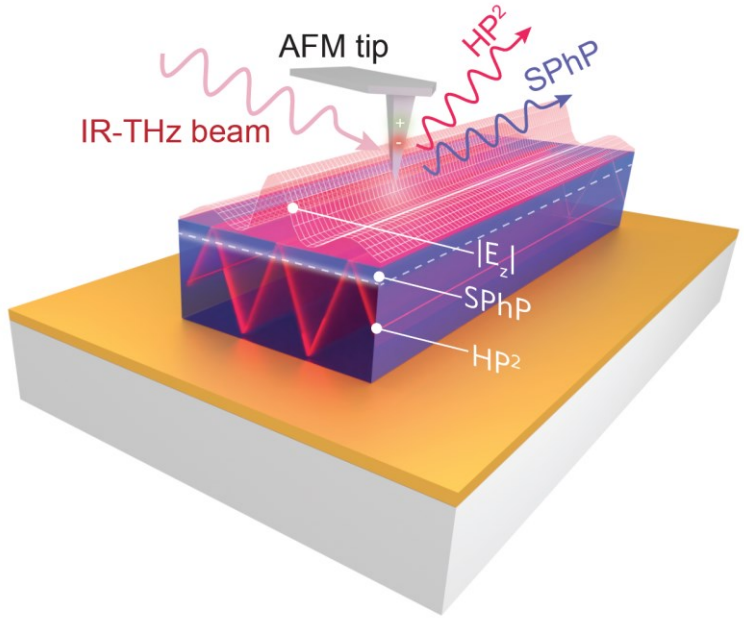


How SINS is serving nanophotonics?



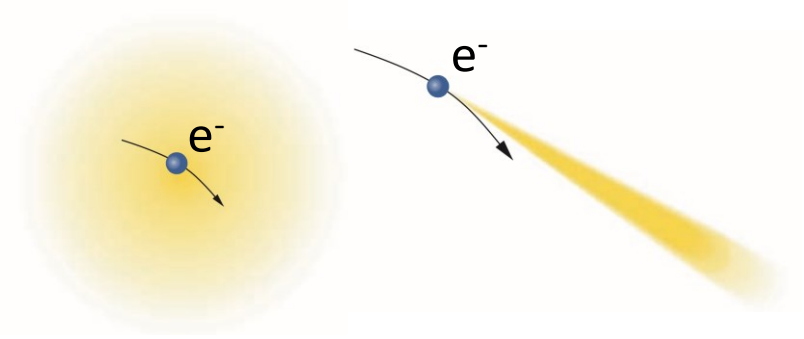
Adapted from Science **354** (2016)

SINS as a probe for covering a wide-IR range



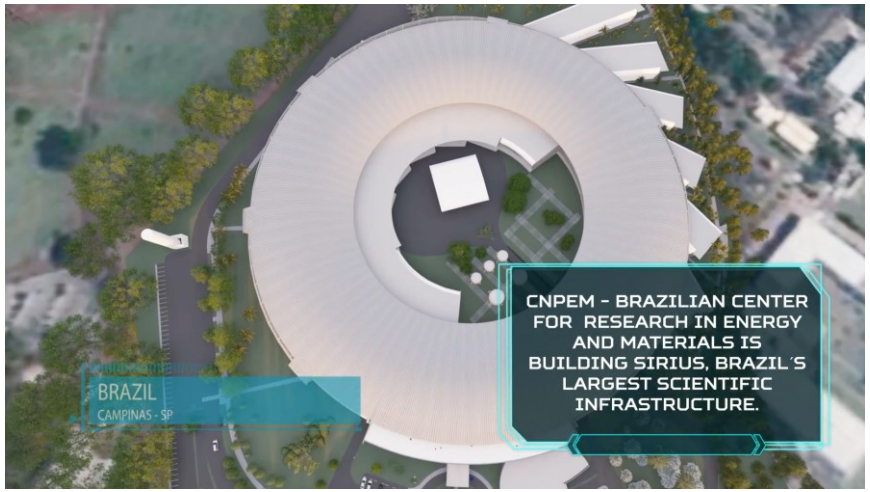
The synchrotron radiation

Synchrotron emission



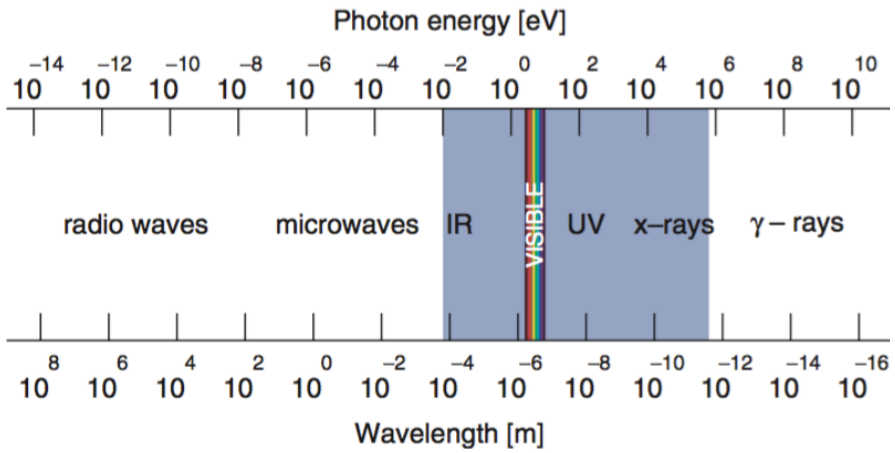
$v \ll c$ $v \sim c$

Brazilian synchrotron light source: Sirius

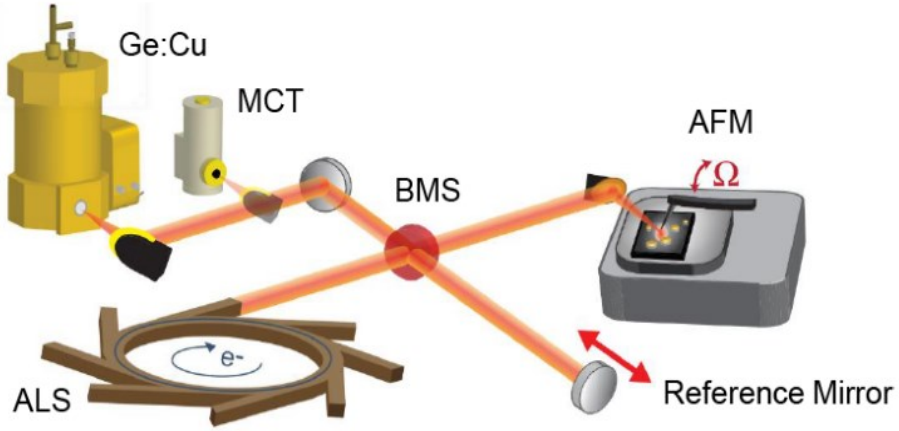


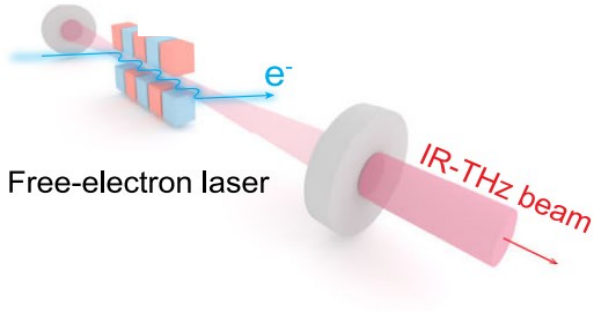
IR frequency range:
70 meV to 400 meV
564 to 3226 cm^{-1}

From THz to hard X-rays



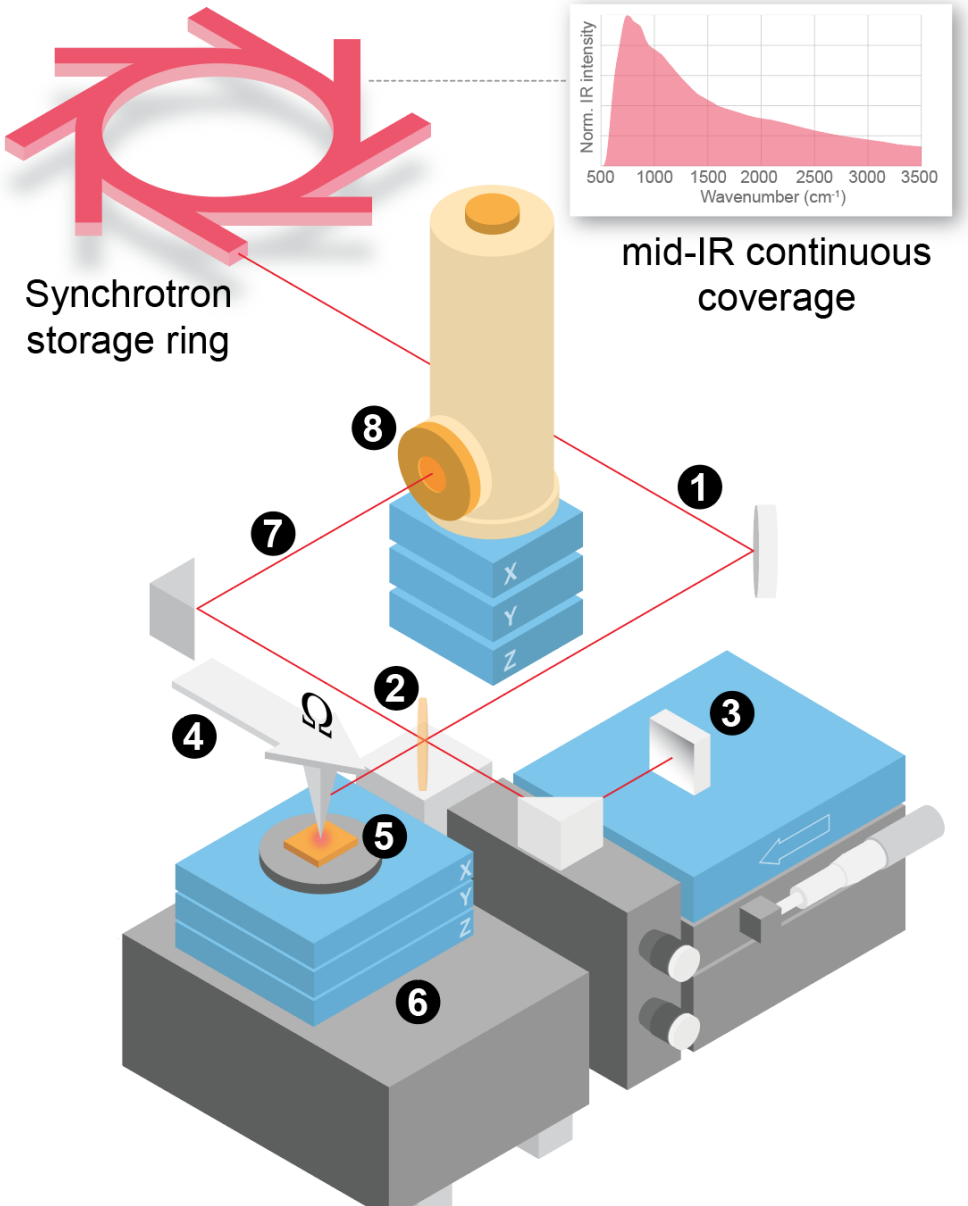
IR synchrotron facilities





Willmott, An Introduction to Synchrotron Radiation, Wiley, London, 2011.

Synchrotron Infrared Nanospectroscopy or SINS

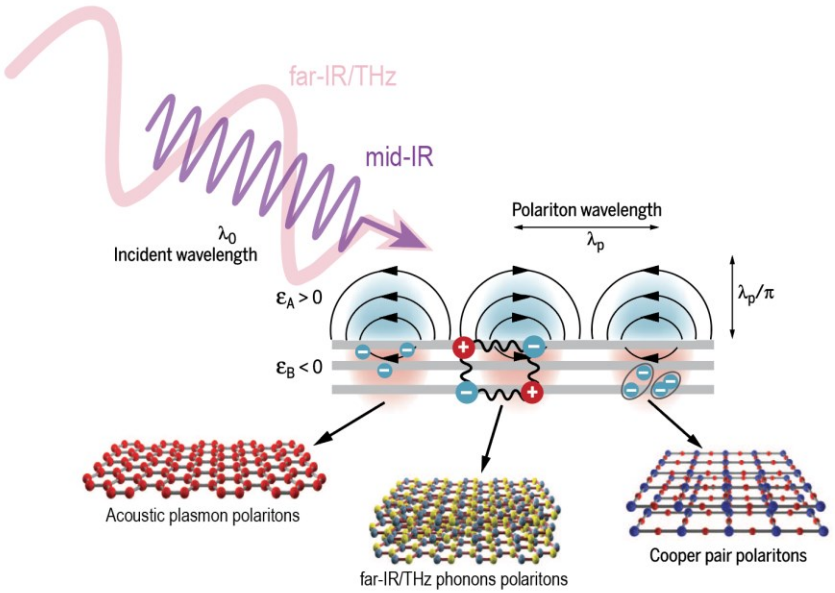


- Up to 1000 times more brilliant than black body sources
- Ultra-broadband (THz to near-IR)

Synchrotron Infrared Nanospectroscopy

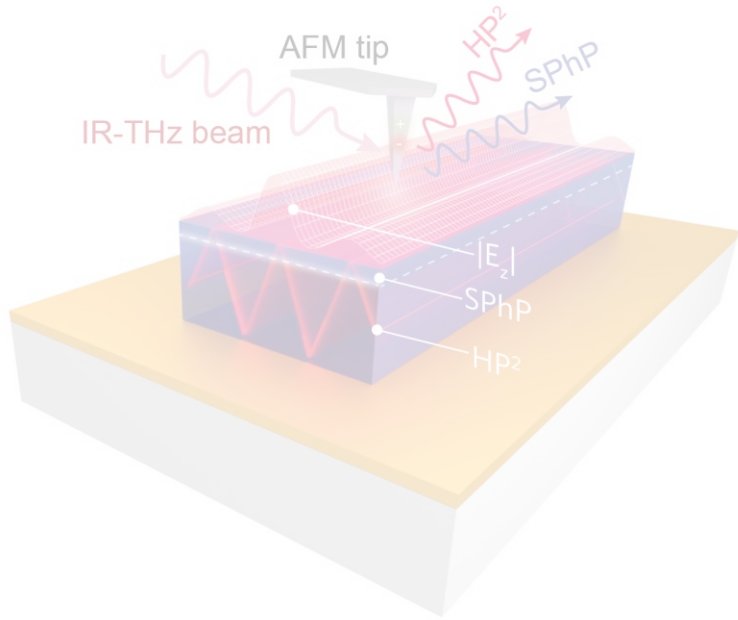
Synchrotron radiation and the ultrabroadband nanospectroscopy

How SINS is serving nanophotonics in 2Ds?

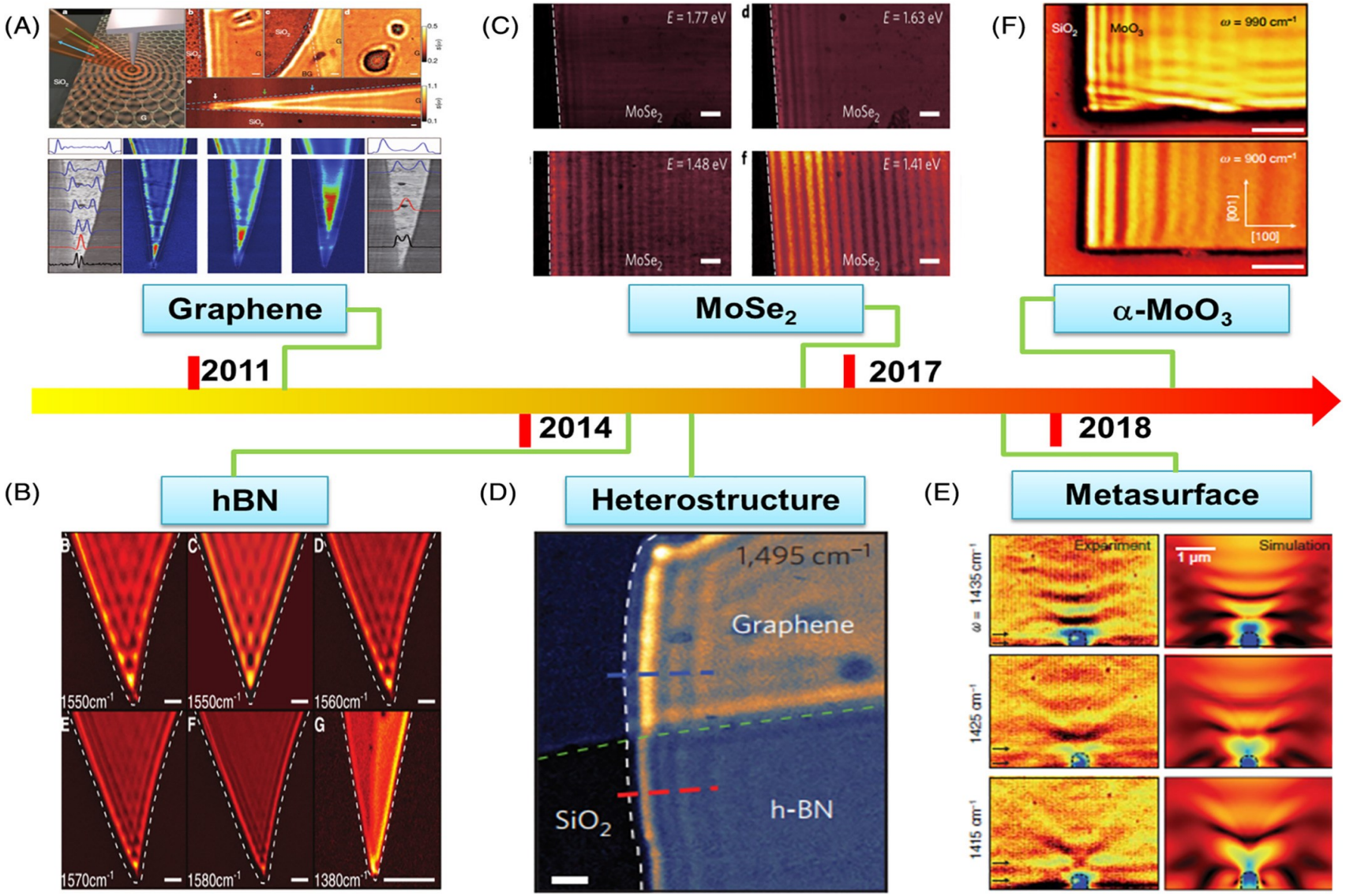


Adapted from Science **354** (2016)

Synchrotron as a promissing probe of new phenomena in 2Ds

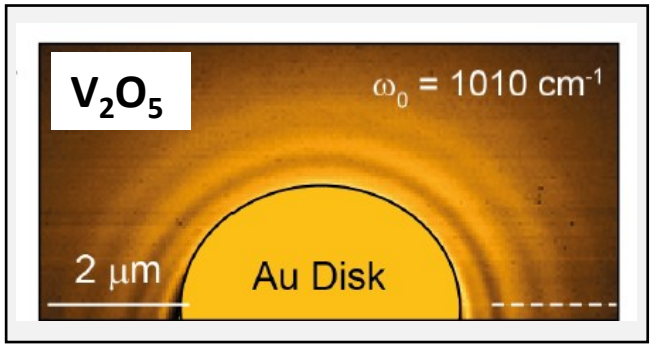


Polaritons

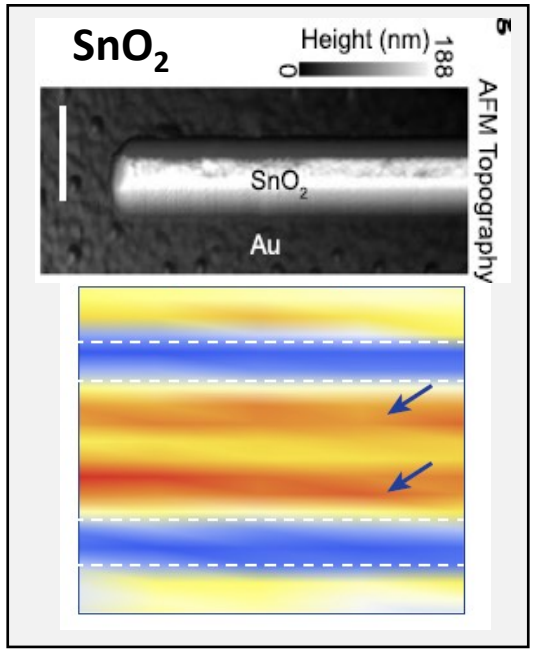


2020

2021



J. Taboada-Gutiérrez, et al; Nat. Mat. (2020)

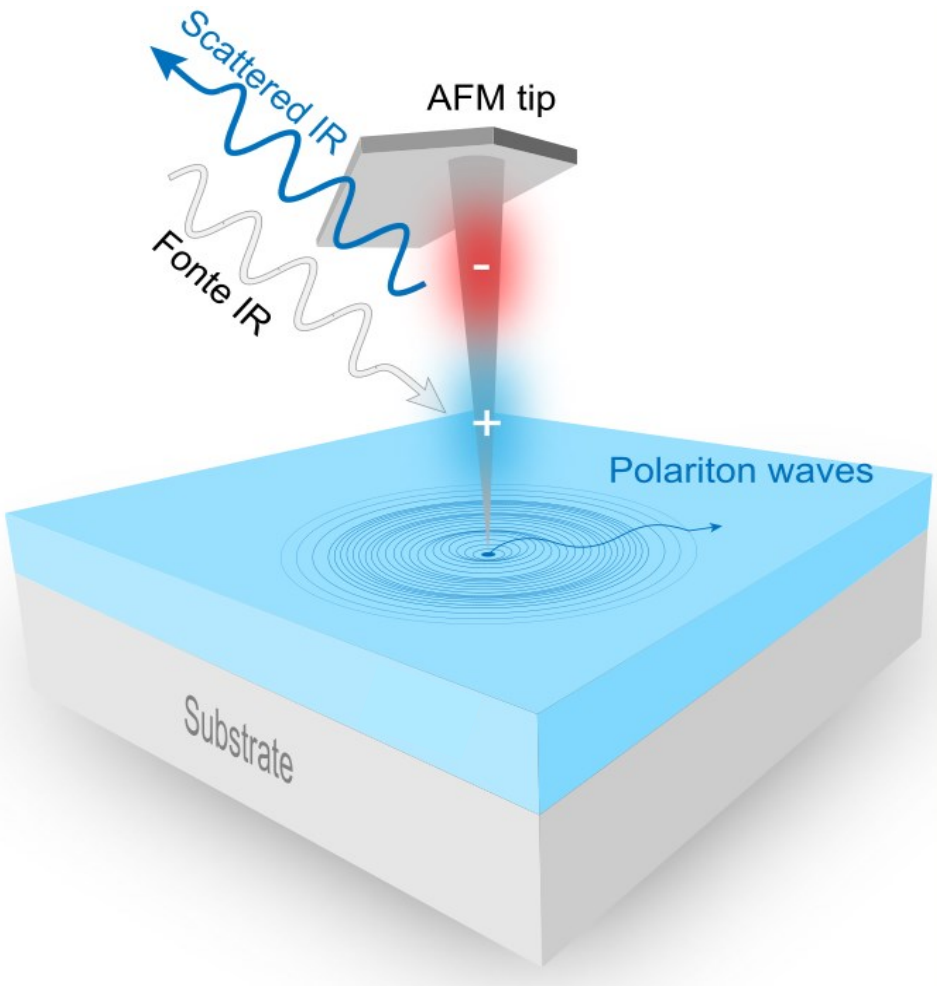


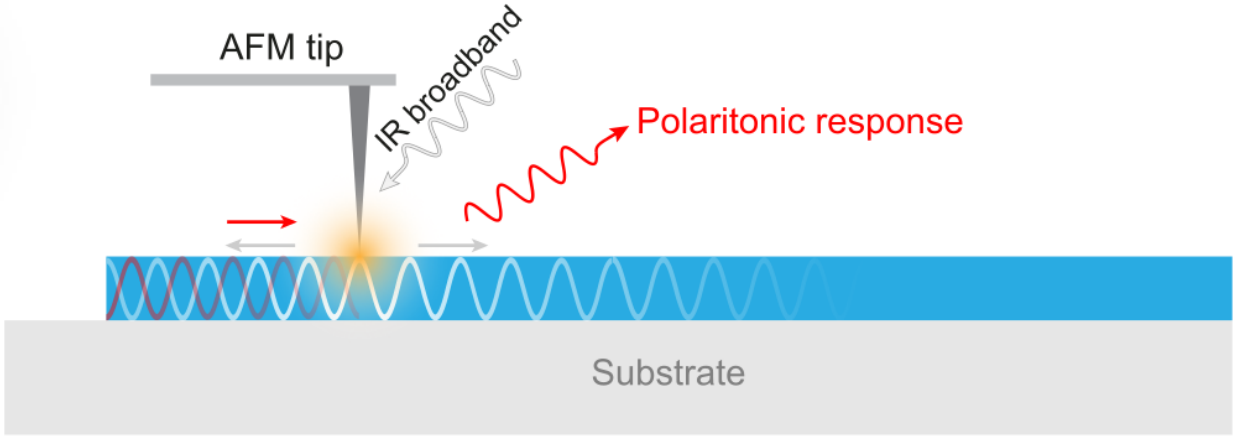
F. H Feres et al; Nat. Comm. (2021)

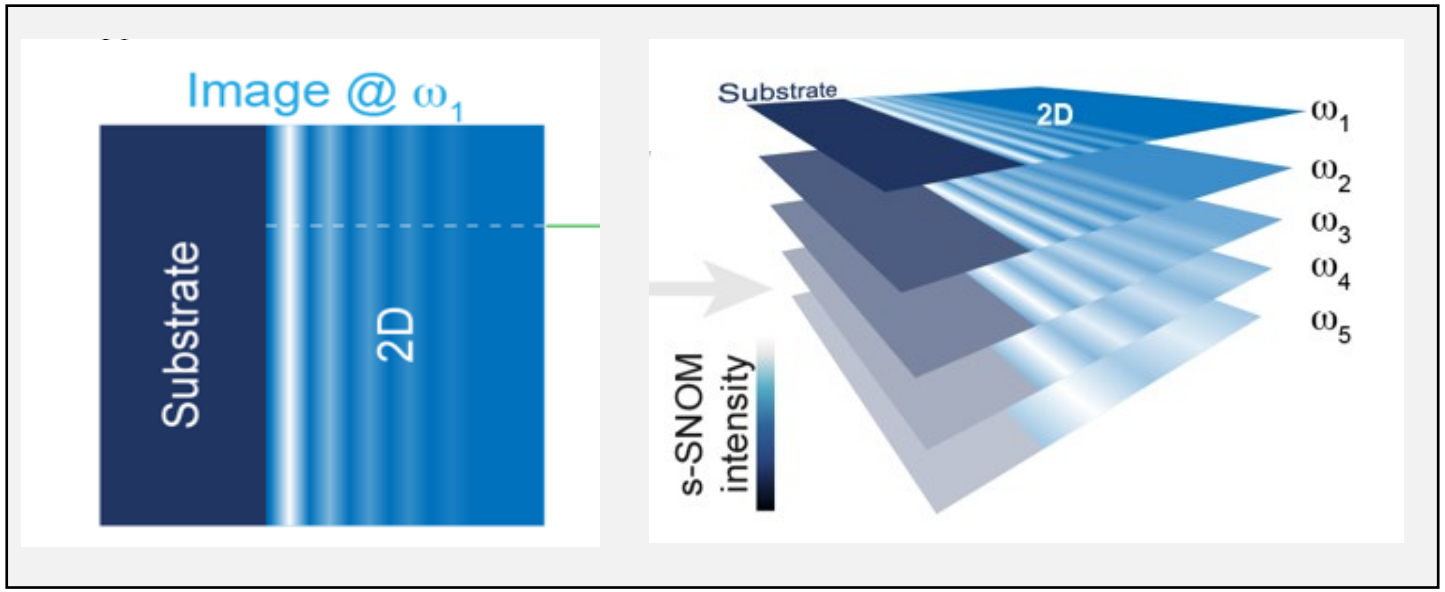
InfoMat, Volume: 2, Issue: 5, Pages: 777-790, First published: 28 April 2020

How SINS is serving nanophotonics?

s-SNOM



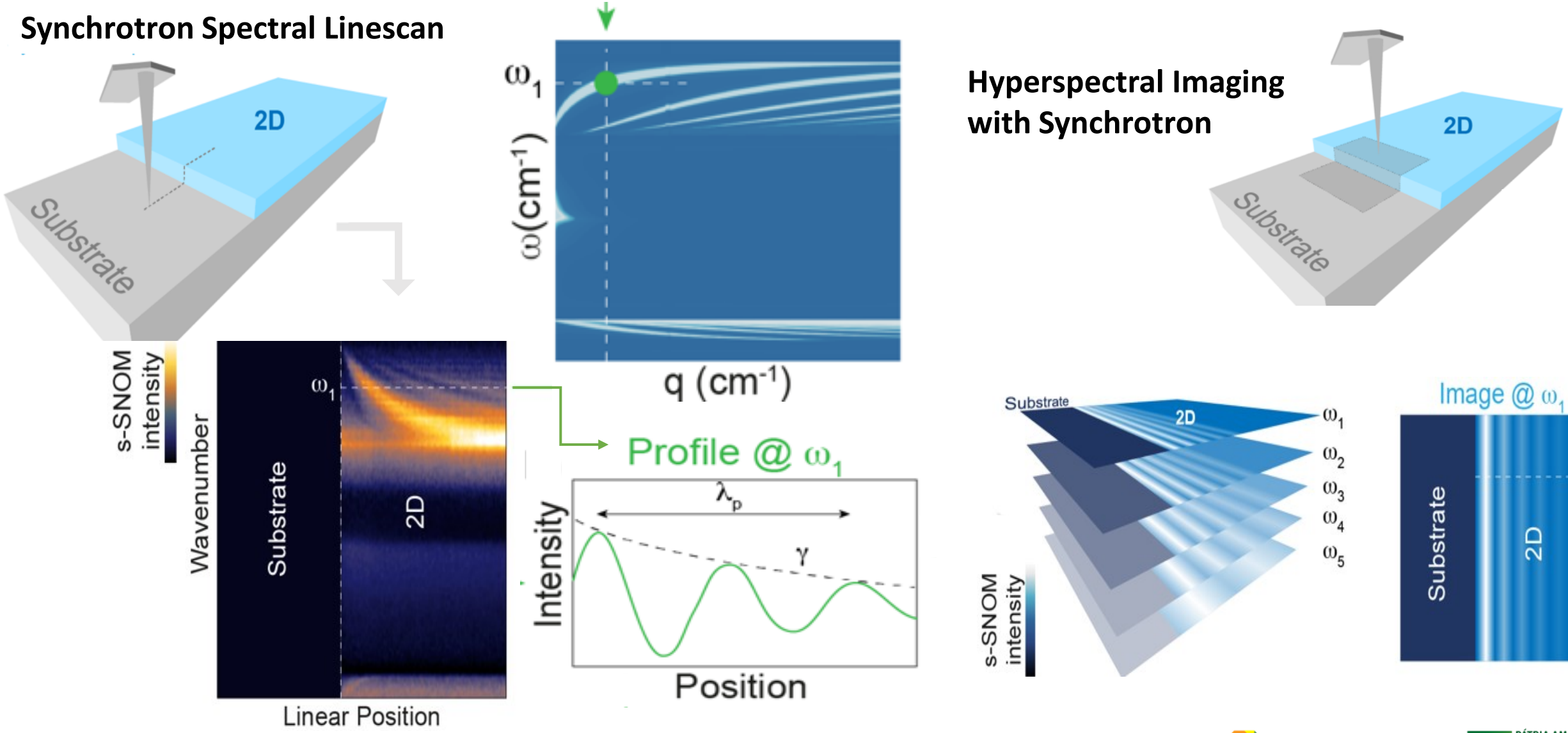




I. Barcelos, et al; Advanced Optical Materials, 2020

How SINS is serving nanophotonics?

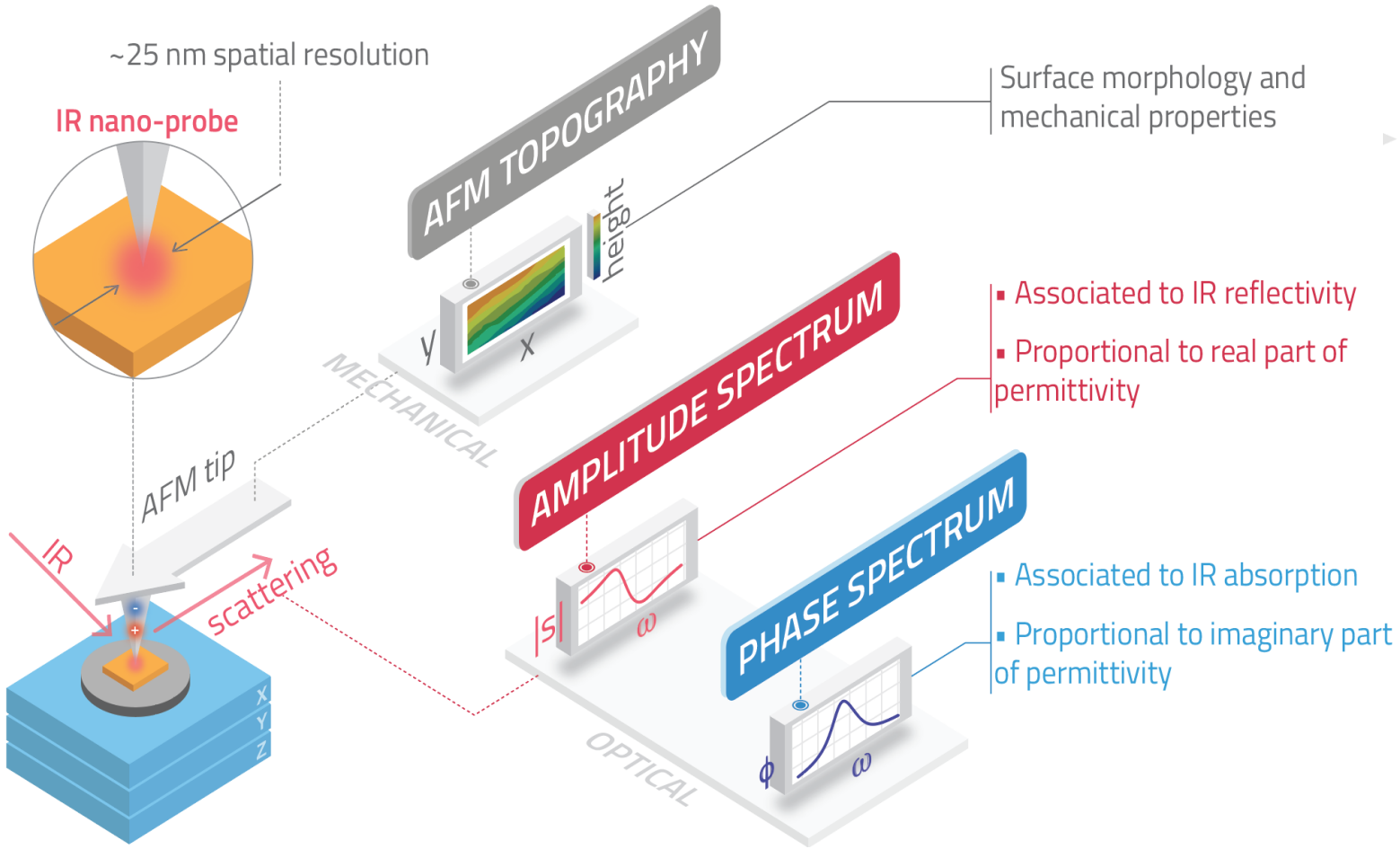
Synchrotron Spectral Linescan



Hyperspectral Imaging with Synchrotron

I. Barcelos, et al; Advanced Optical Materials, 2020

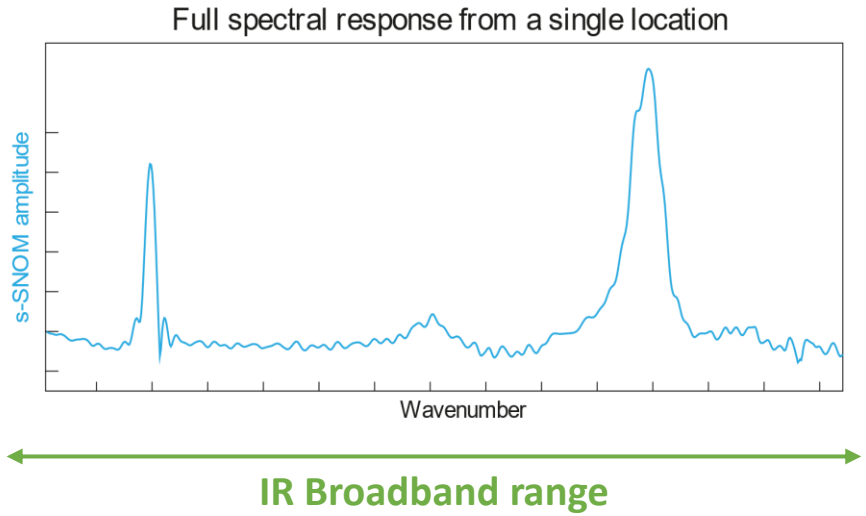
How SINS is serving nanophotonics?

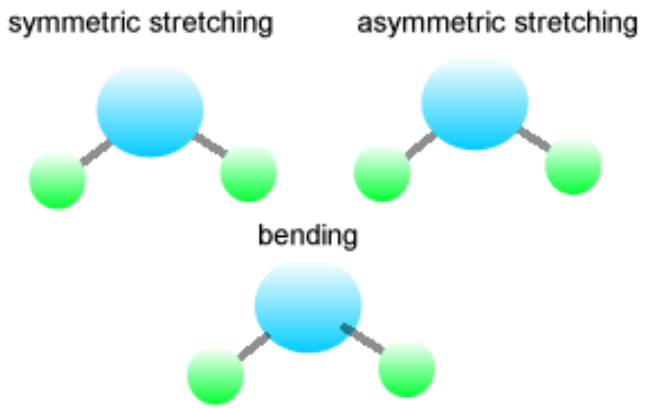


Surface morphology and mechanical properties

- Associated to IR reflectivity
- Proportional to real part of permittivity

- Associated to IR absorption
- Proportional to imaginary part of permittivity



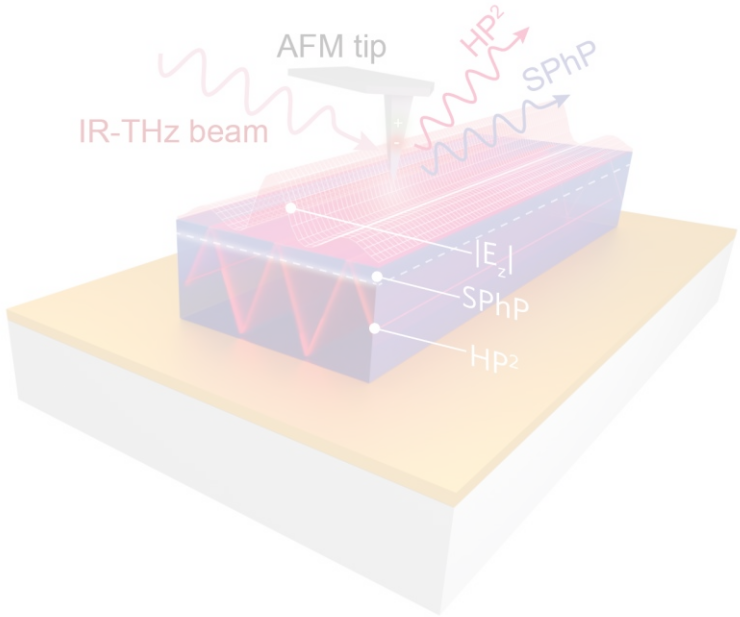


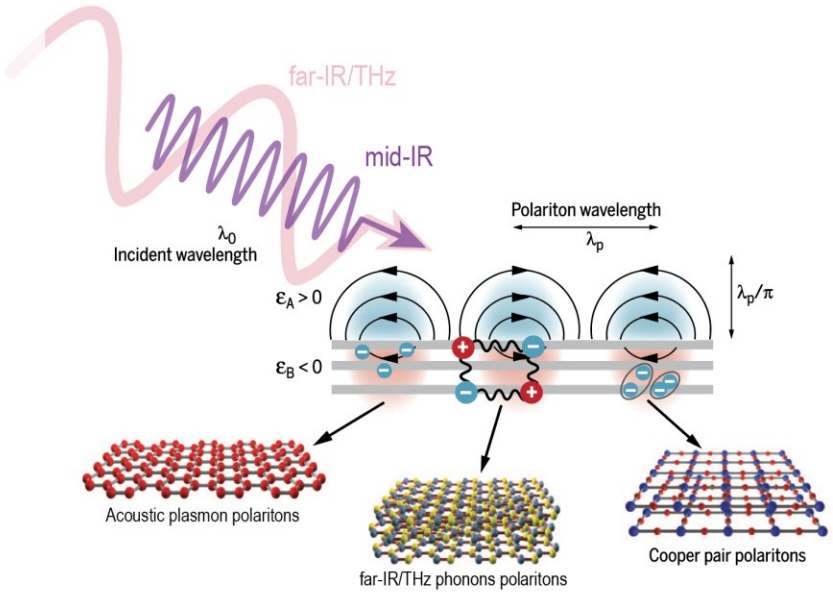
Scientific cases

Synchrotron radiation and the ultrabroadband nanospectroscopy

How synchrotron s-SNOM is serving nanophotonics in 2Ds?

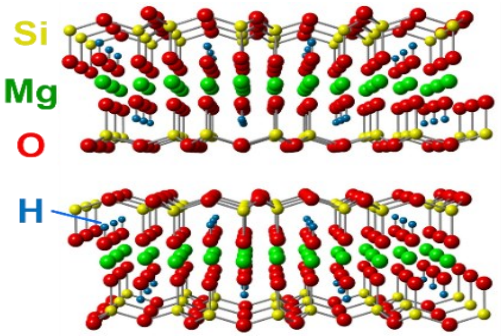
Synchrotron as a promissing probe of new phenomena in 2Ds



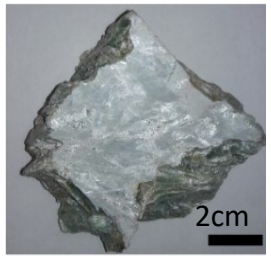


Adapted from Science **354** (2016)

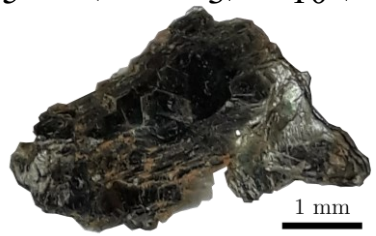
Novel 2D material

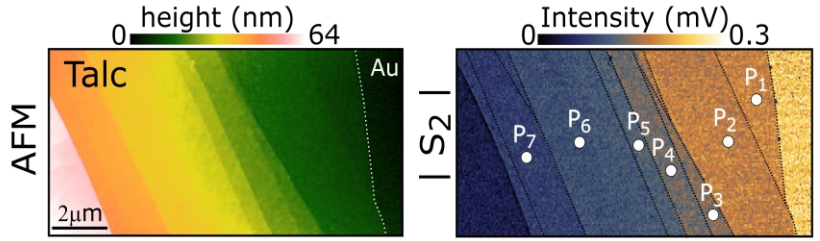


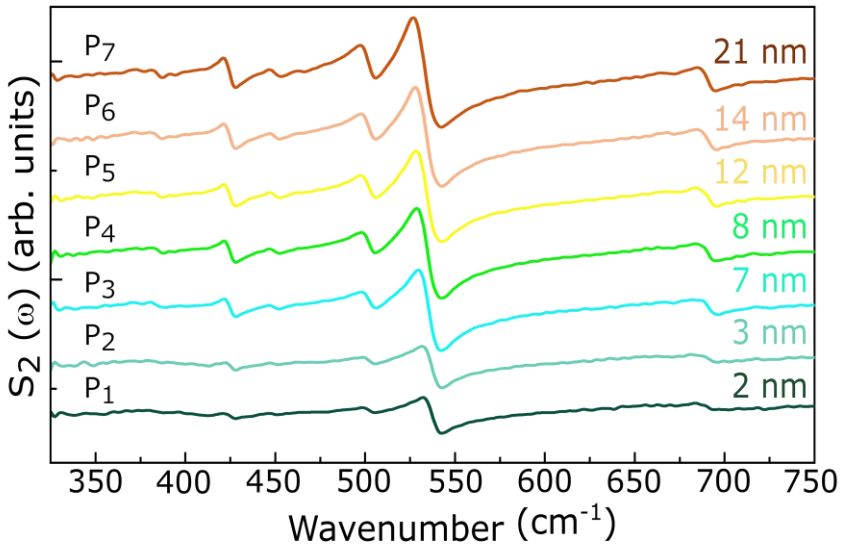
$Mg_3Si_4O_{10}(OH)_2$

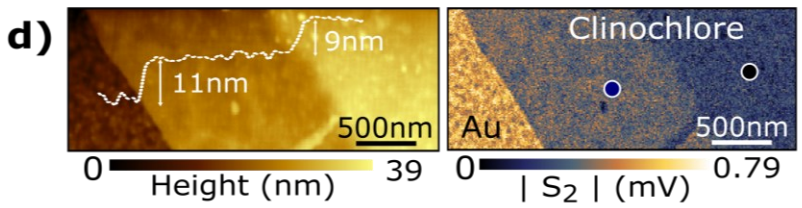


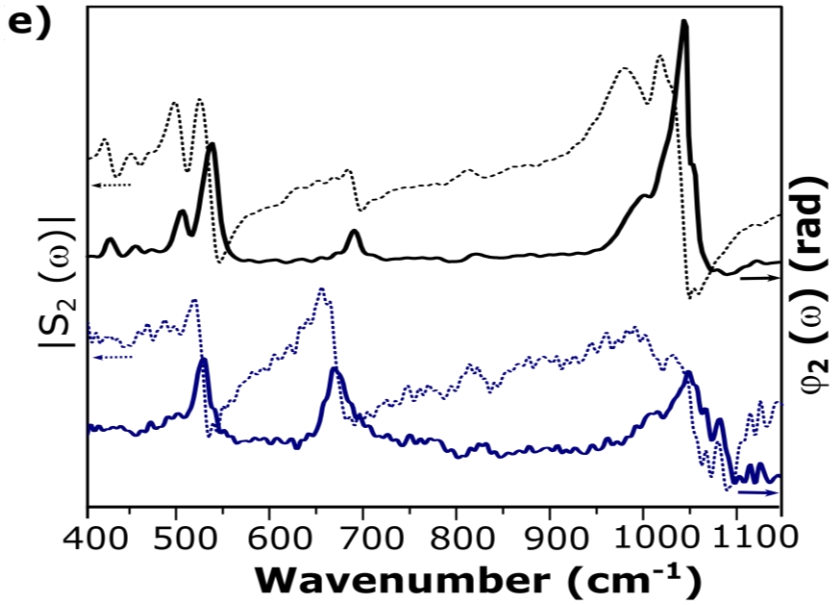
$Mg_5Al(AlSi_3)O_{10}(OH)_8$



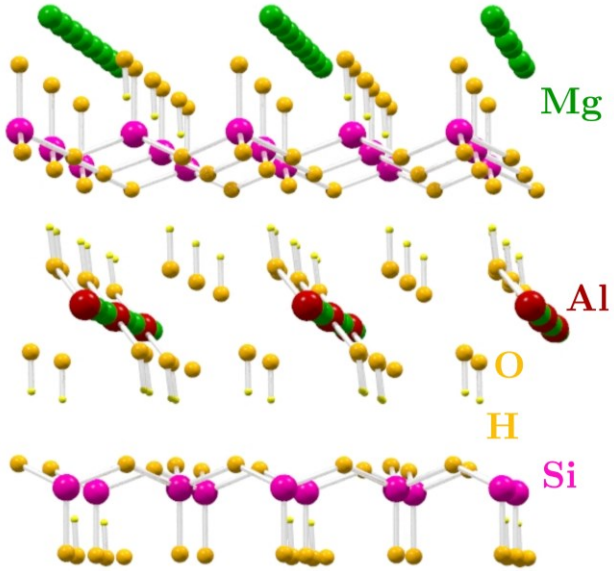








Atomically flat 2D insulator

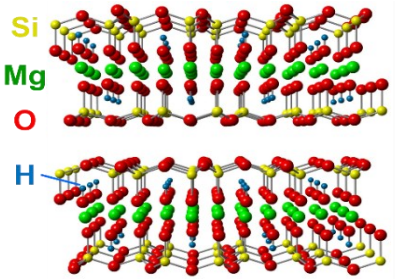


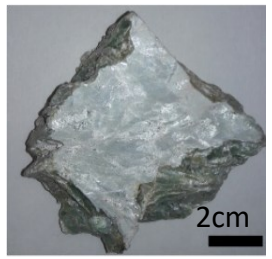
Far-IR Synchrotron s-SNOM
(@ 2.4 BL ALS/Berkeley)

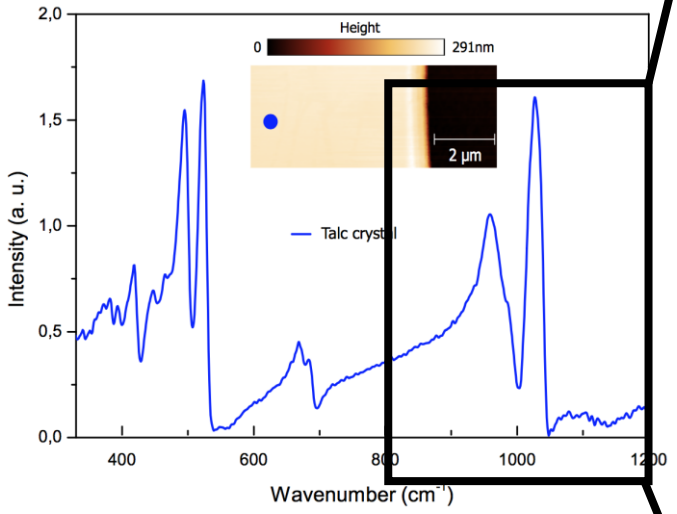
Broadband detection up to 30 μm (Ge:Cu detector)

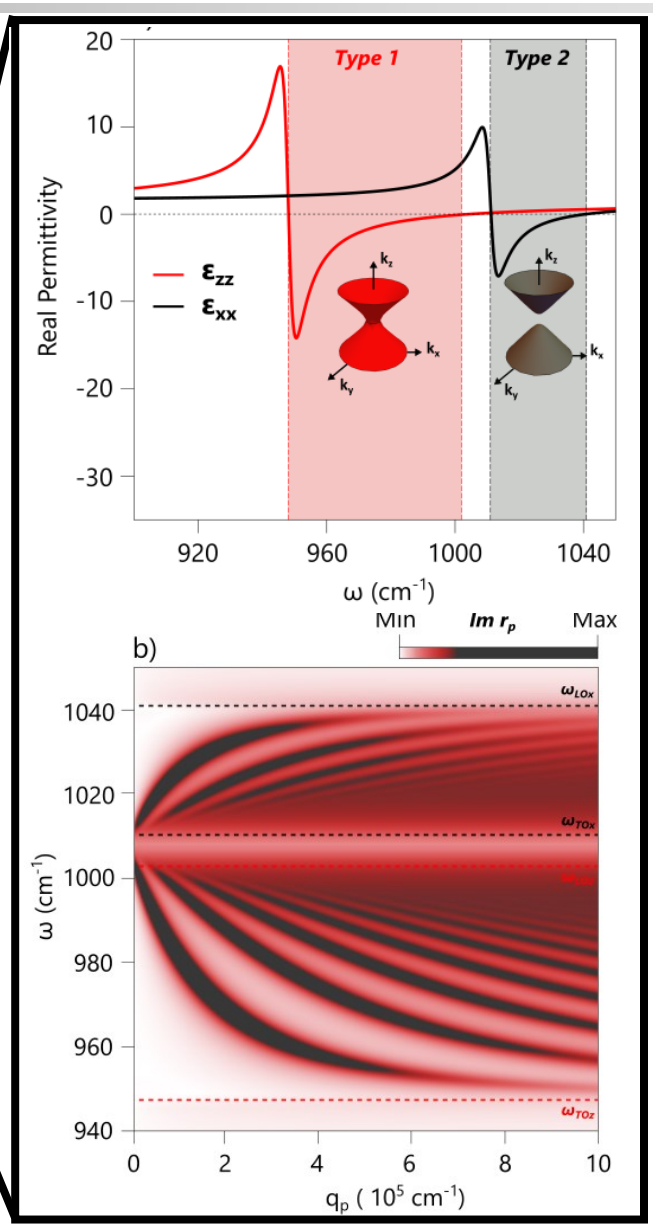
Novel 2D material

$Mg_3Si_4O_{10}(OH)_2$

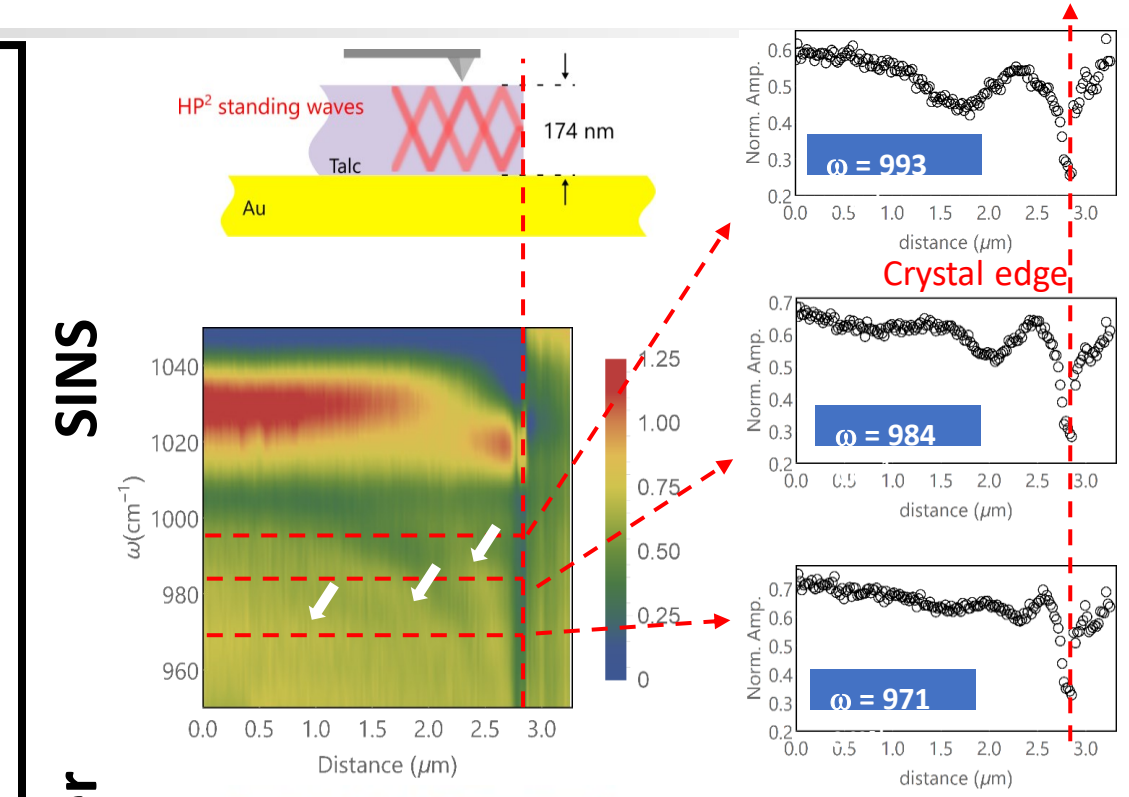




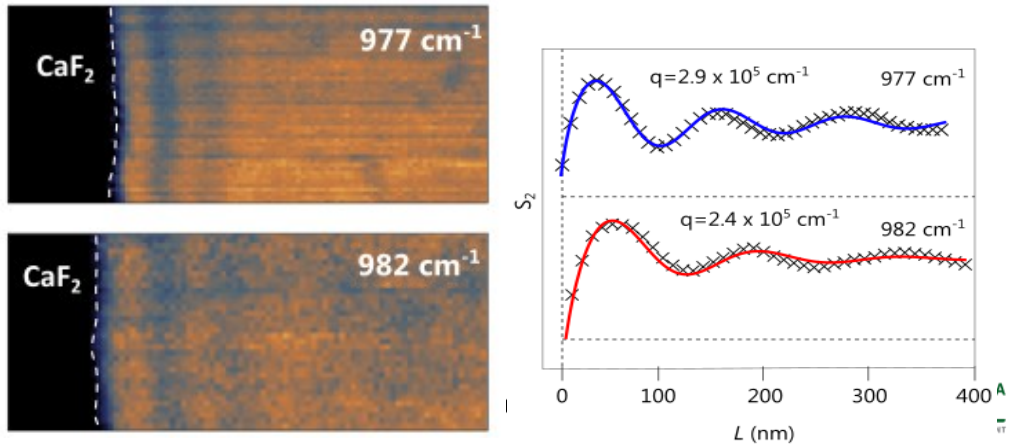




SINS



Narrowband laser

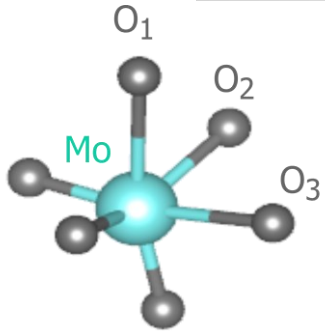


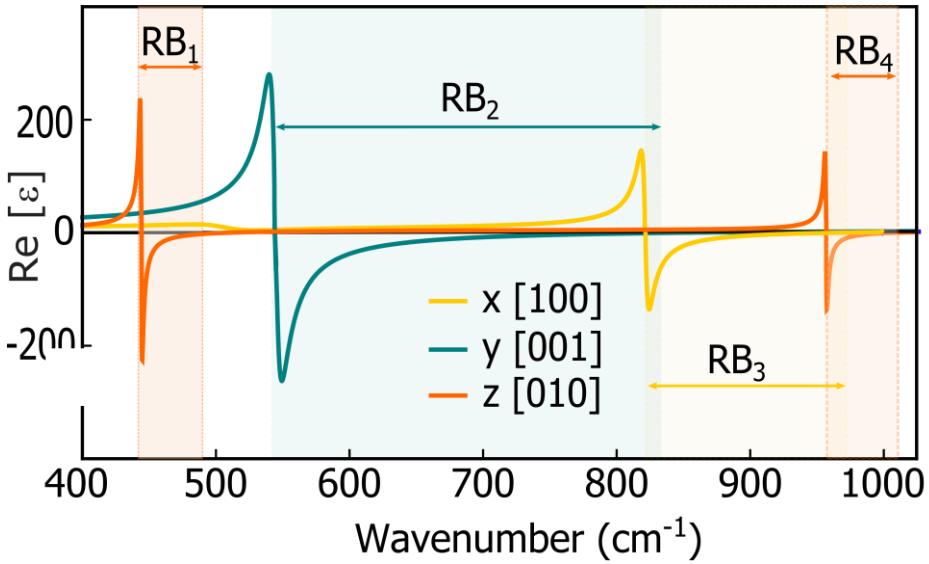
I. D. Barcelos, et al. TBP 2021

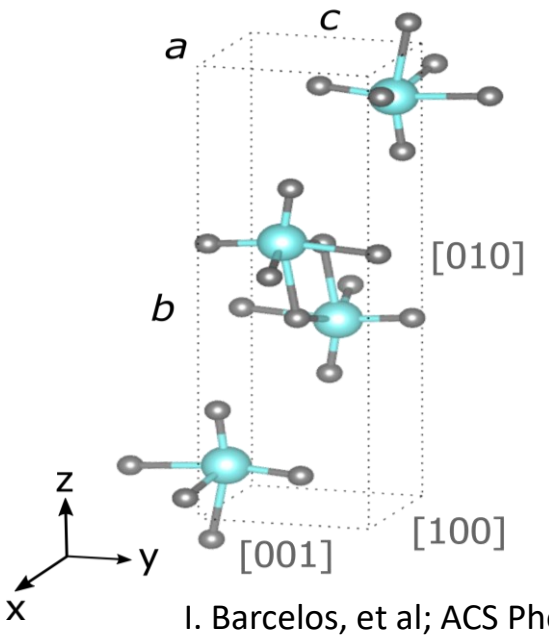
Ultrabroadband IR nanocavities of α-MoO_3

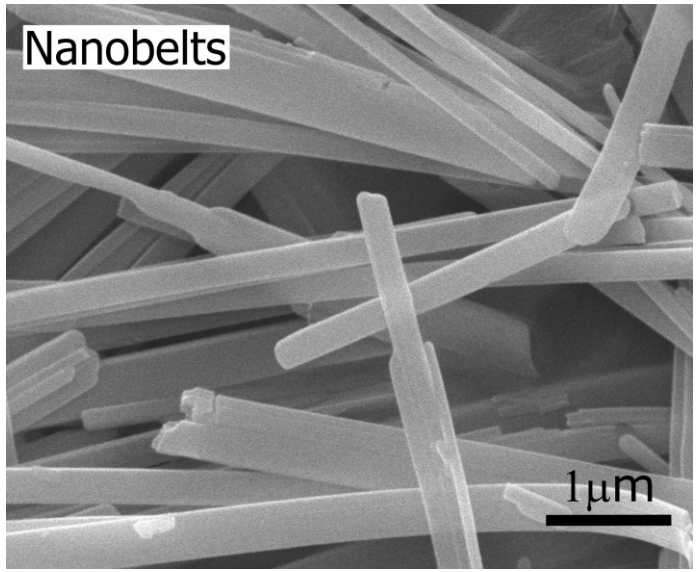
Hydrothermal method

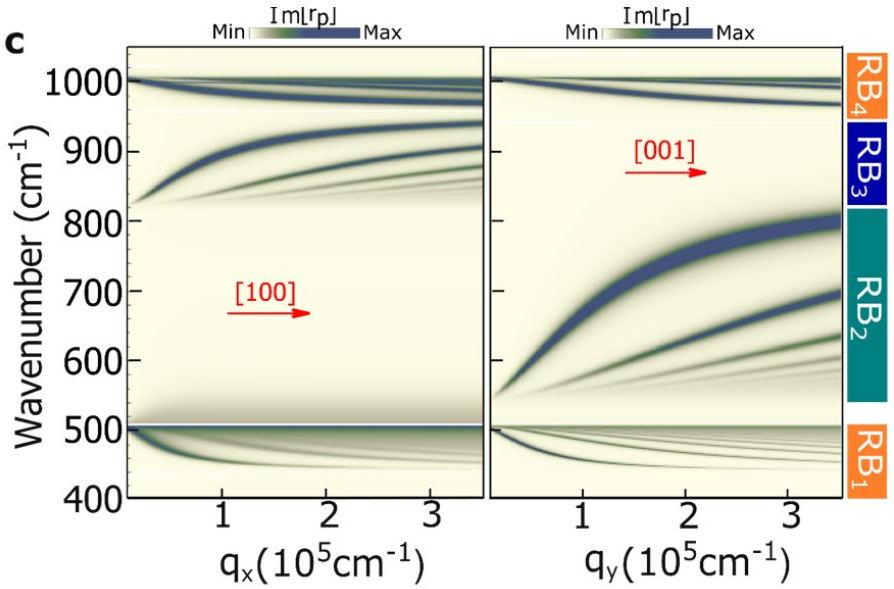
- $(NH_4)_6Mo_7O_{24}.4H_2O + HNO_3$
- Autoclave at 180 °C for 20h
- Washed with distilled water and ethanol
- Oven-dried at 70°C for 24h





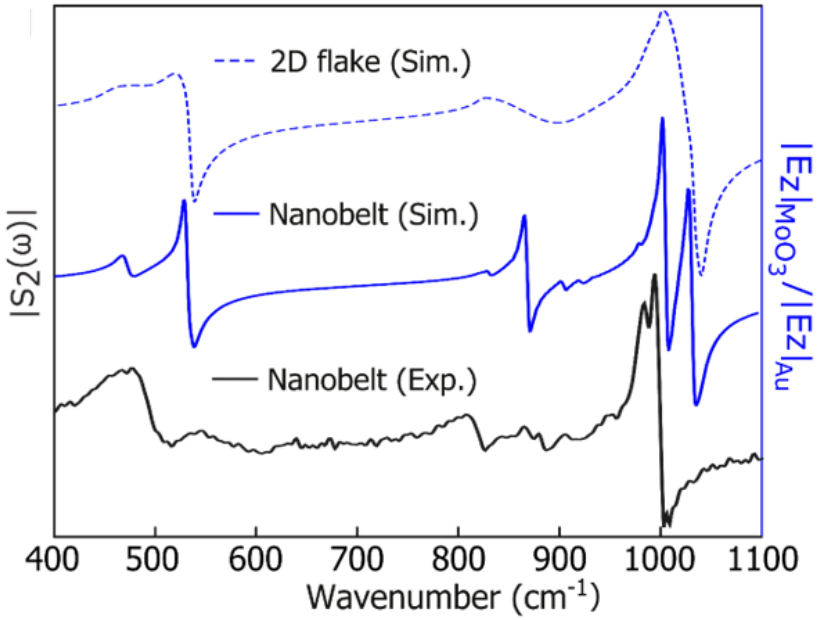


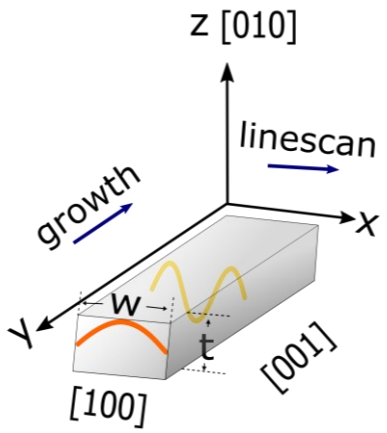


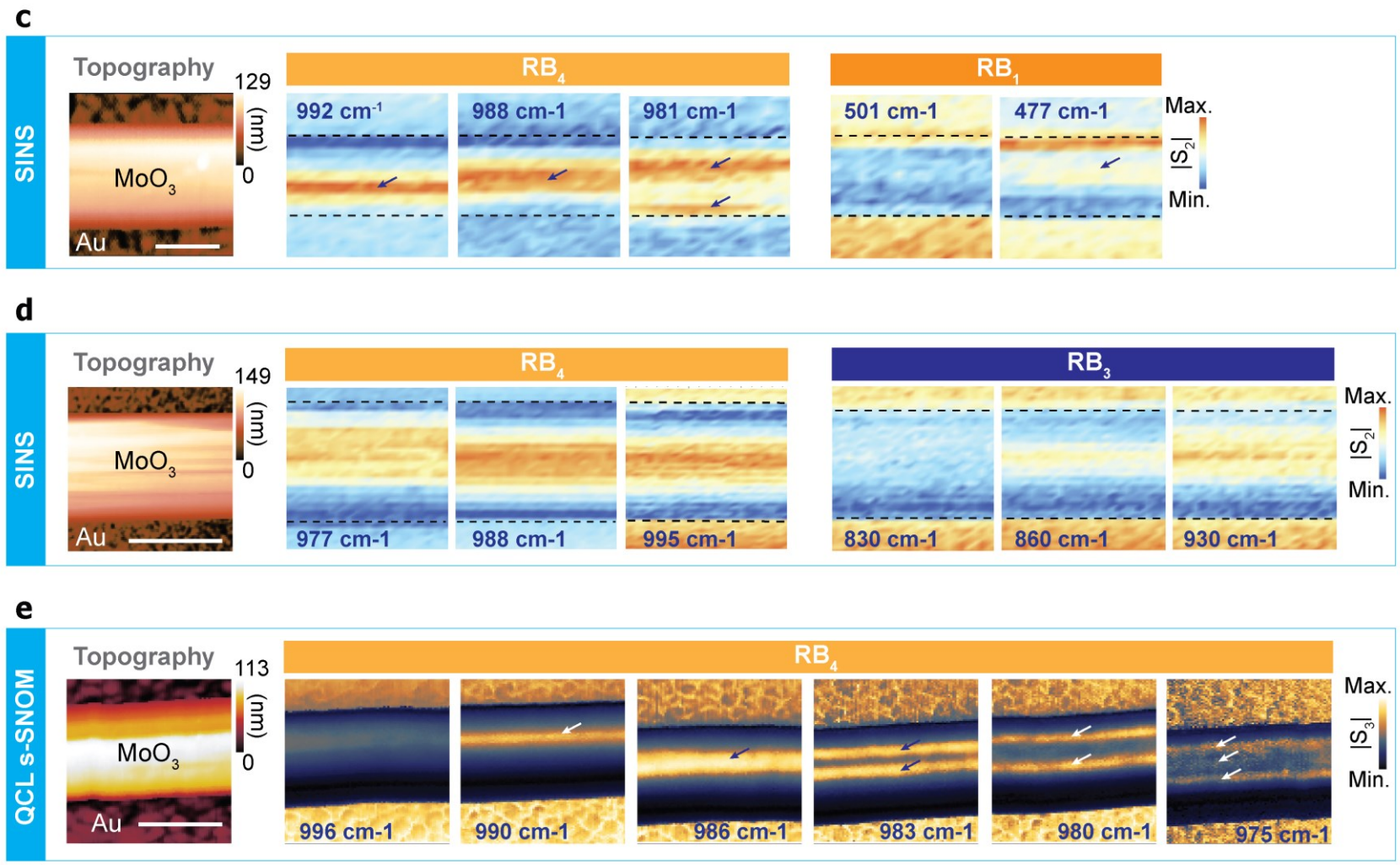


I. Barcelos, et al; ACS Photonics (2021)

Ultrabroadband IR nanocavities of α-MoO_3







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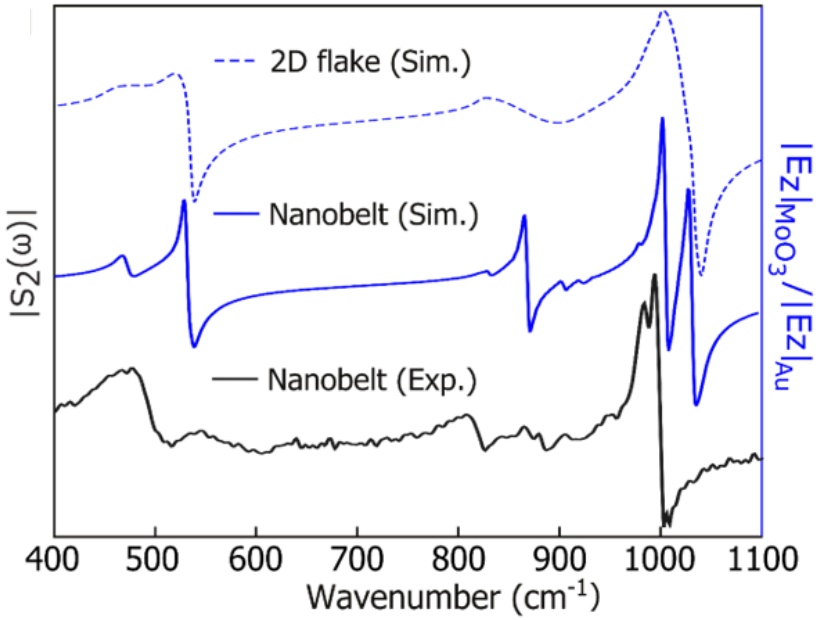
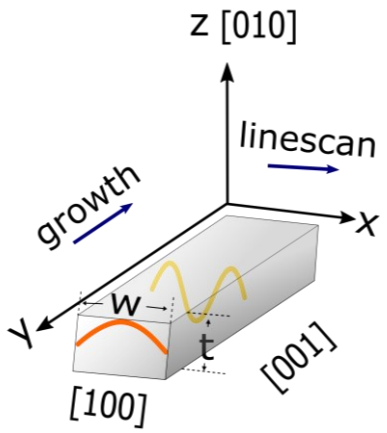
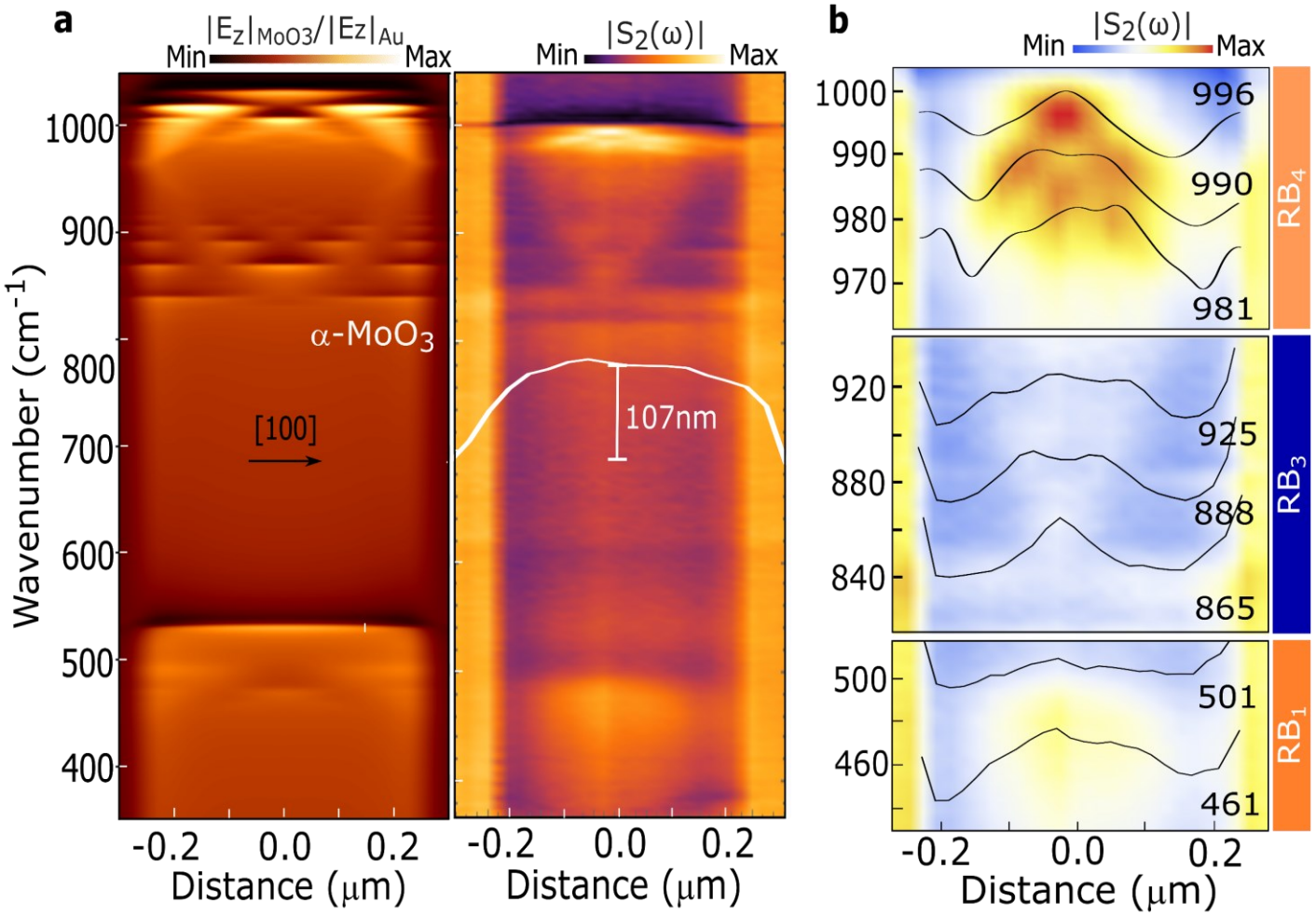
Ultrabroadband IR nanocavities of α-MoO_3



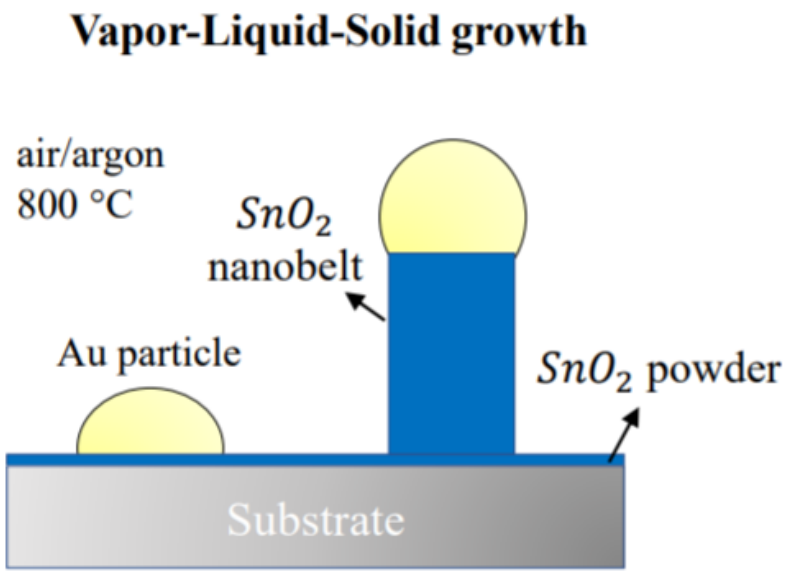


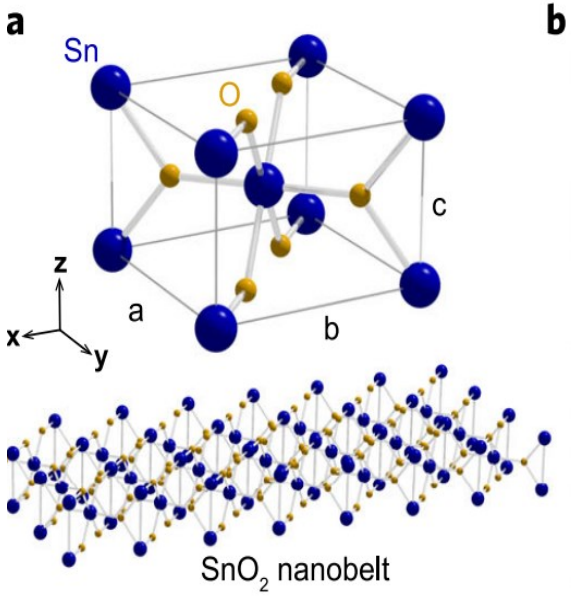
FDTD simulations **Experiment at the ALS**

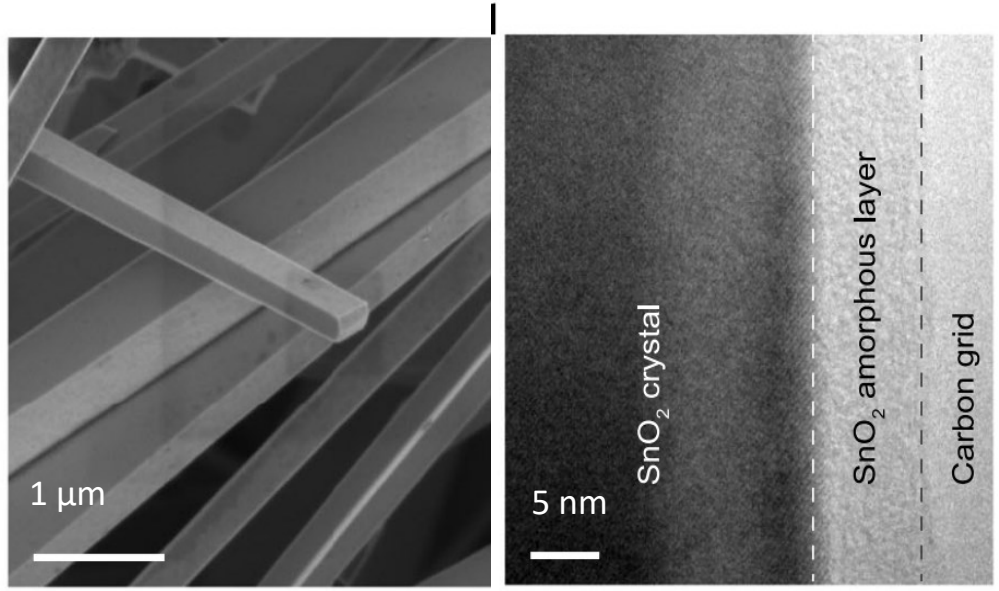


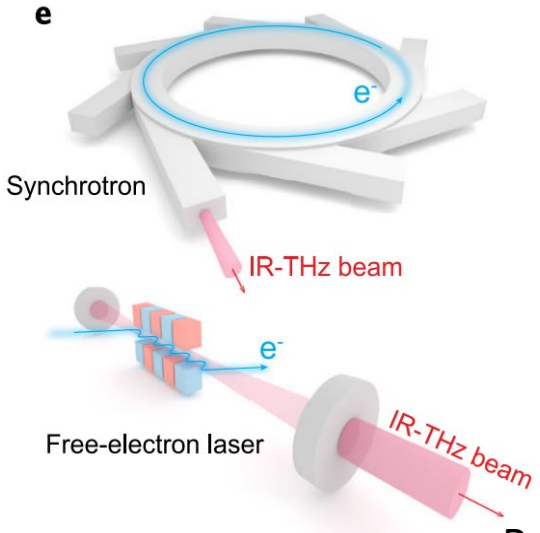
I. Barcelos, et al; ACS Photonics (2021)

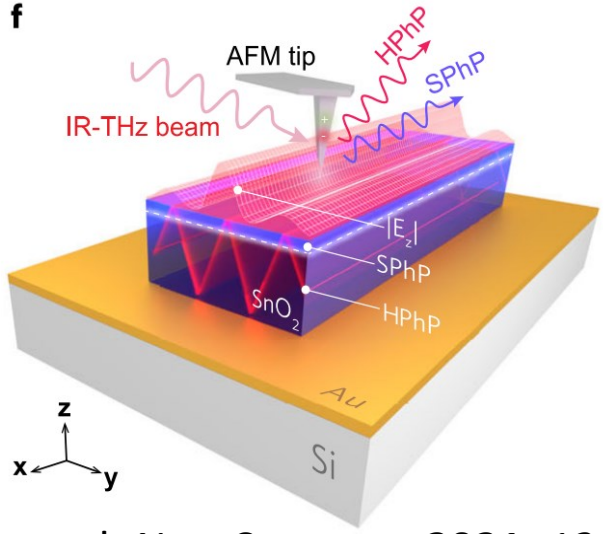
Tin oxide nanobelts for far-IR light handling

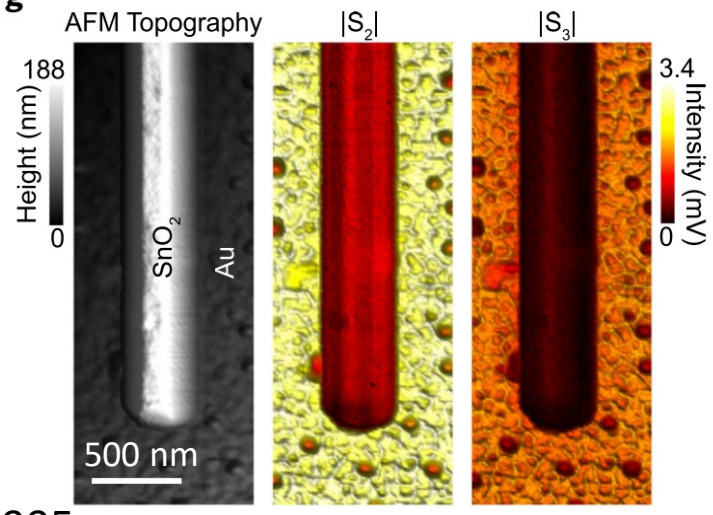












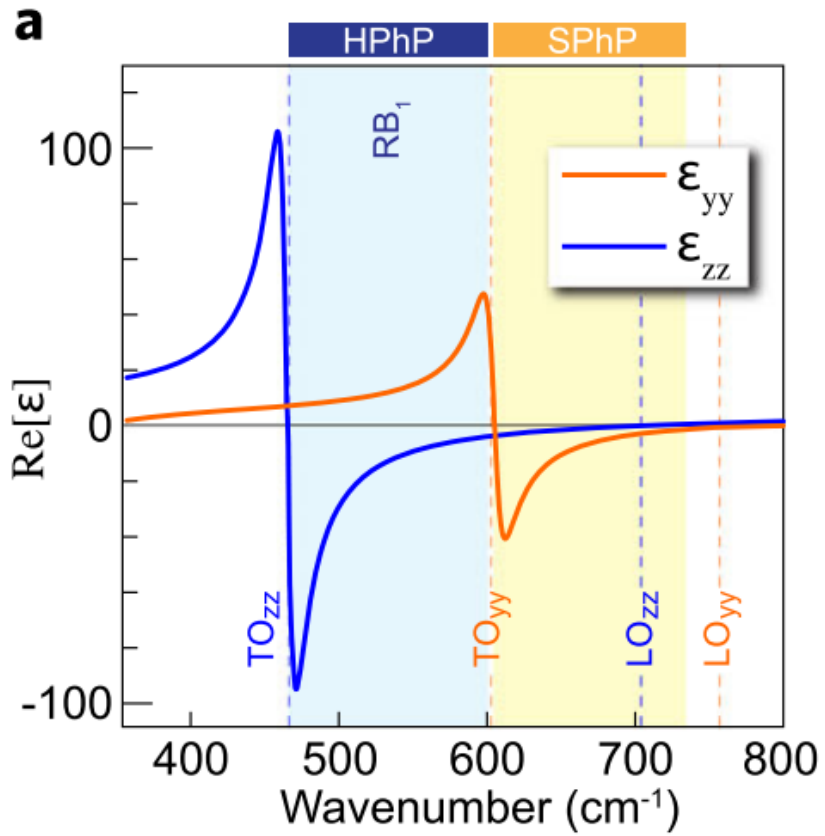
Collaboration LNLS-ALS-FELBE

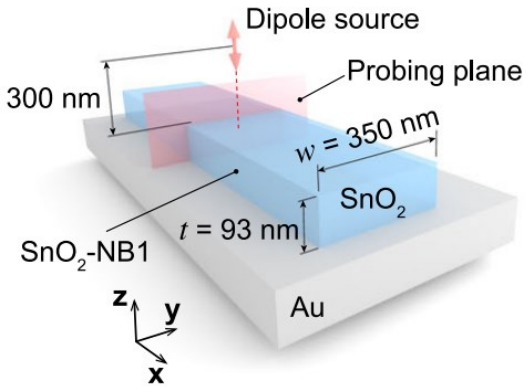
R. Feres et al. *Nat. Commun.* **2021**, *12*, 1995.

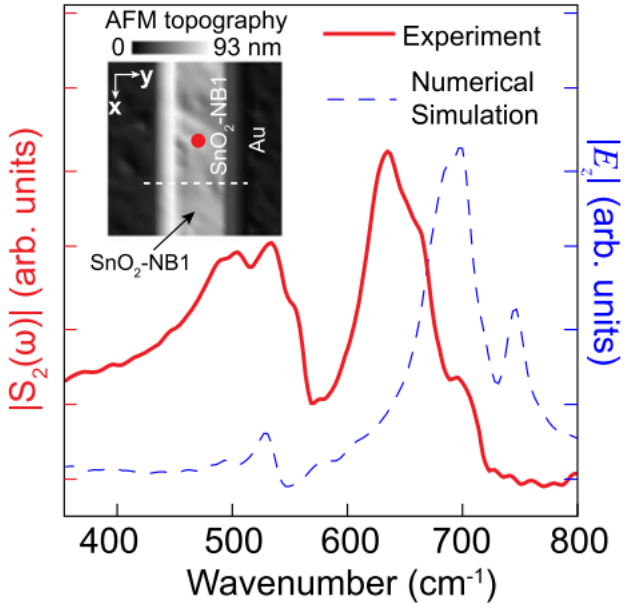
Tin oxide nanobelts for far-IR light handling

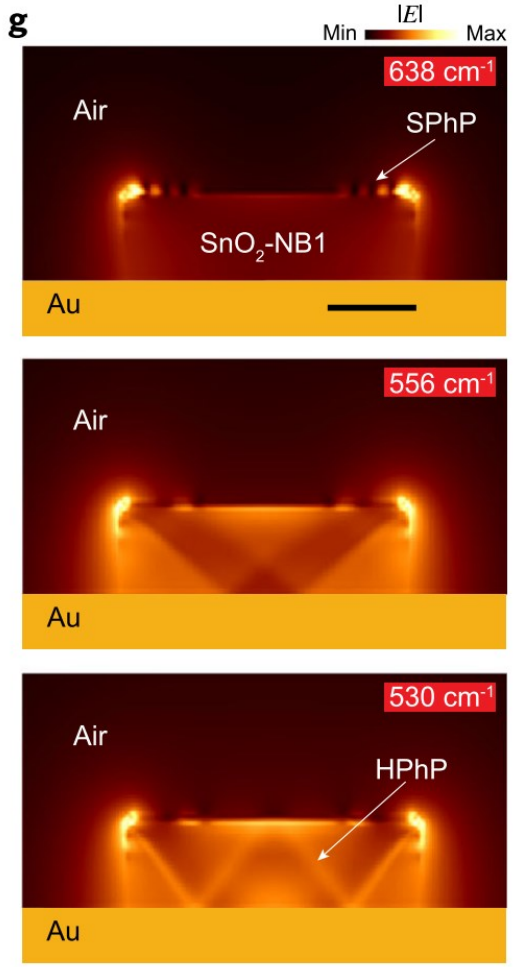
Far-IR nano-cavities

Surface and volume phonon-polaritons









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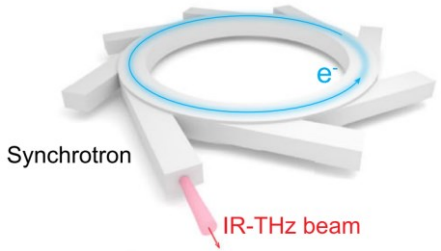
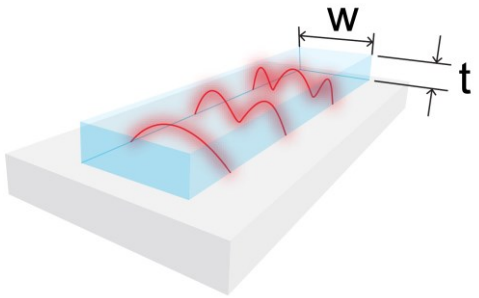
Tin oxide nanobelts for far-IR light handling

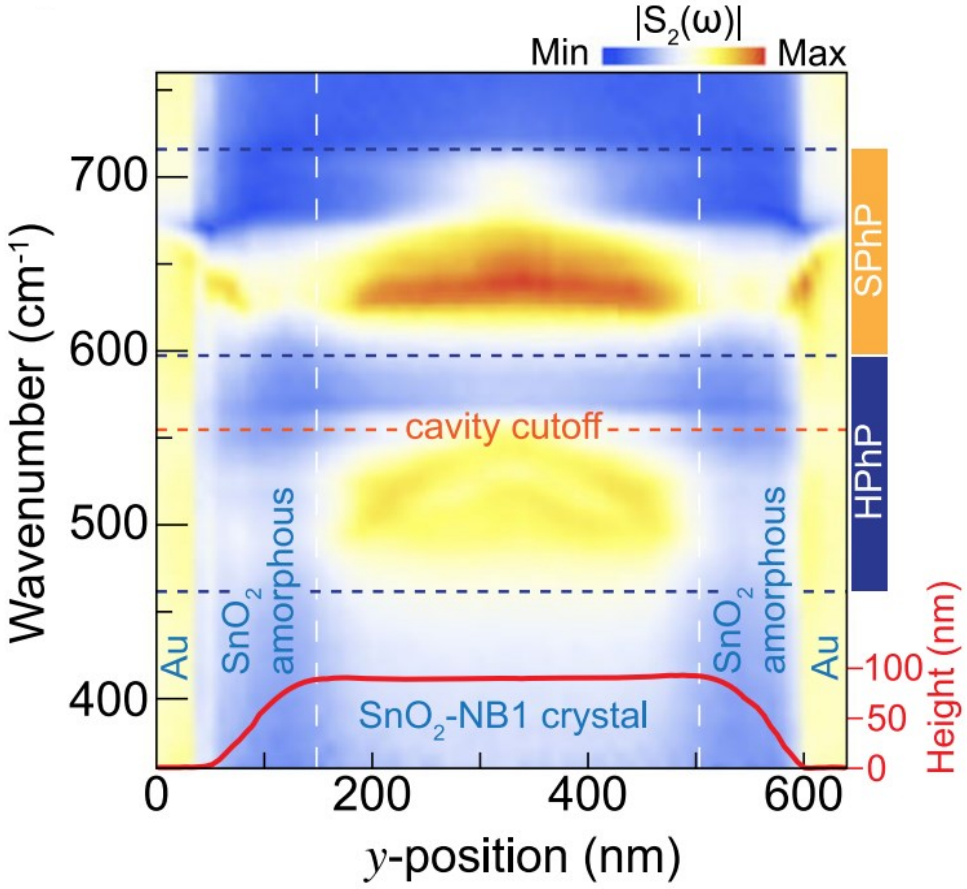
Far-IR nano-cavities

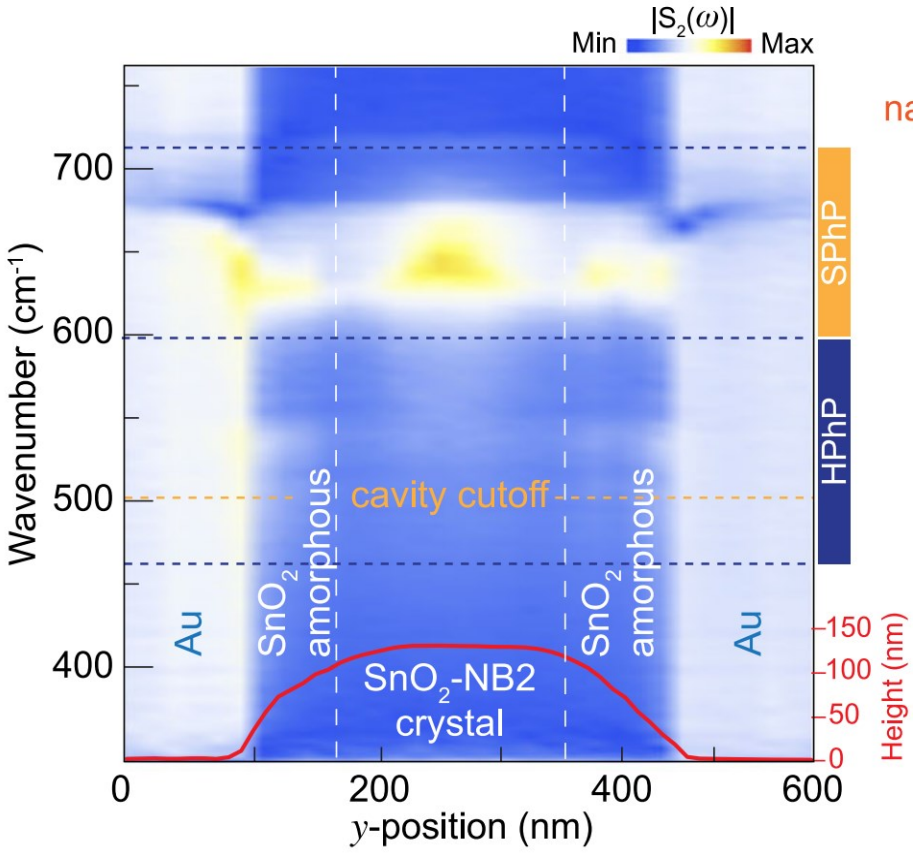


Fabry-Perot hypothesis



Far-IR broadband spectral linescans





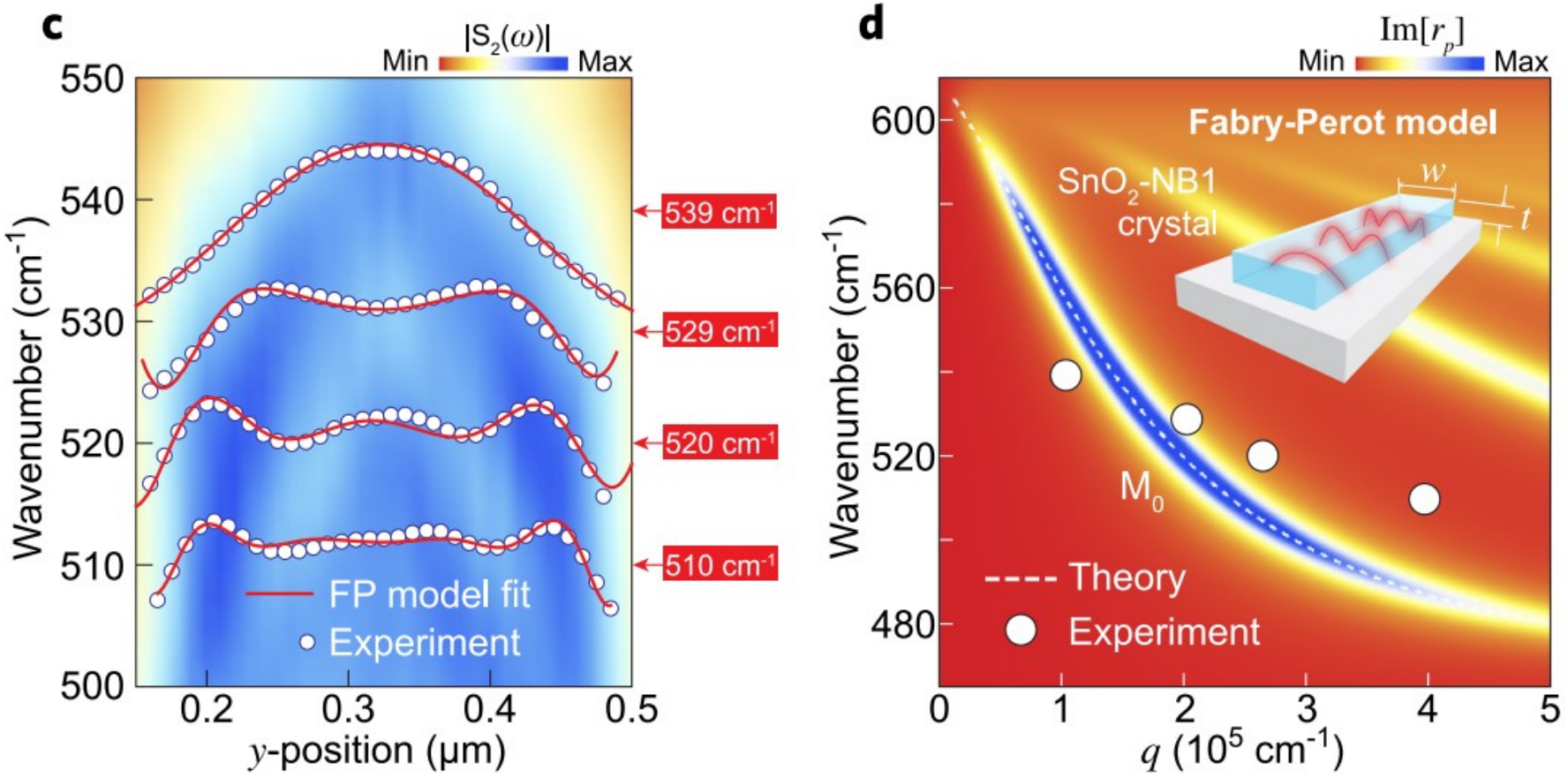
Collaboration LNLS-ALS-FELBE

R. Feres et al. *Nat. Commun.* **2021**, *12*, 1995.

Tin oxide nanobelts for far-IR light handling

Far-IR nano-cavities

Confirming the Fabry-Perot mechanism



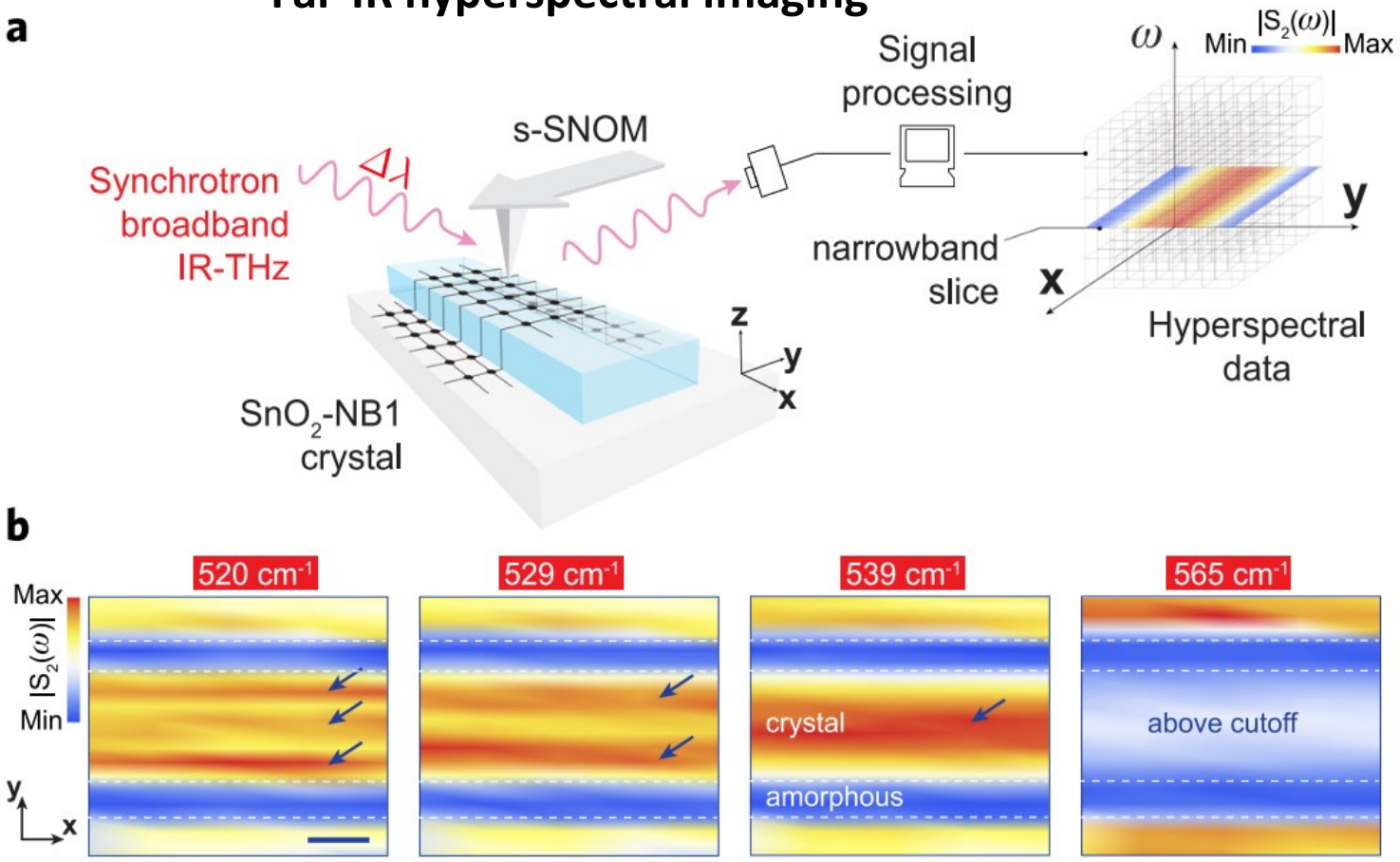
R. Feres et al. *Nat. Commun.* **2021**, *12*, 1995.

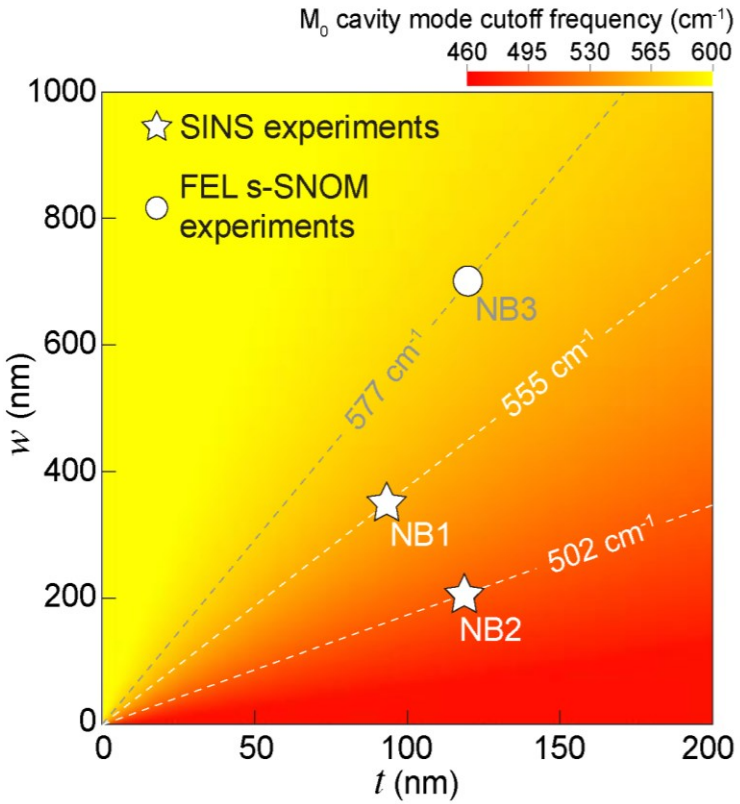
Collaboration LNLS-ALS-FELBE

Tin oxide nanobelts for far-IR light handling

Far-IR nano-cavities

Far-IR hyperspectral imaging





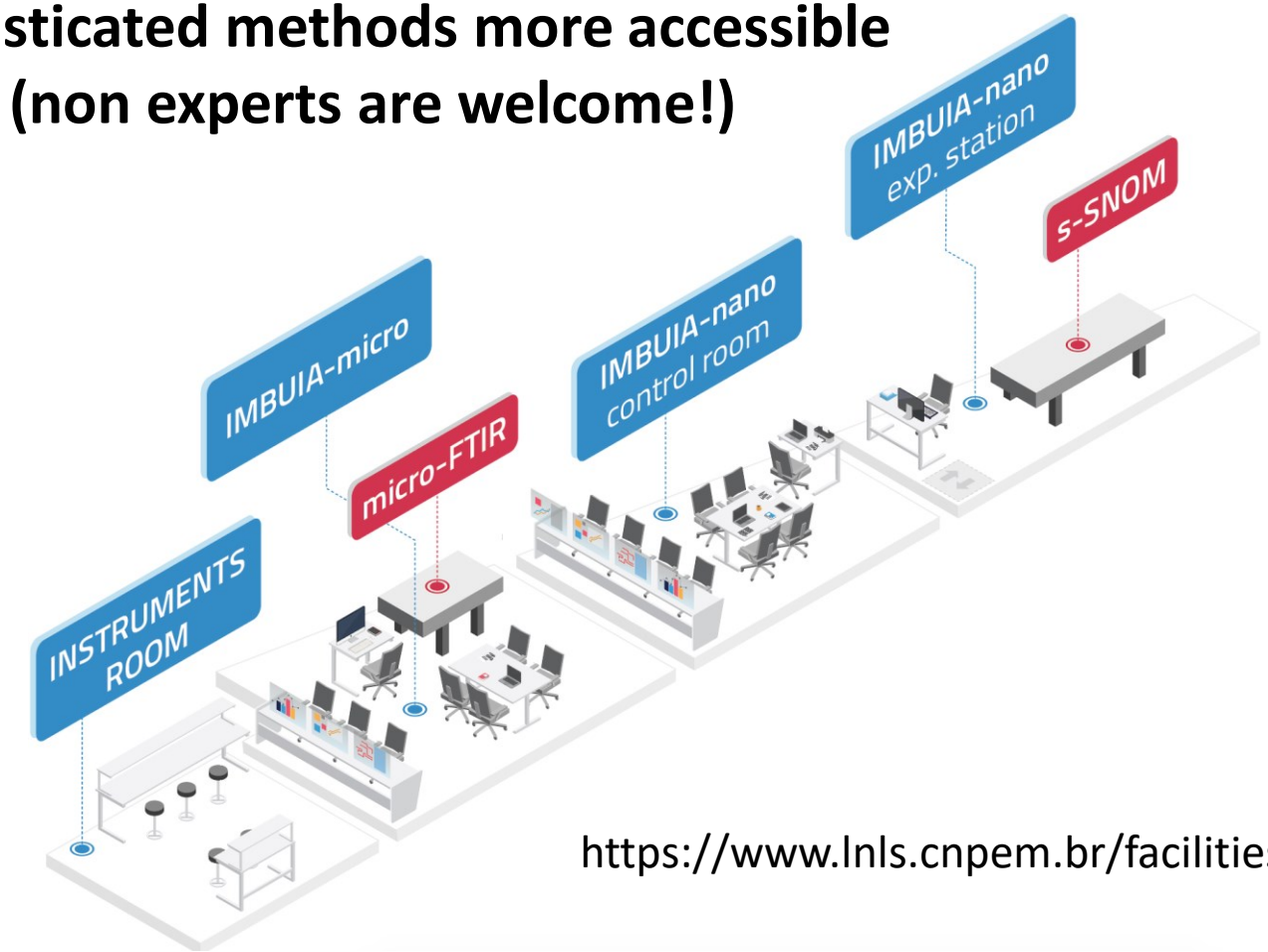
- Hyperbolic medium suitable for multimode polaritons in the mid- to far-IR frequency ranges.

R. Feres et al. *Nat. Commun.* **2021**, *12*, 1995.

Synchrotron Infrared Sources: are they good for your IR research?

A unique source (far-IR continuous coverage)

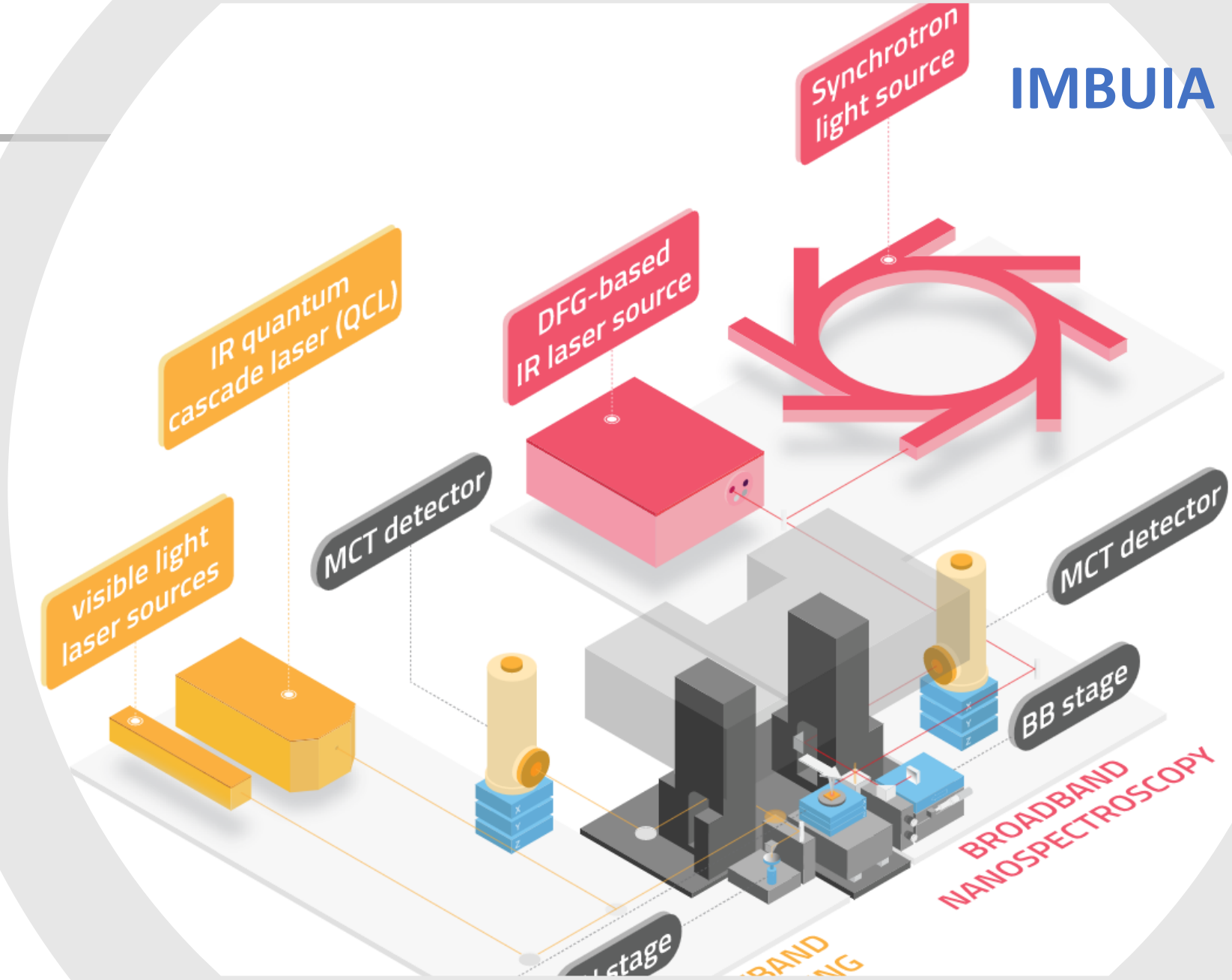
Sophisticated methods more accessible (non experts are welcome!)



- Service for users throughout the whole process:
  - samples preparation
  - Experimental support
  - Post-processing guidance
  - Open for collaborating

https://www.lnls.cnpem.br/facilities/imbuia/

IMBUIA beamline status



https://www.lnls.cnpem.br/facilities/imbuia/

Thank you!

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Alisson R. Cadore
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Emilson Viana
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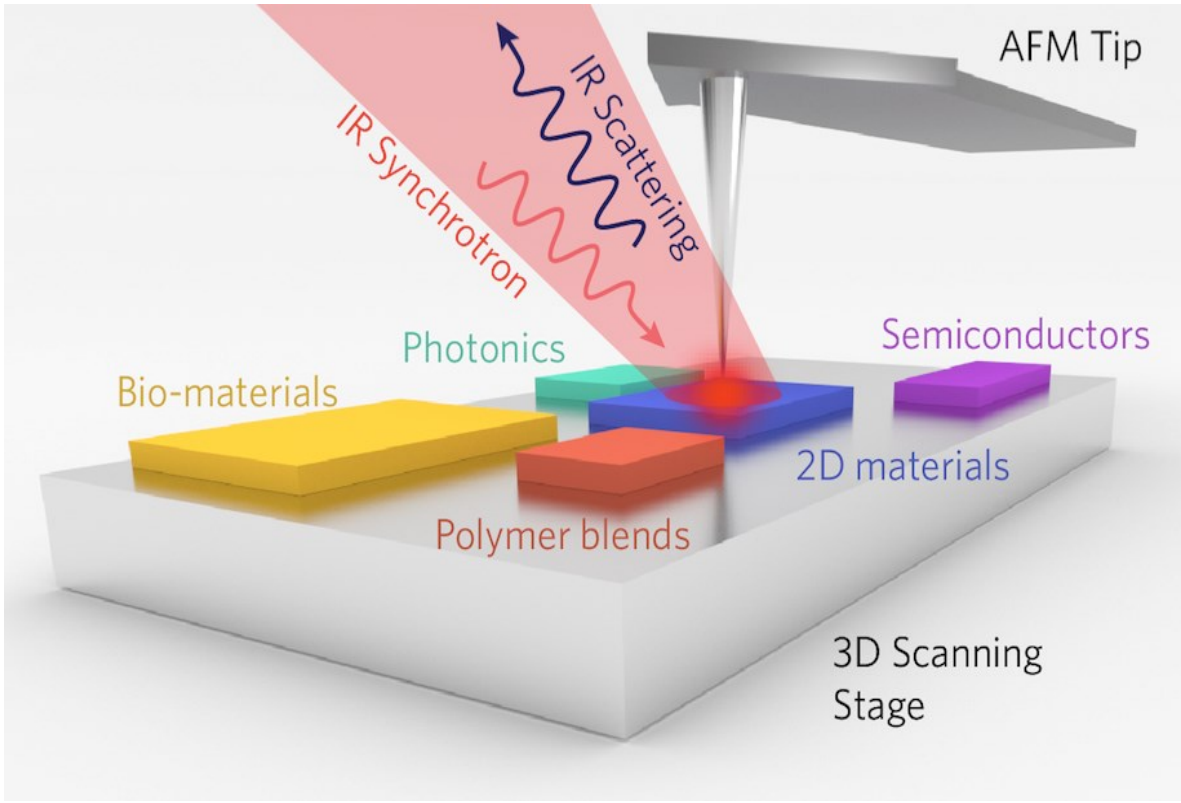

https://www.lnls.cnpem.br/facilities/imbuia/

Funding and Institutions:

FAPESP CNPq CAPES CNPEM Centro Nacional de Pesquisa em Energia e Materiais INCT National Institute of Science and Technology Carbon Nanomaterials

Technical Support

nea spec see the nanoworld BRASIL

Thank you!

Ingrid.barcelos@lnls.br

CNPEM

MINISTRY OF SCIENCE, TECHNOLOGY AND INNOVATIONS

PÁTRIA AMADA BRASIL
BRAZILIAN GOVERNMENT

Funding:

FAPESP

CNPq
Conselho Nacional de Desenvolvimento Científico e Tecnológico

CAPES

INCT
National Institute of Science and Technology
Carbon Nanomaterials

Technical Support

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Facility updates

IMBUIA beamline status

Project schedule

IMBUIA-micro

Beamline primary

IR source

Q1 - 2021
Acomplish design

Q2 - 2021
Instalation of front-end and external optics

Q3 - 2021
M1 instalation and start commissioning with SR IR

Q4 - 2021
Commissioning

Q1 - 2022
End comissioning + remote proposals

Q1 - 2022
Remote proposals