LABORATORY OF PHOTONICS AND BIOPHOTONICS

DF-UFPE

www.ufpe.br/df

O que é NANOFOTÔNICA?

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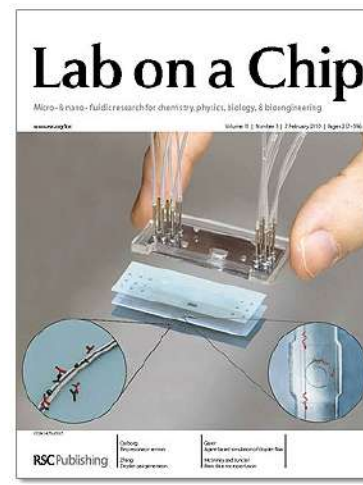
Laboratório de Fotônica e Biofotônica

Departamento de Física e PPG Odontologia

Universidade Federal de Pernambuco

PPG Ciências dos Materiais, UNIVASF



19/agosto/2020

O que é…………..

Nanofotônica

ou Nanoóptica

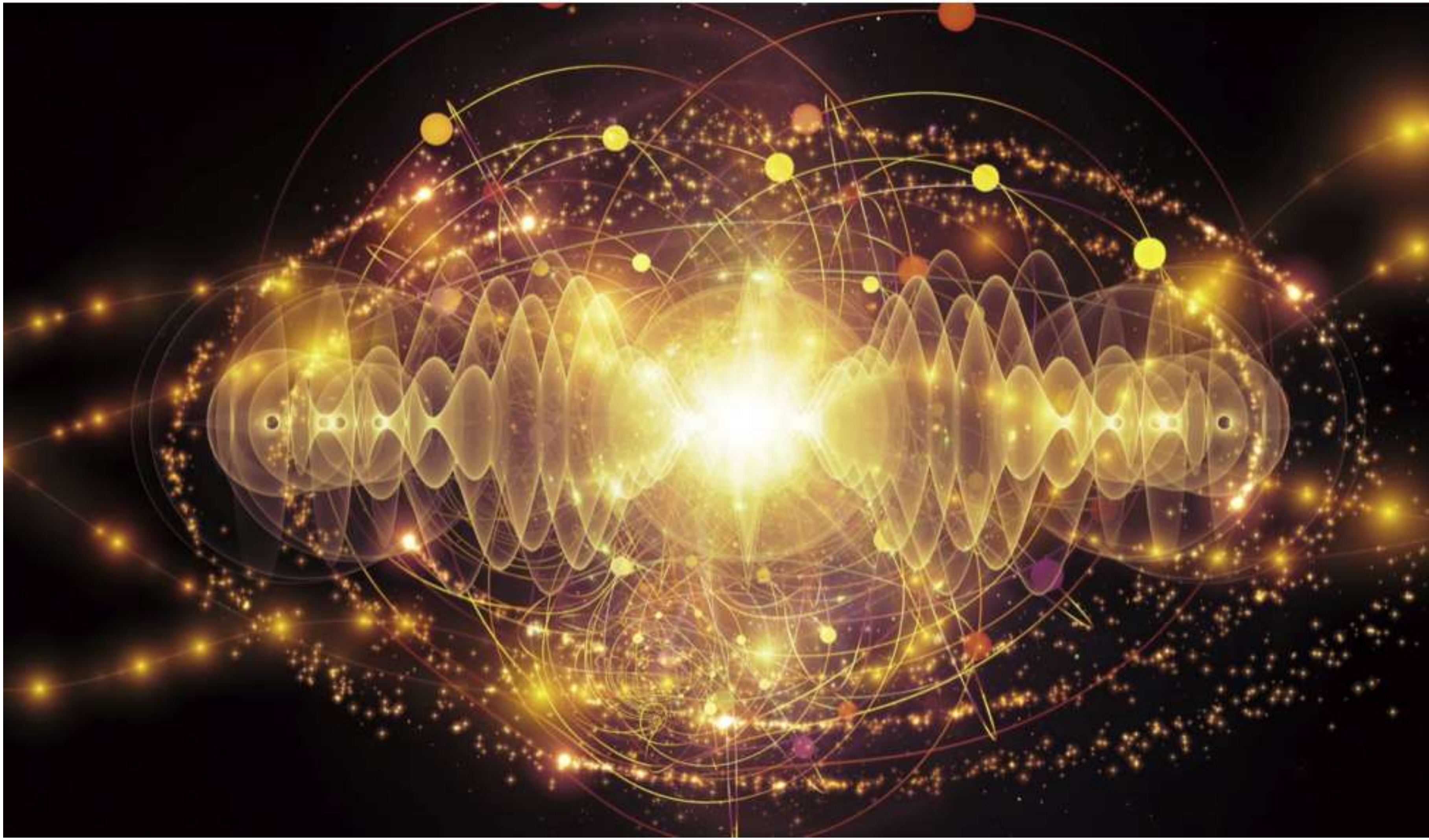
Fotons

Fotônica

A **fotônica** é a ciência da geração, emissão, transmissão, modulação, processamento, amplificação e detecção da **luz**.

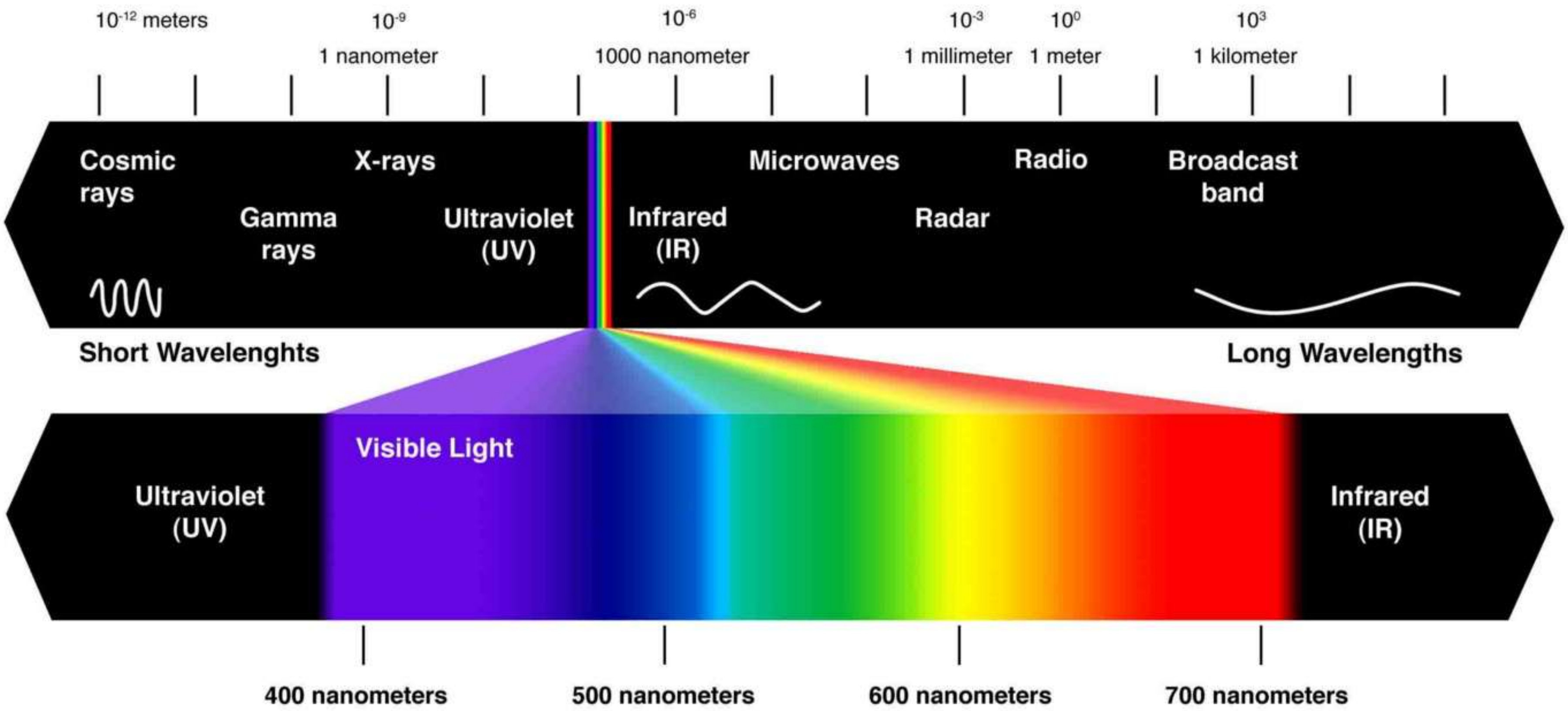
Óptica

Adaptado de: https://medium.com/@hannah.lgbhan/an-introduction-to-nanophotonics-dff86b045565



Adaptado de: https://medium.com/@hannah.lgbhan/an-introduction-to-nanophotonics-dff86b045565

O Espectro Eletromagnético

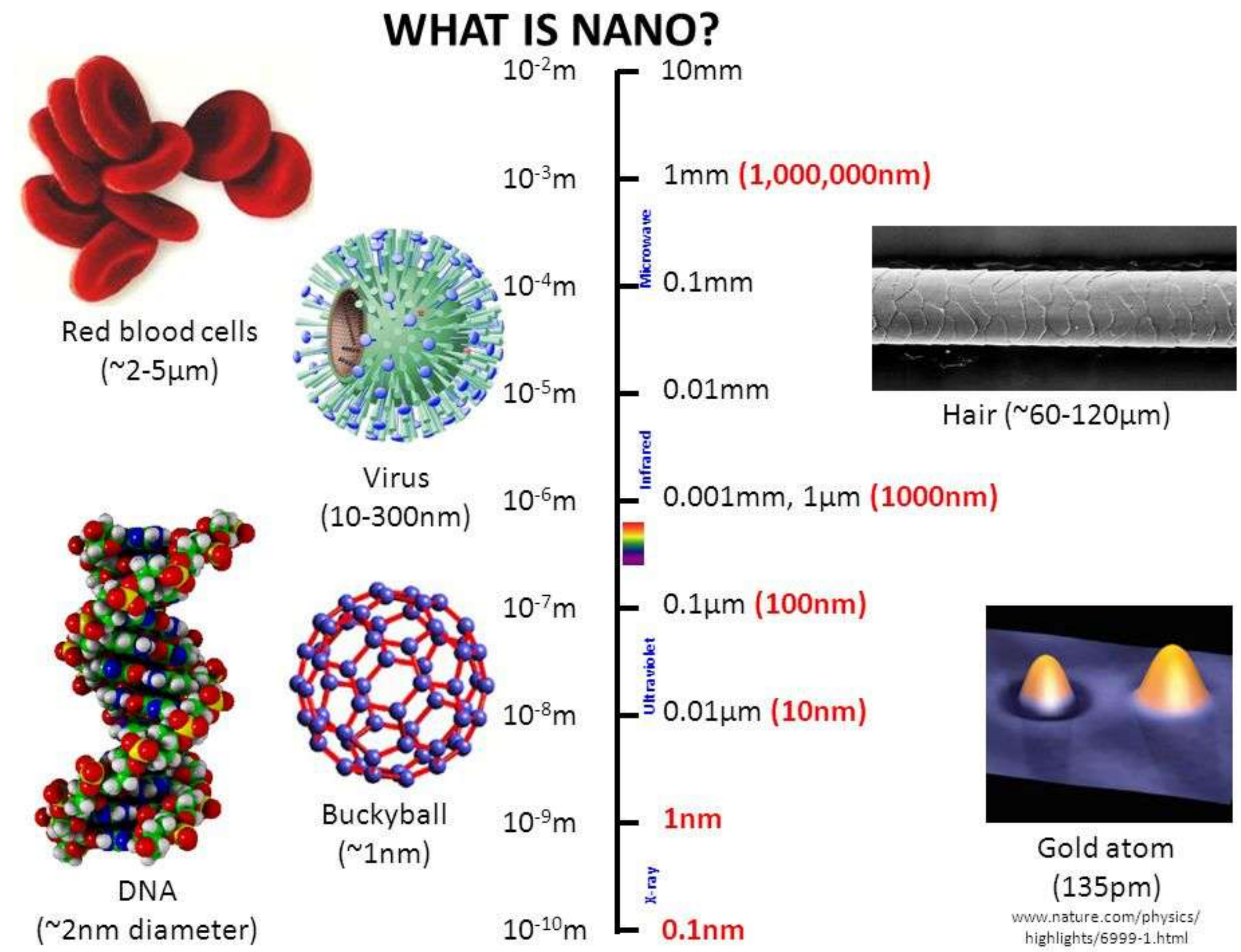


Luz é uma forma de radiação eletromagnética cuja frequência é visível ao olho humano.

Adaptado de: https://medium.com/@hannah.lgbhan/an-introduction-to-nanophotonics-dff86b045565

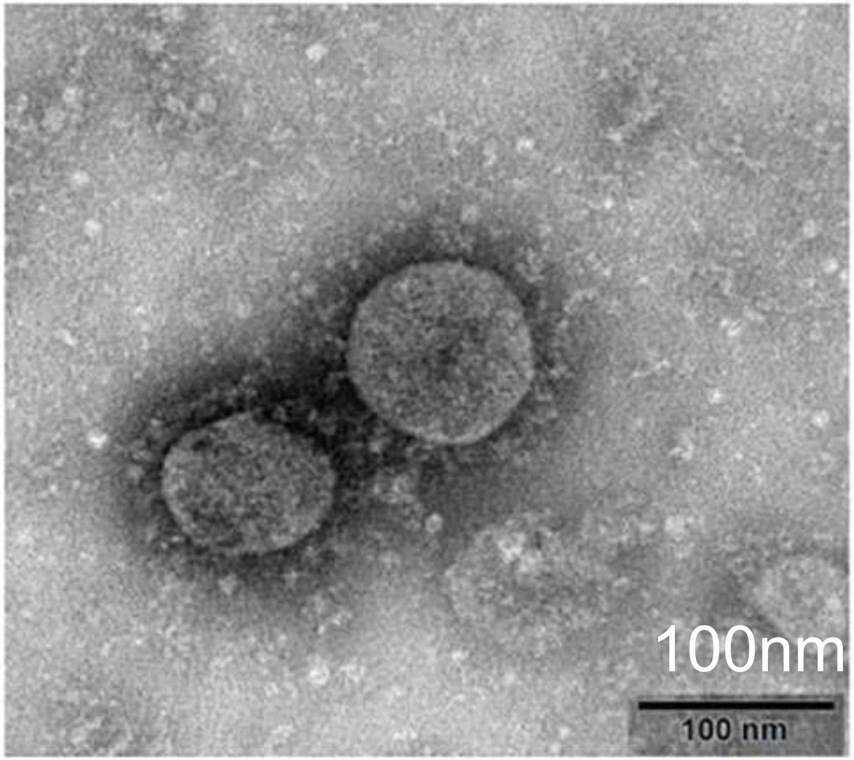
Nanociências e Nanotecnologias

E nano?



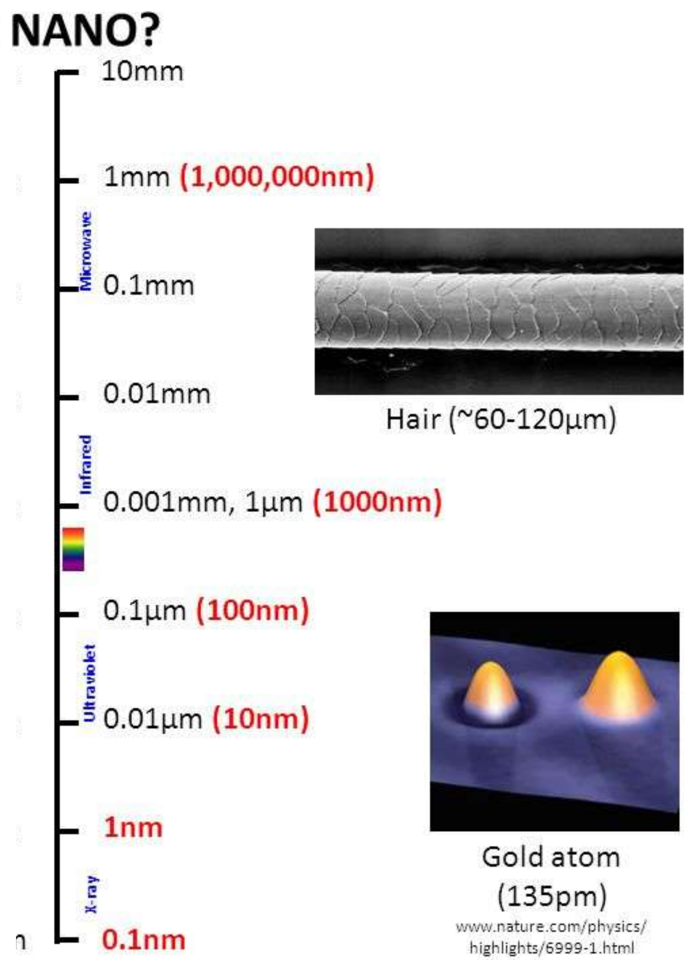
http://www.enteknomaterials.com/nano-malzemeler/nano-malzemeler-5

Nanociências e Nanotecnologias



Coronavirus (SARS-CoV-2)

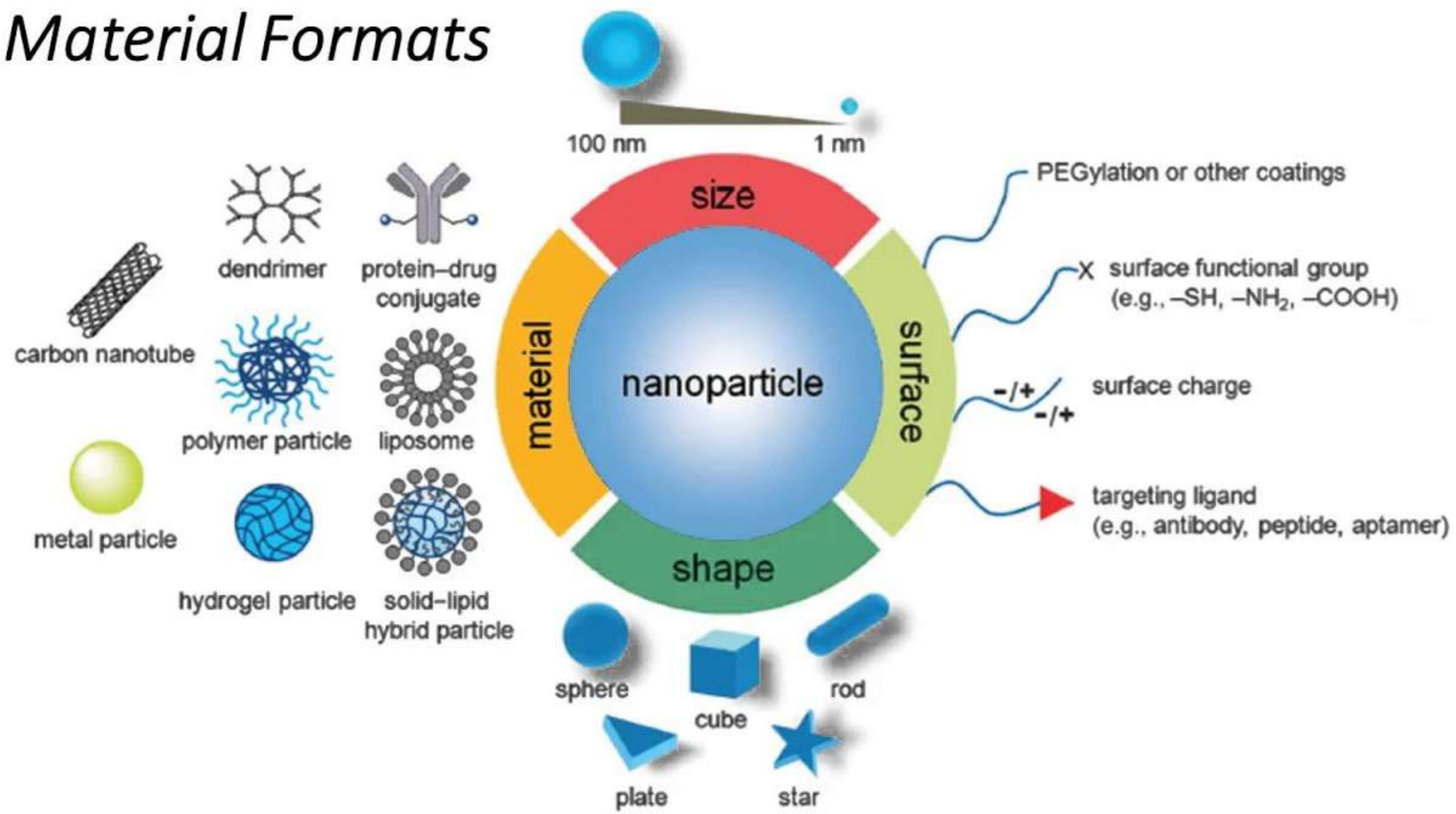
Source: Chinese Center for Disease Control and Prevention



http://www.enteknomaterials.com/nano-malzemeler/nano-malzemeler-5

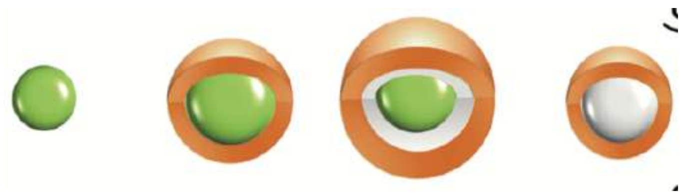
E nano?

Nanociências e Nanotecnologias



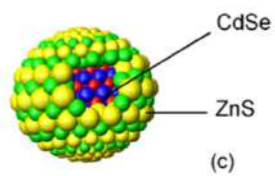
Mundo de Nanomateriais

Ions de terras raras



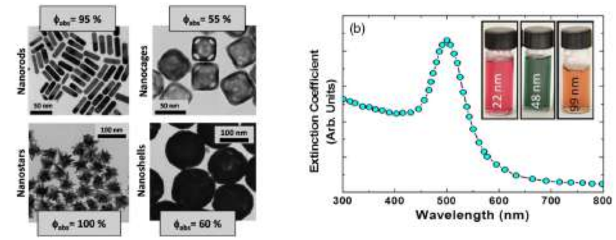
Lukasz Marciniak et al,
Nanoscale, 2017, 9, 8288

Pontos Quânticos



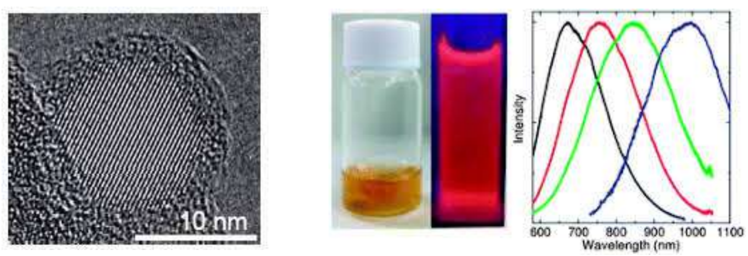
Leandro P. Alves et al,
J. of Dentistry 38 (2010) 149–152

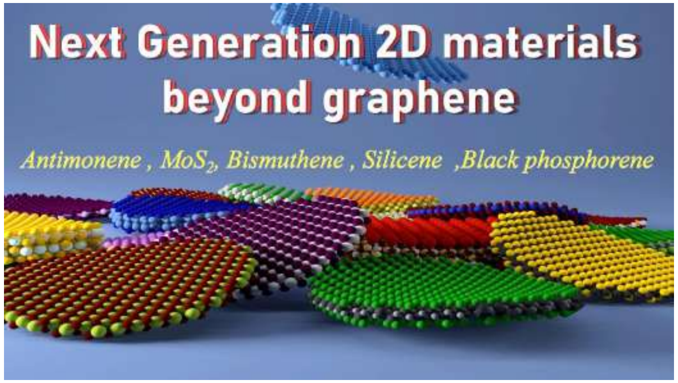
NP metálicas



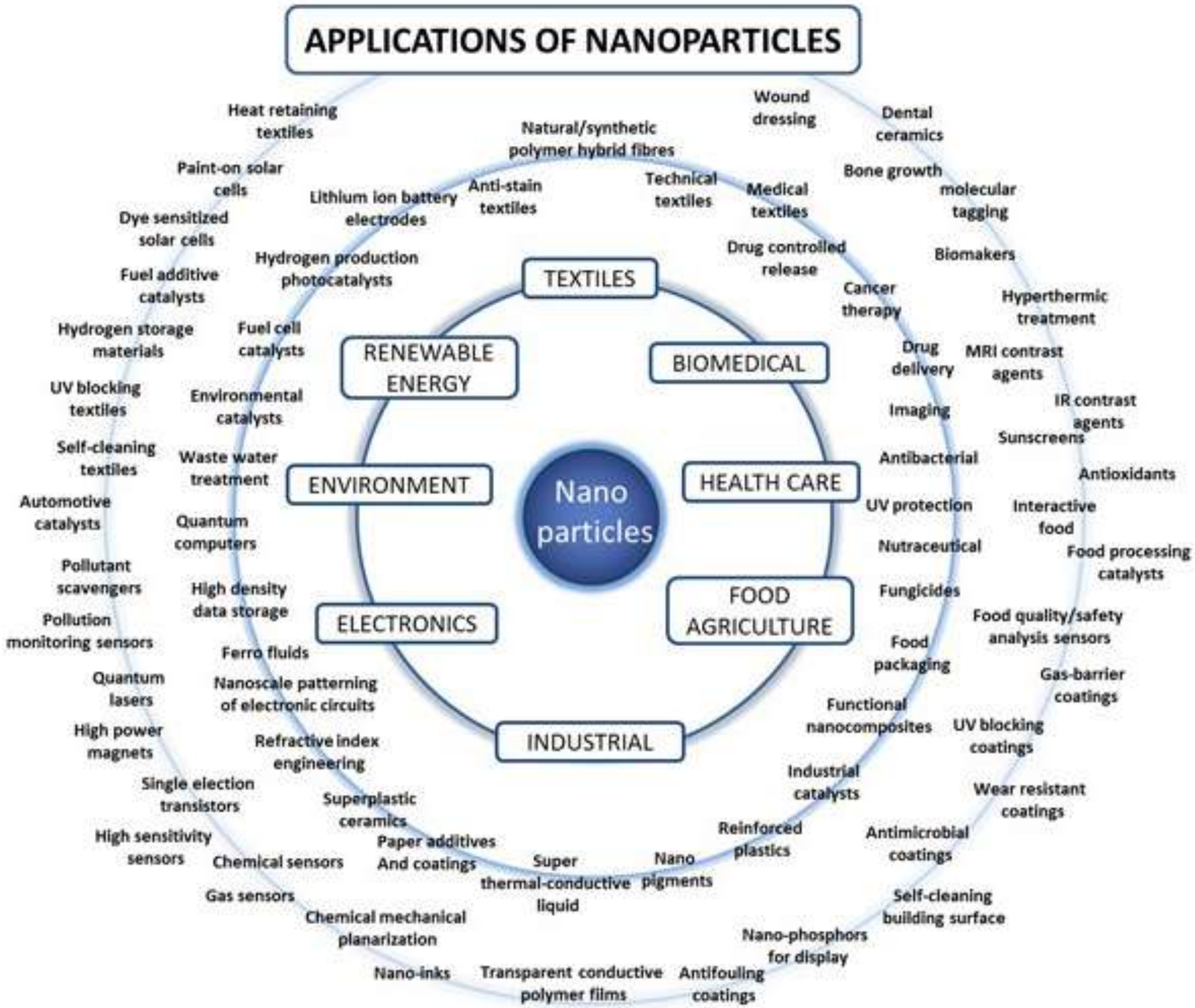
D. Jaque et al,
Adv in Opt and Photon. 8, 1 (2016)

QD de Silício





Nanociências e Nanotecnologias



Fotônica

Nanotecnologia

Nanofotônica

↓

Nanobiofotônica

↑

Biofotônica

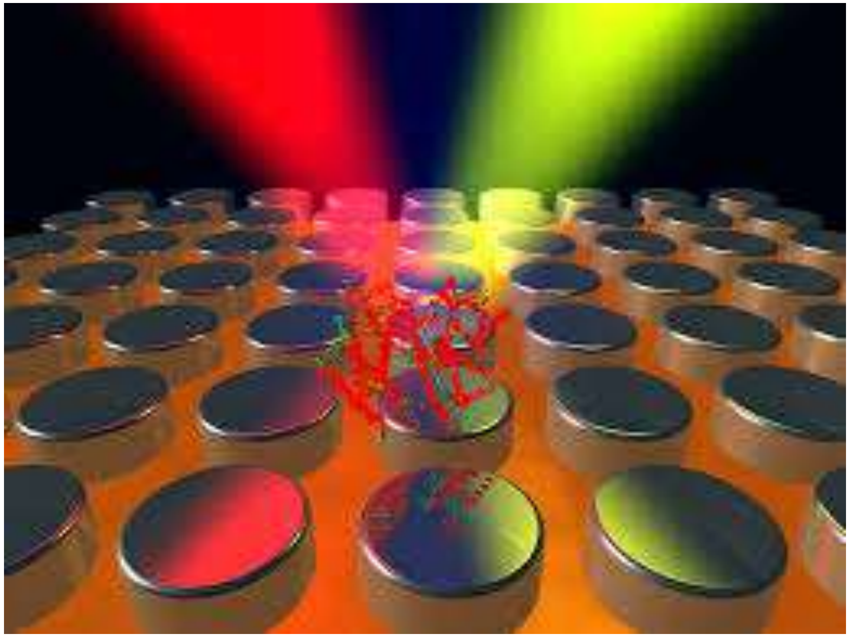
Fotônica

Biomedicina, Biociências...

.........é a área de convergência da pesquisa e aplicações da FOTÔNICA com as áreas BIO......

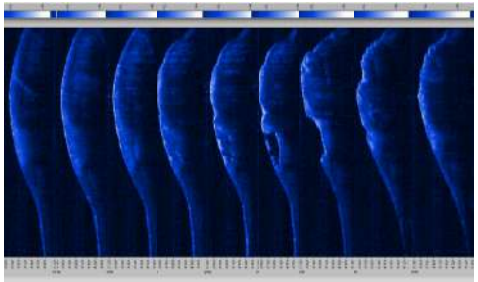
O que é nanofotônica?

É o estudo do *comportamento da luz em escala nanométrica*, e de *sua interação com objetos em escala nanométrica.*

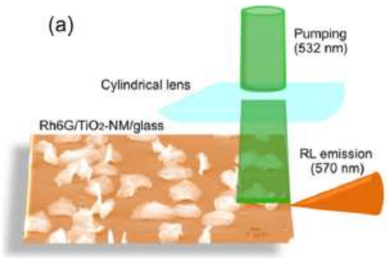


Laboratory of Photonics and Biophotonics
Research and Educational Activities
@ LPB, Physics Department, UFPE, Brazil

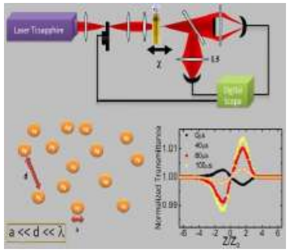
Biophotonics



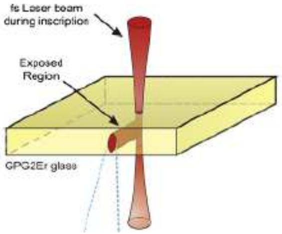
Nanophotonics

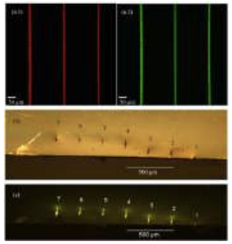


Nonlinear Optics



Photonics Devices



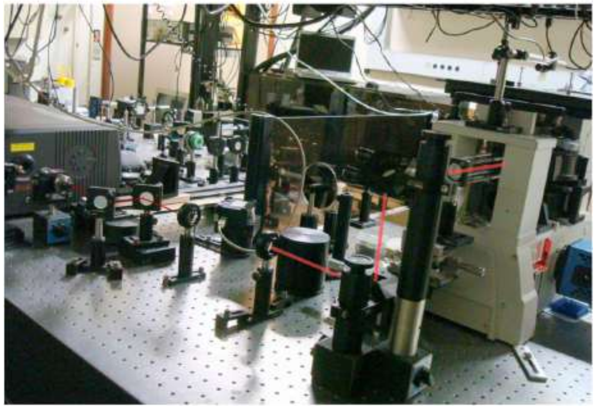


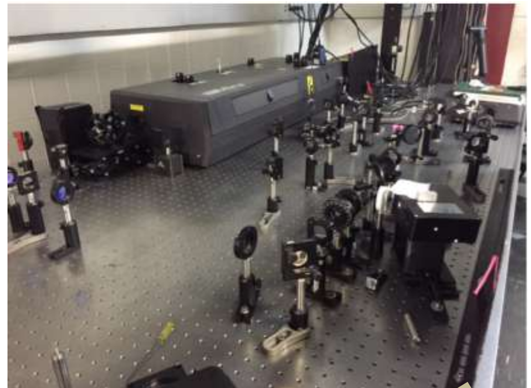
Educational Activities

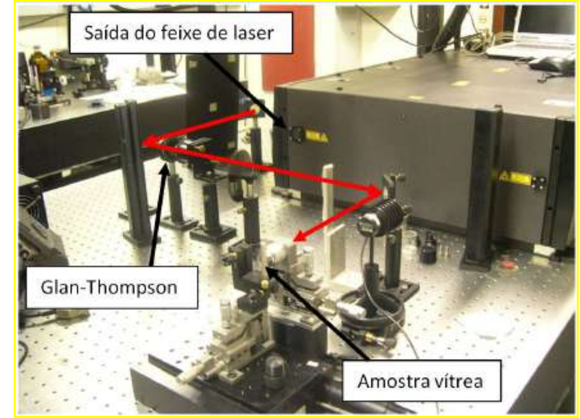
LPB

Biofotônica

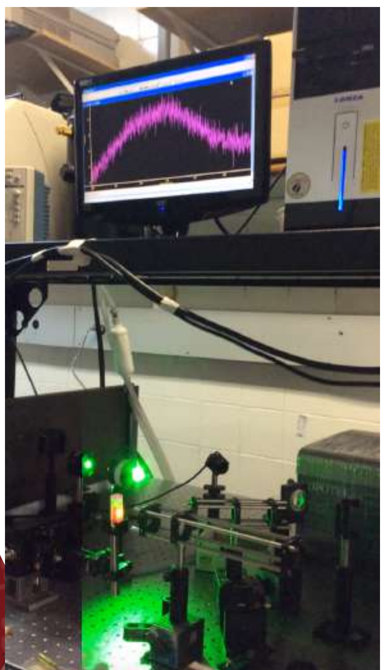
LPB

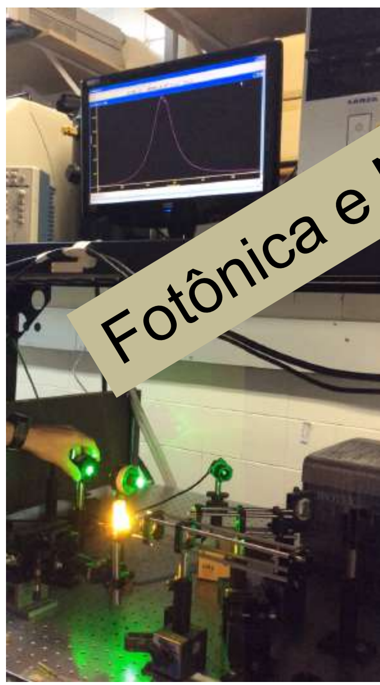


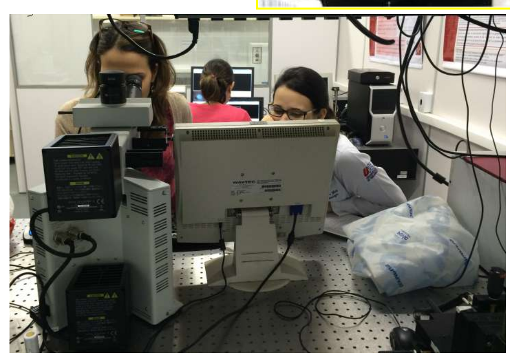


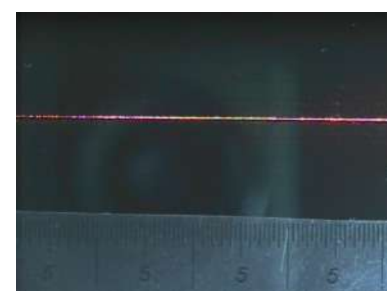


Fotônica e Nanofotônica









Many thanks to former students and national collaborators







CAPES

CNPq Conselho Nacional de Desenvolvimento Científico e Tecnológico

FACEPE

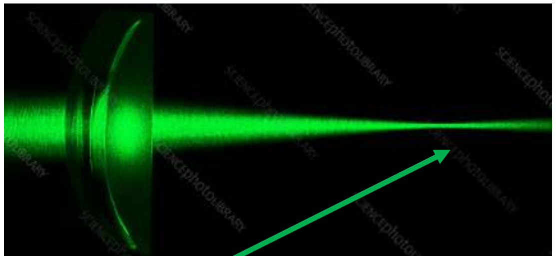
National Institute of Photonics
INCT de Fotônica

Restante do tempo........

- *Como focalizar a luz em dimensões nanométricas*
- *Como ver objetos em nanoescala*
- *Algumas aplicações da nanofotônica e nanobiofotônica*
  - *Na natureza*
  - *Lasers, LEDs, Imagem, Sensores, Nanotermômetros, etc*
- *A palavra com vocês...........*

Principles

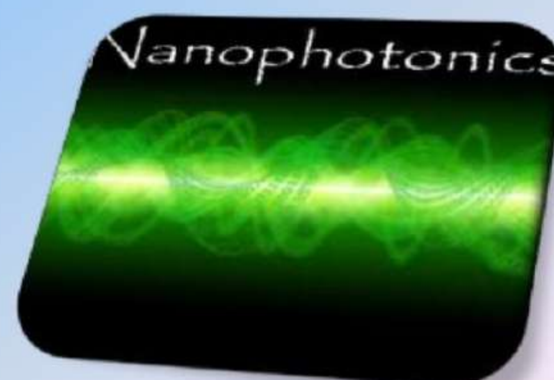
- Normal optical components, like lenses and microscopes cannot focus light to nanometer scale.



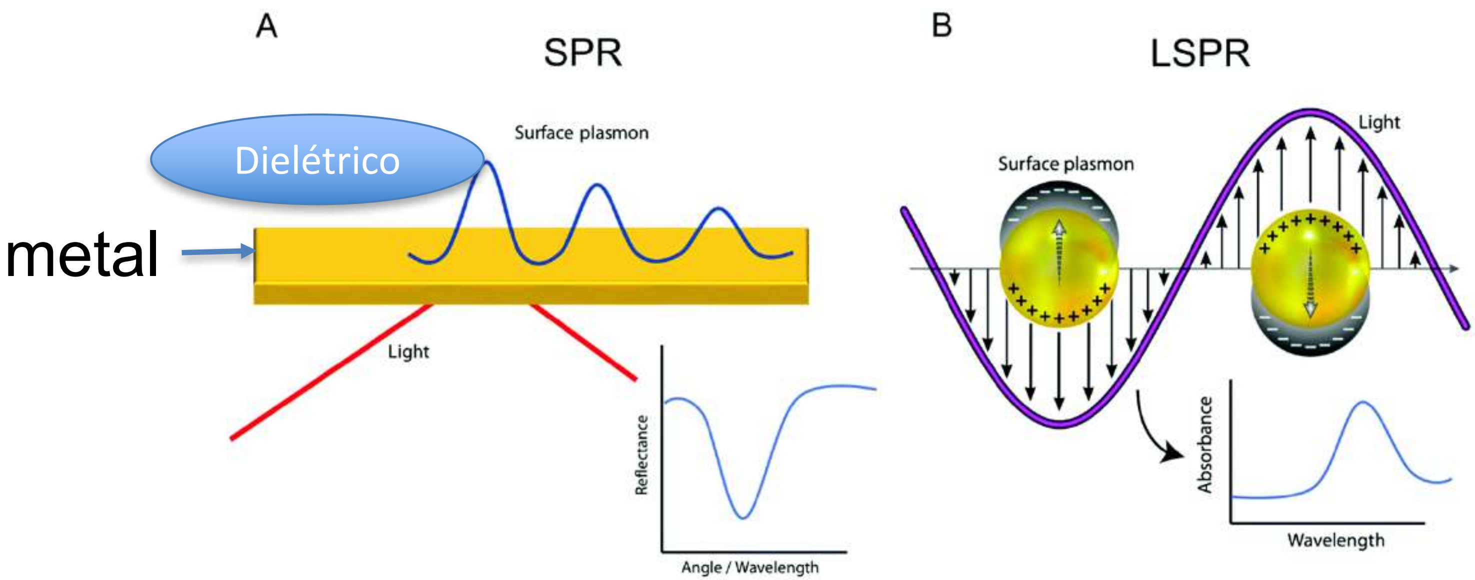
$$d = \lambda/(2\underbrace{n \sin\theta}_{NA})$$

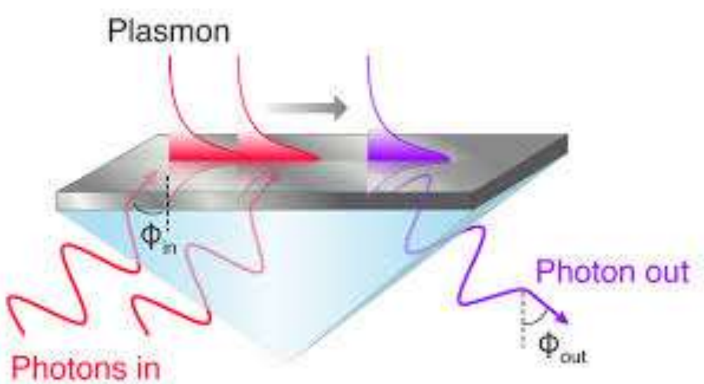
$$d = 500nm/(2x1) = 250nm$$

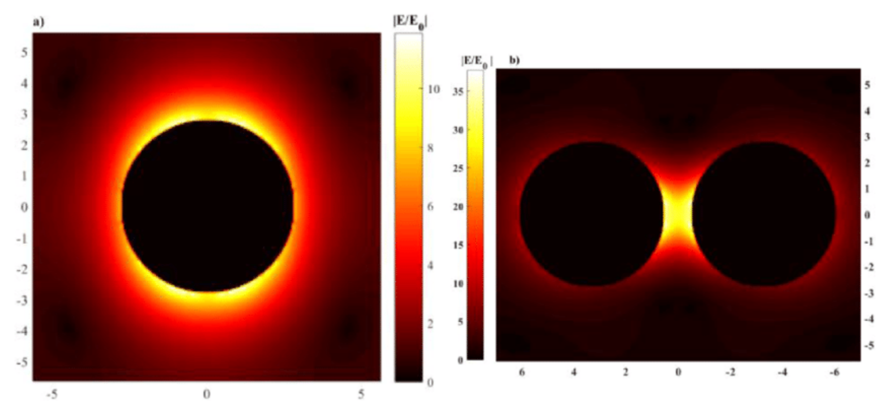
- But, it is possible to squeeze light into a nanometer scale using other techniques like
  - Surface plasmons
  - Metal optics
  - Near field optics
  - Metamaterials



Plasmons de Superfície/ Óptica de Metais

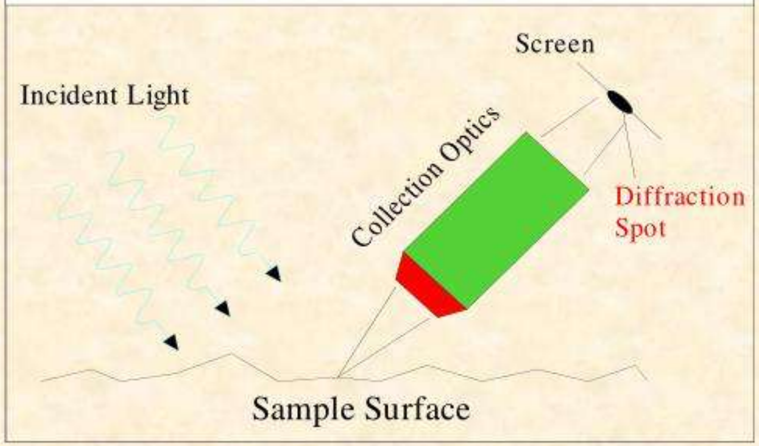






Far-Field Vs Near-Field Microscopy

Far-Field Microscopy



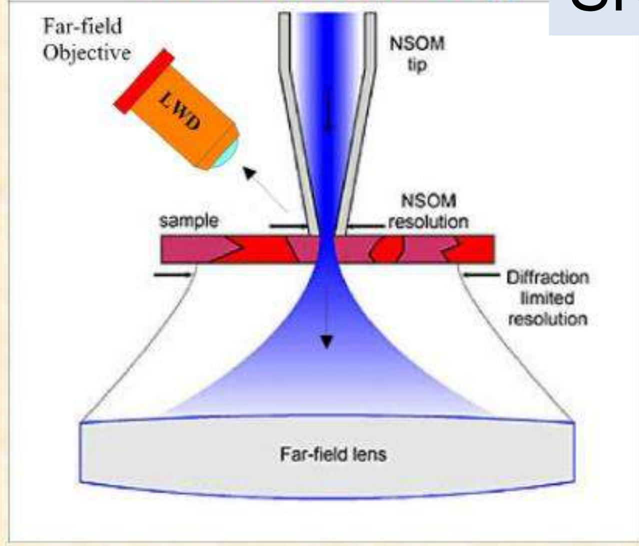
• Both the light source and the antenna are placed at several wavelengths from the sample.

•The Lateral resolution is determined by the Abbe diffraction limit.

$$\Delta x \sim 0.61 \frac{\lambda}{2\,NA} \sim 250\ nm$$

Near-Field Microscopy

SNOM



• The sample is illuminated by a nanoscopic light source located close to the surface (10 nm).

• The resolution is limited by the source diameter

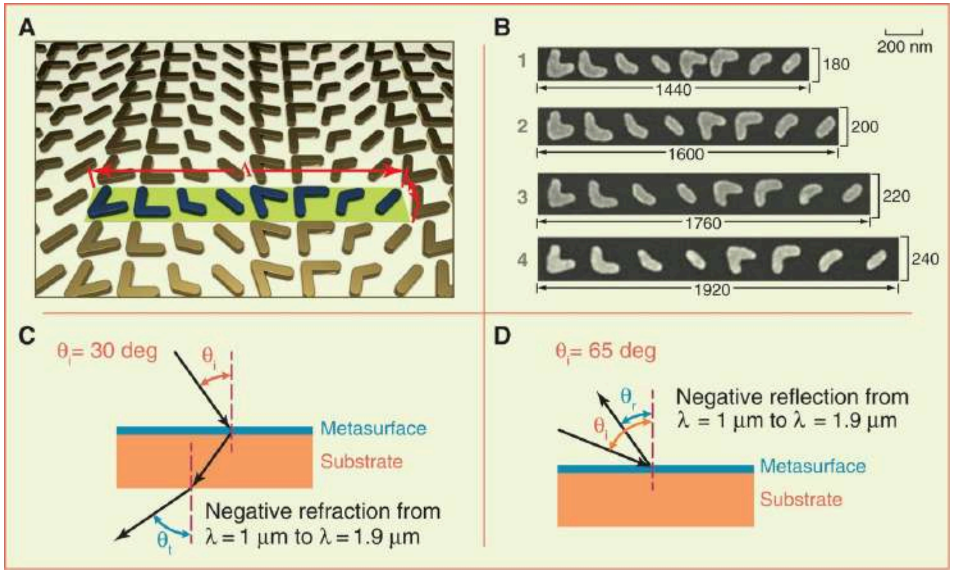
$$\Delta x \sim a \leq 100\ nm$$

https://www.slideserve.com/lonna/sub-diffraction-raman-imaging-by-near-field-optical-microscopy

”Google: Breaking the diffraction limit”

Metamateriais

Metamateriais são materiais artificiais projetados para terem propriedades que não são encontradas na natureza



Metasuperfície óptica

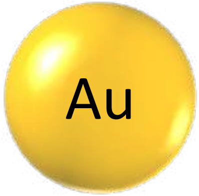
Normalmente composta por uma ou algumas subcamadas de elementos plasmônicos de dimensões $<\lambda$, precisamente orientados ou posicionados em uma grande superfície.

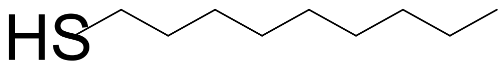
ADVANCED OPTICAL MATERIALS
www.advopticalmat.de
Adv. Optical Mater. **2013**, *1*, 100–106
MaterialsViews
www.MaterialsViews.com

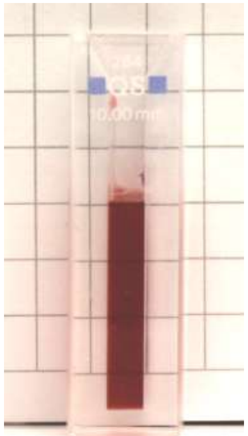
Macroscopic Self-Assembly and Optical Characterization of Nanoparticle–Ligand Metamaterials

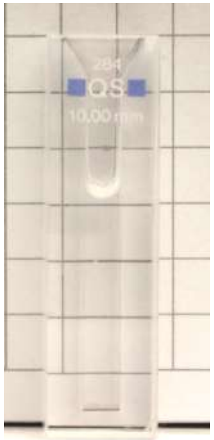
Jake Fontana, Jawad Naciri, Ronald Rendell, and Banahalli R. Ratna*

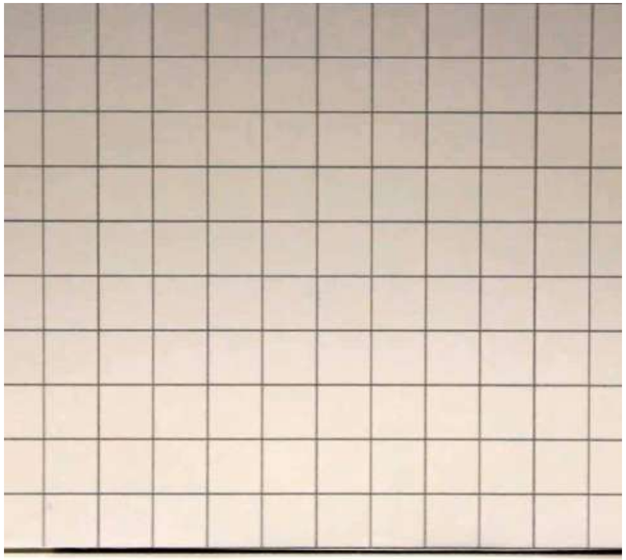
- Au nanospheres suspended in water
- thiol-ligands suspended in water-miscible organic liquid

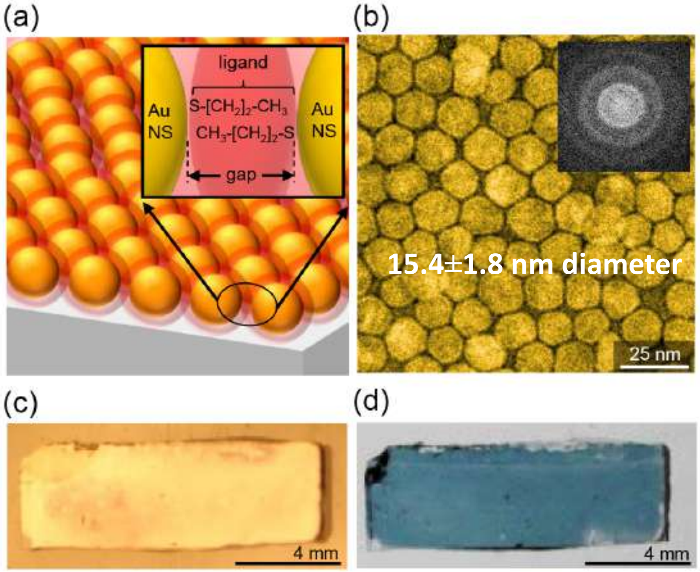






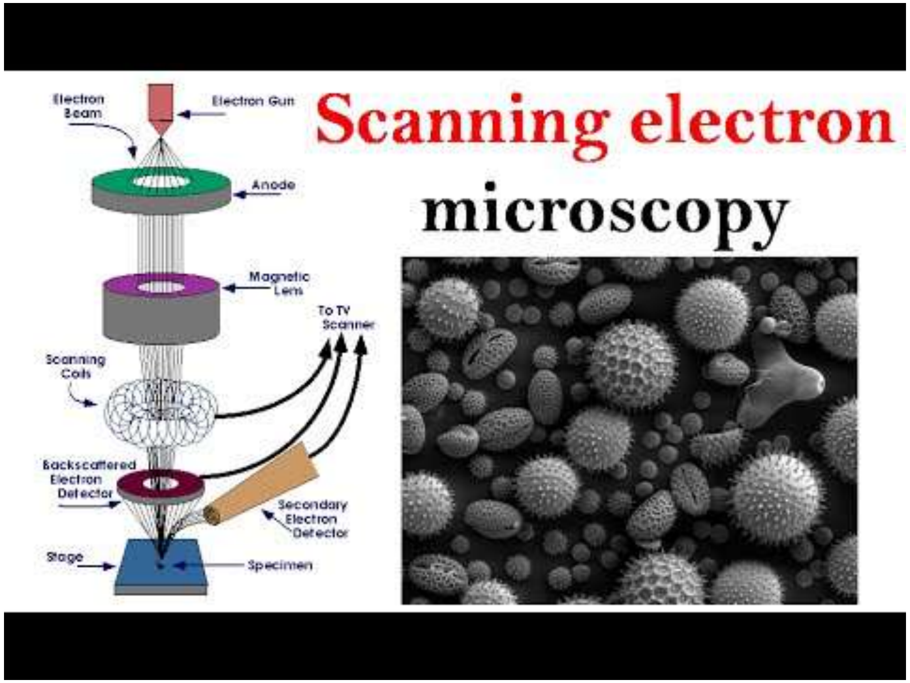


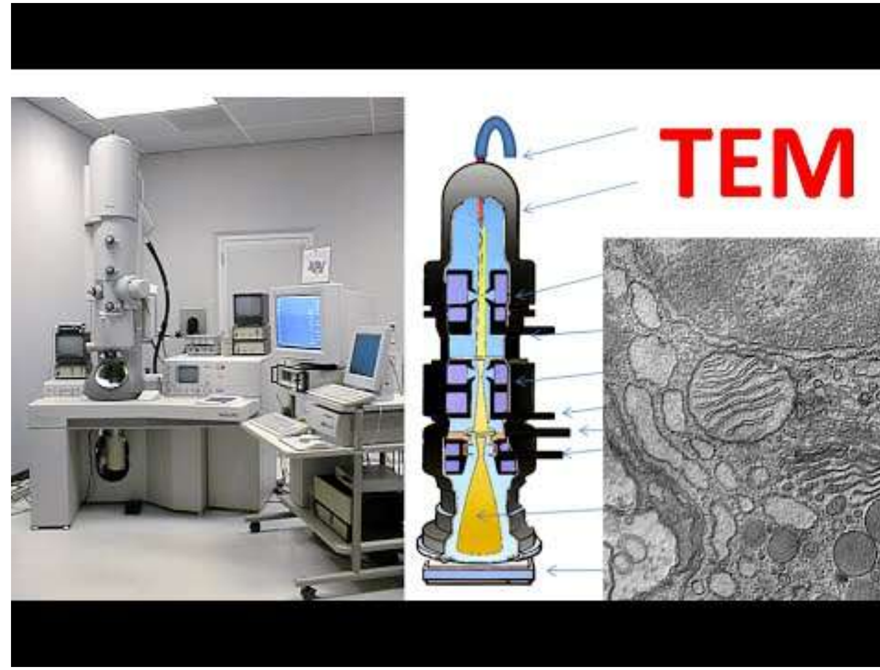


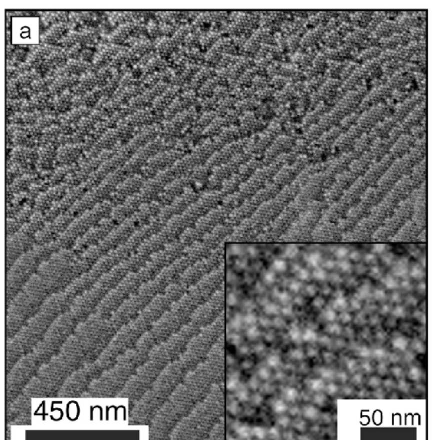


Courtesy of Jake Fontana, NRL

Como ver objetos em nanoescala

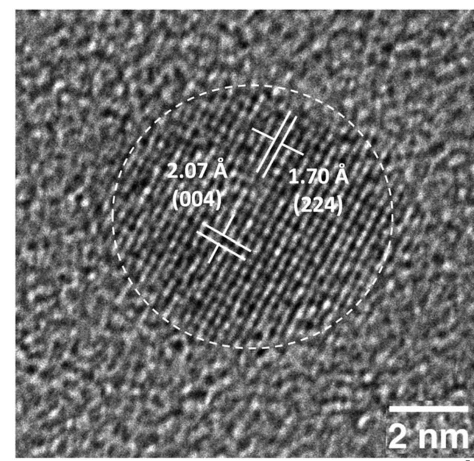






General Comparison

Types of Microscope	Resolution Power
Compound Microscope	200 nanometers
Scanning Electron Microscope	10 nanometers
Transmission Electron Microscope	0.2 nanometers



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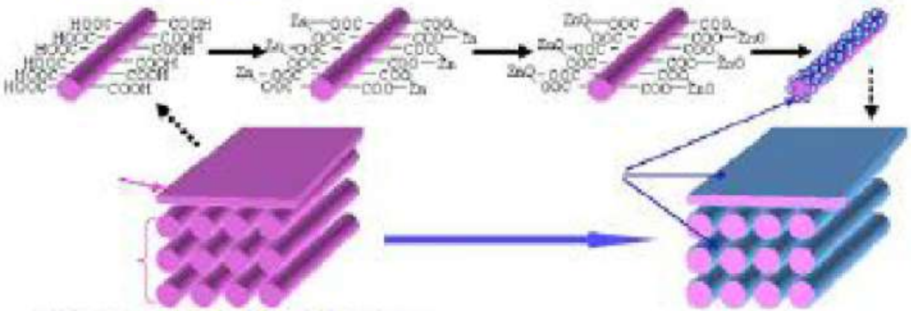
Nanophotonics in Mother Nature

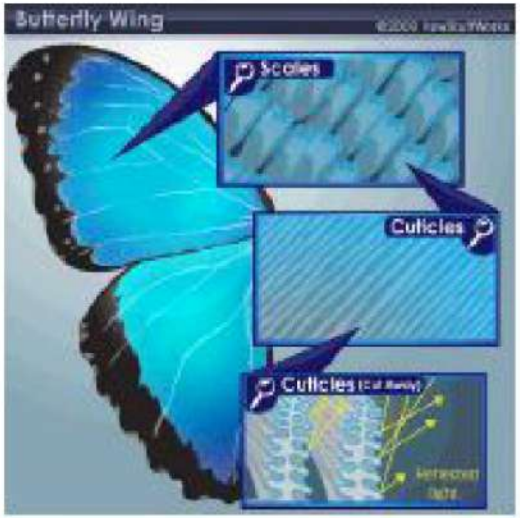
Feathers

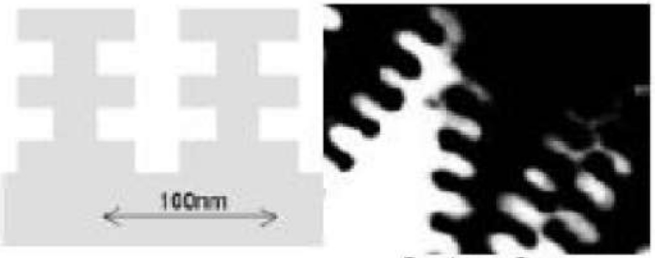


ZnO nanoparticles in peacock feathers

Zhang, Nanotechnology 2008

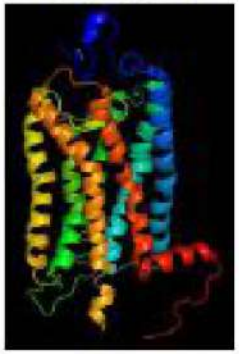
Butterfly wings





Courtesy: Onera

Photoreceptor rhodopsin

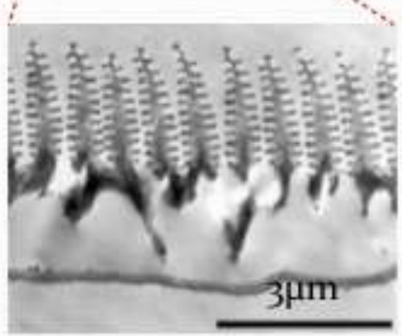


Photonic Crystals in Nature

Morpho rhetenor butterfly

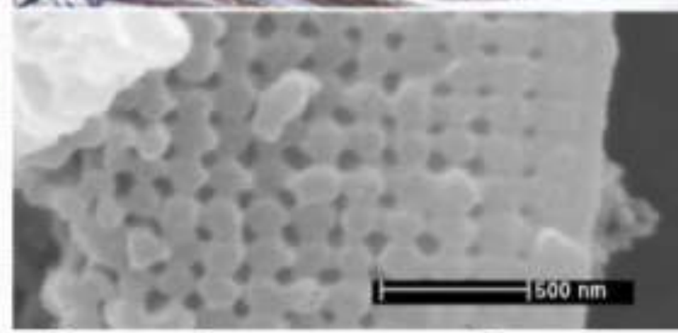
wing scale:

[P. Vukosic *et al.*, *Proc. Roy. Soc: Bio. Sci.* **266**, 1403 (1999)]



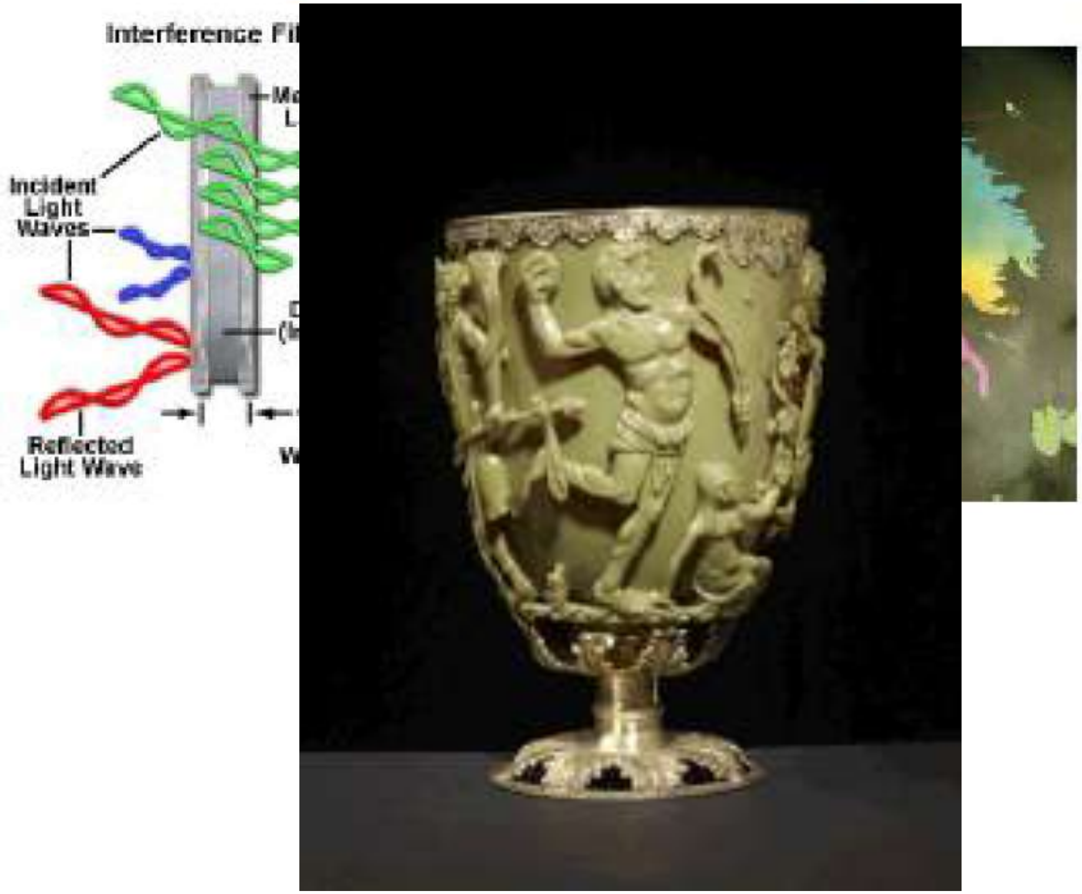
[also: B. Gralak *et al.*, *Opt. Express* **9**, 567 (2001)]

Peacock feather



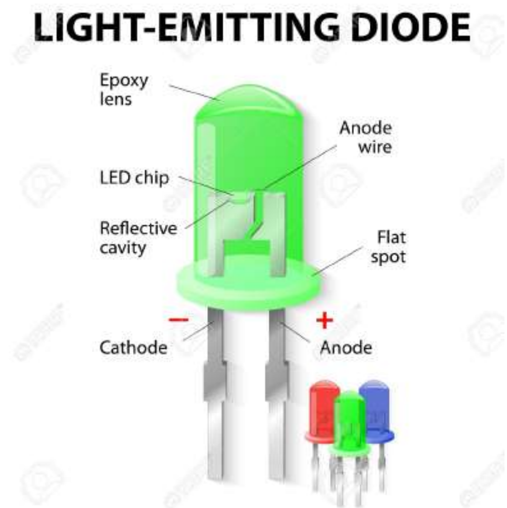
[J. Zi *et al*, *Proc. Nat. Acad. Sci. USA*, **100**, 12576 (2003)]
[figs: Blau, *Physics Today* **57**, 18 (2004)]

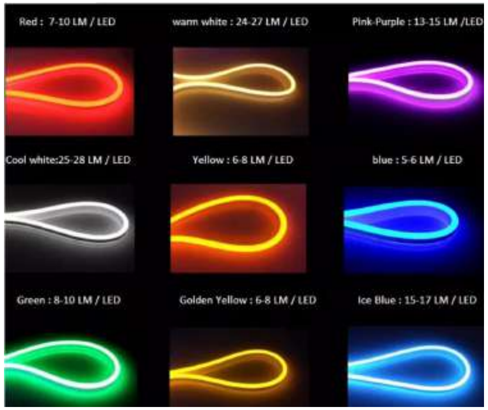
Early Examples of Nanophotonics

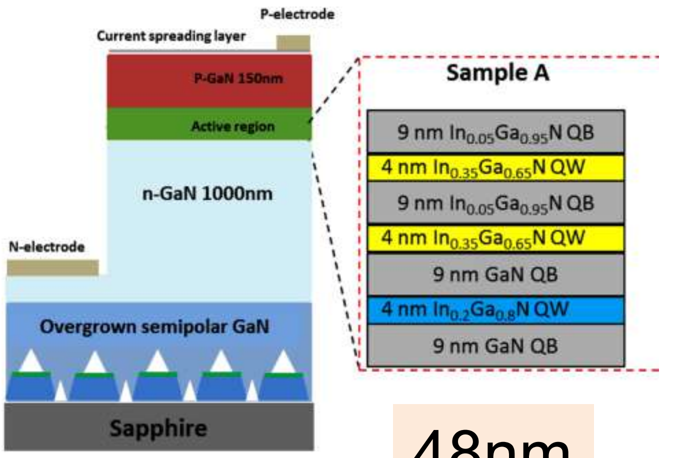


Taça de Lycurgus, Roma, Sec. IV.

LEDs



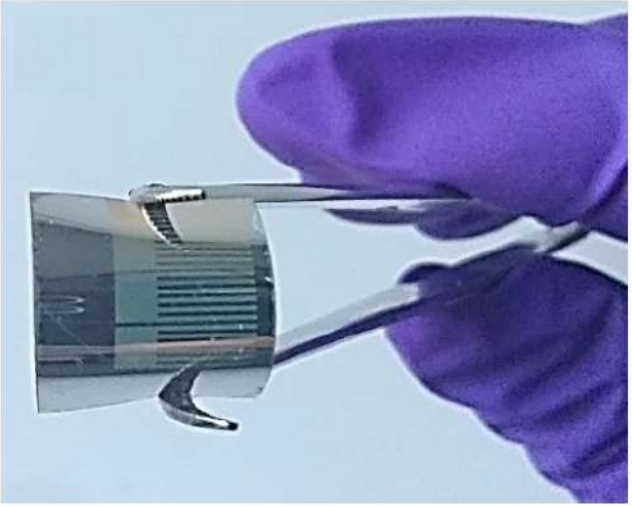


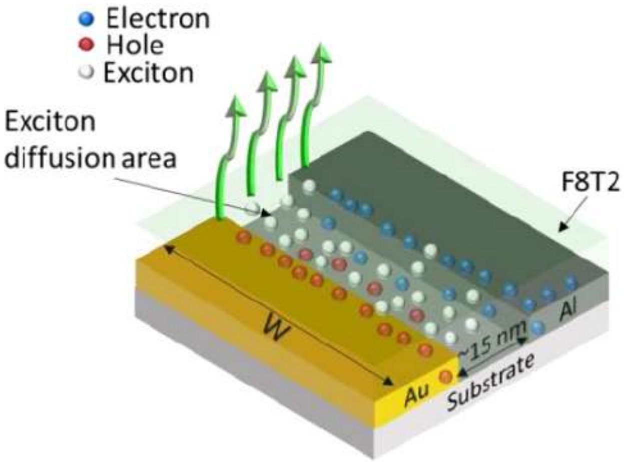


48nm

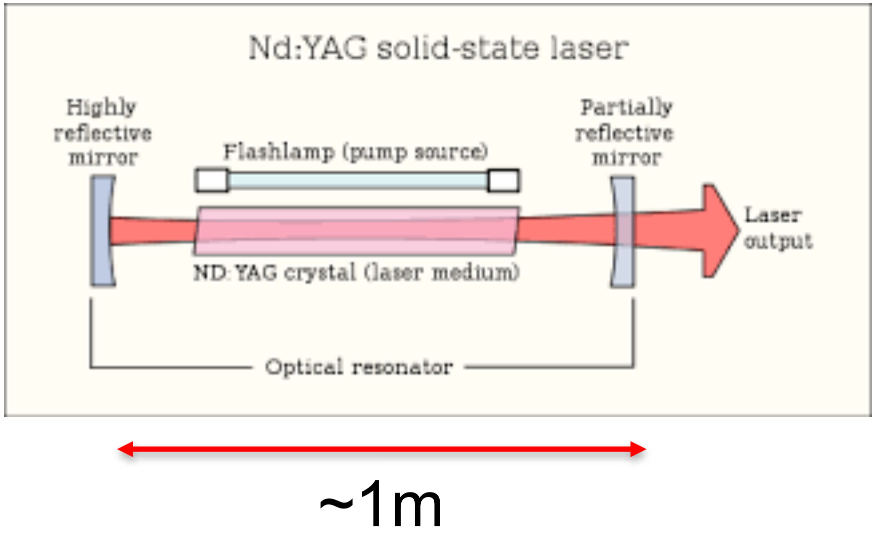
Polymer LEDs go nano (2018)

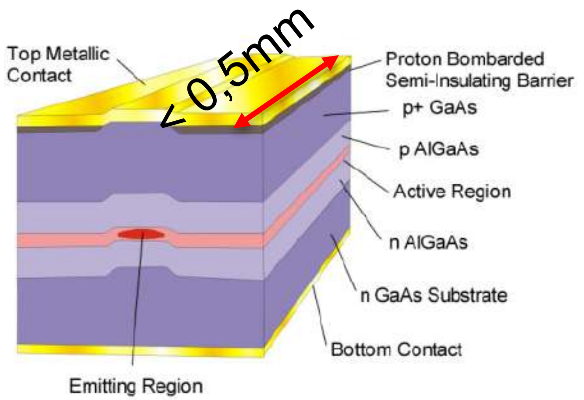
https://physicsworld.com/a/polymer-leds-go-nano/





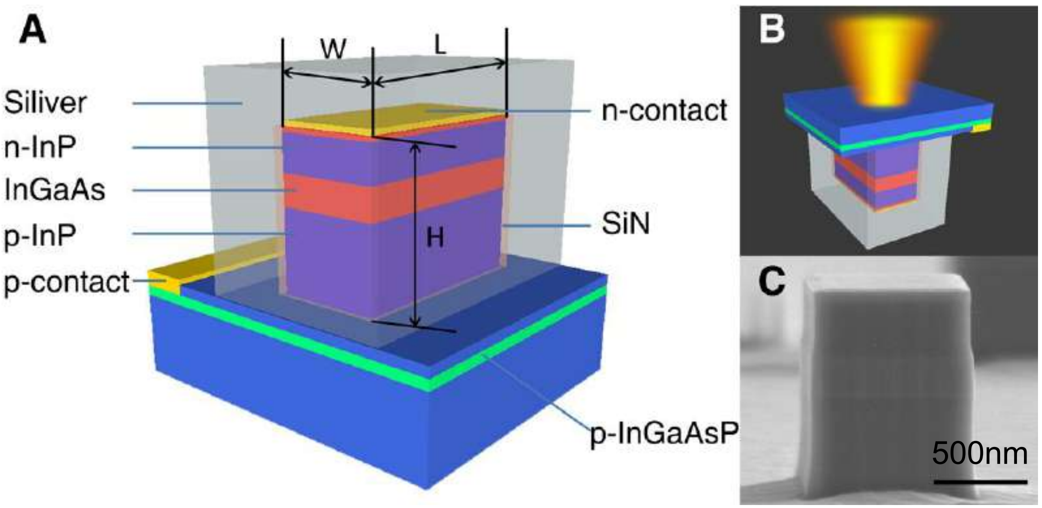
LASERS - Cavidades tipo: Fabry-Perot





Laser de diodo semicondutor

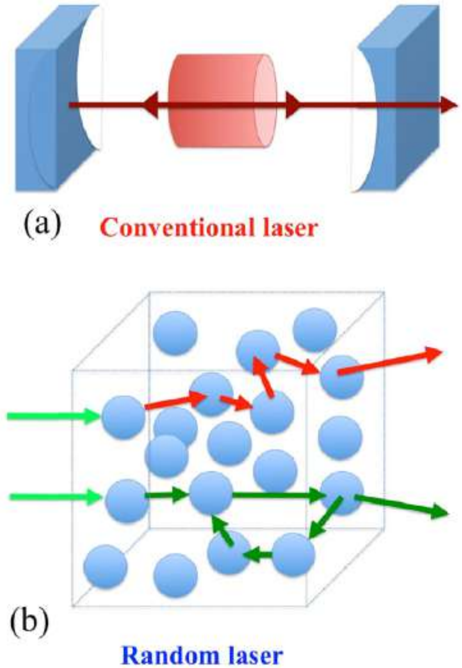
Room Temperature CW Operation of Metal-Semiconductor Plasmonic Nanolasers with Subwavelength Cavity , Ding et al, CTuG2.pdf, OSA/CLEO, 2011



$$\lambda = 1550nm$$

Um outro tipo de ”nanolaser”

Random Lasers – Lasers Aleatórios



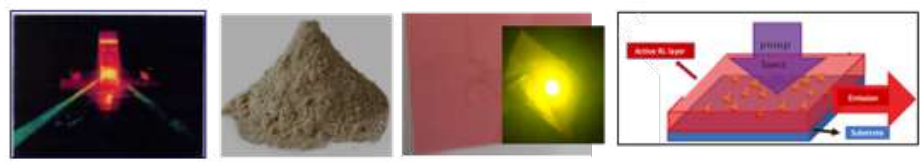
Lasing in nanocomposite random media
Luan... ASL GOMES....Prasad
NanoToday, 2015

Scatterers
(dielectric or metal NPs)
outside active medium
(dyes, polymers, etc)

Scatterers and
active medium the same
(semiconductors, RED ions, etc)

Passive scatterers
(dielectric or metallic)
and active NP combination

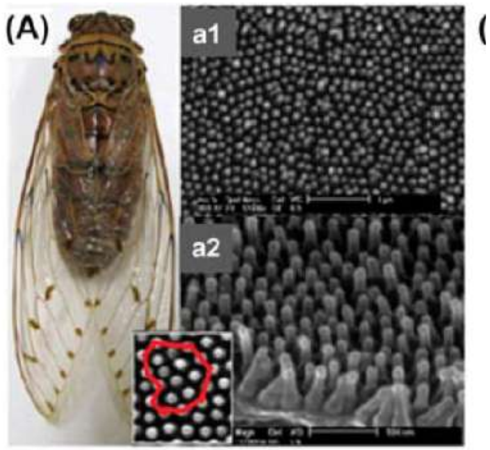
Colloids | Powders | Flexible Membranes | 2D (Thin films, "chips")

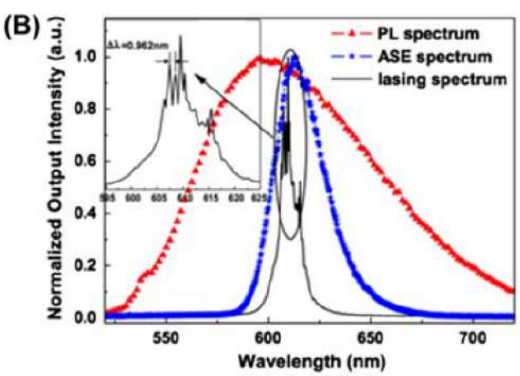


Random Lasers

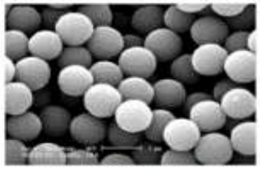
Dyes + NP

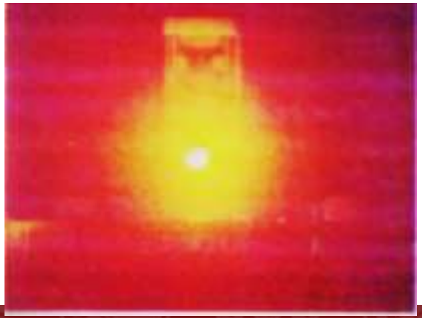
Cigarra!

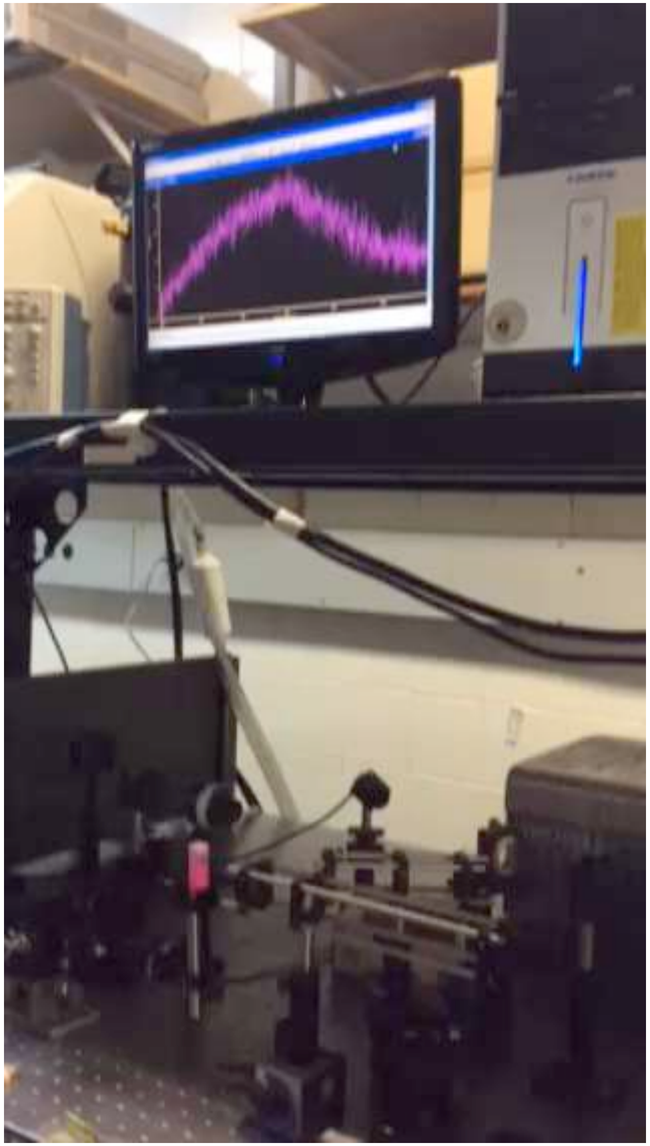




D. Zhang et al, Random lasing from dye doped polymer within biological source scatters: the pomponia imperatorial cicada wing random nanostructures, Org.Electron. 13 (2012) 2342e2345.







Labfoton

Materiais 2D

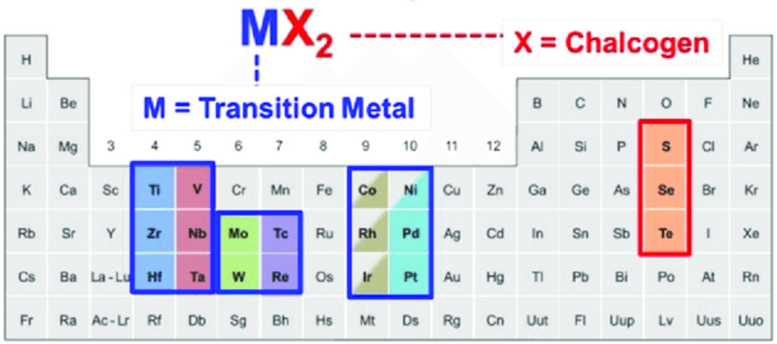
Nano-Micro Lett. (2017) 9:50 Page 3 of 23 50

Table 1 2D materials family [1, 9, 20, 29, 42, 66–70]

Graphene Family
- Graphene (Stable in Air at 300K)
- BCN (Stable in Air at 300K)
- Flourographene (Stable in Air at 300K)
- Grahene Oxide (Stable in Air at 300K)

2D Chalcogenides
- **Semiconducting dichalcogenide:** MoS_2, WS_2, $MoSe_2$, WSe_2 (Stable in Air at 300K)
- **Semiconducting dichalcogenide:** $MoTe_2$(2H), WTe_2(2H), ZrS_2, $ZrSe_2$ (Stable in Air)
- **Metallic dichalcogenide:** $NbSe_2$, NbS_2, TiS_2, $NiSe_2$ and so on (Stable in Inert Cond)
- **Layered Semiconductor beyond dichalcogenides:** GaSe, GaTe, InSe, Bi_2Se_3 and so on (Stable in inert Cond)

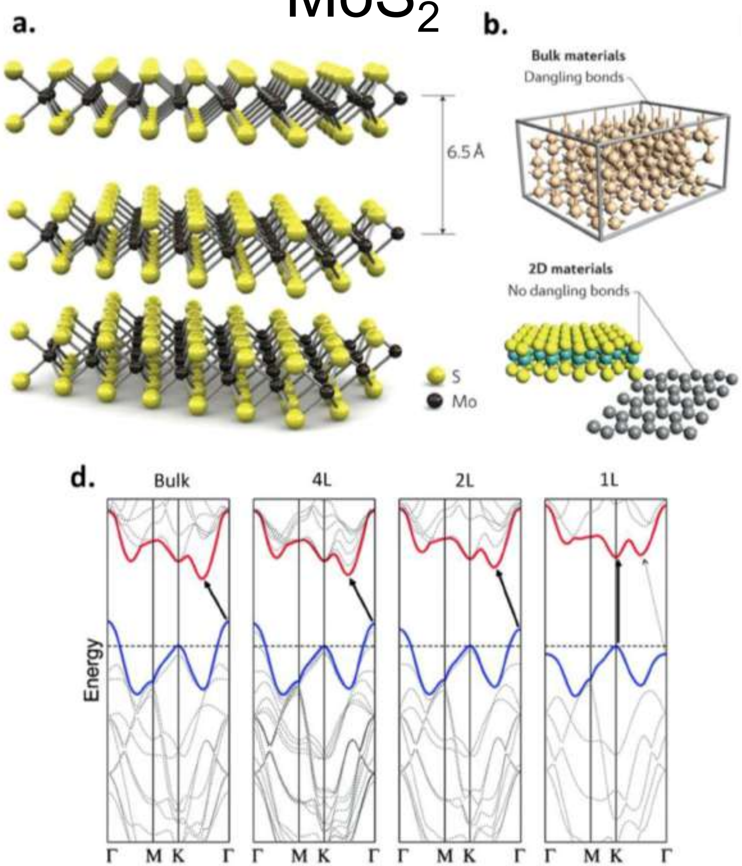
2D Oxides
- Micas, BSCCO (Stable in Air at 300K)
- MoO_3, WO_3, Layered Cu oxides (Stable in Air)
- TiO_2, MnO_2, V_2O_5, TaO_3, RuO_2 and so on (Stable in Air at 300K)
- Perovskite-type: $LaNb_2O_7$, $(Ca,Sr)_2Nb_3O_{10}$, $Bi_4Ti_3O_{12}$, $Ca_2Ta_2TiO_{10}$ and so on (Stable in Air at 300K)
- Hydroxides: $Ni(OH)_2$, $Eu(OH)_2$ and so on (Stable in Air at 300K)
- Others



Materiais 2D

Applications

MoS_2



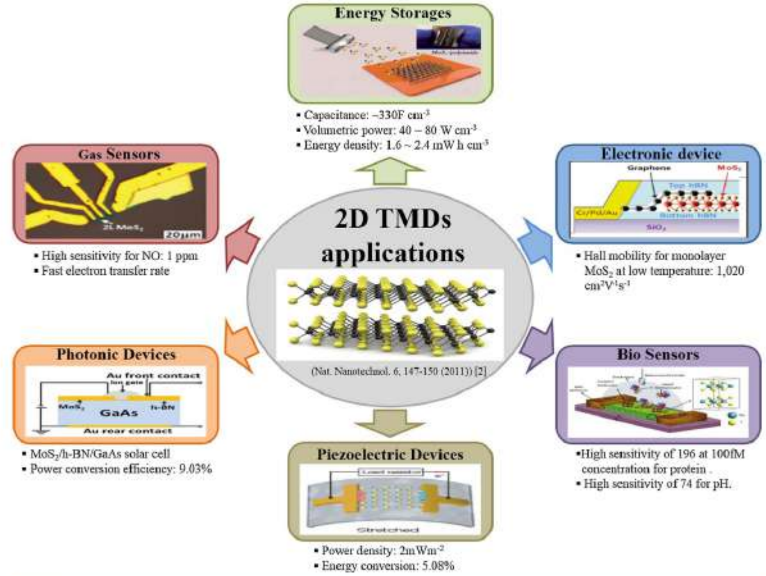
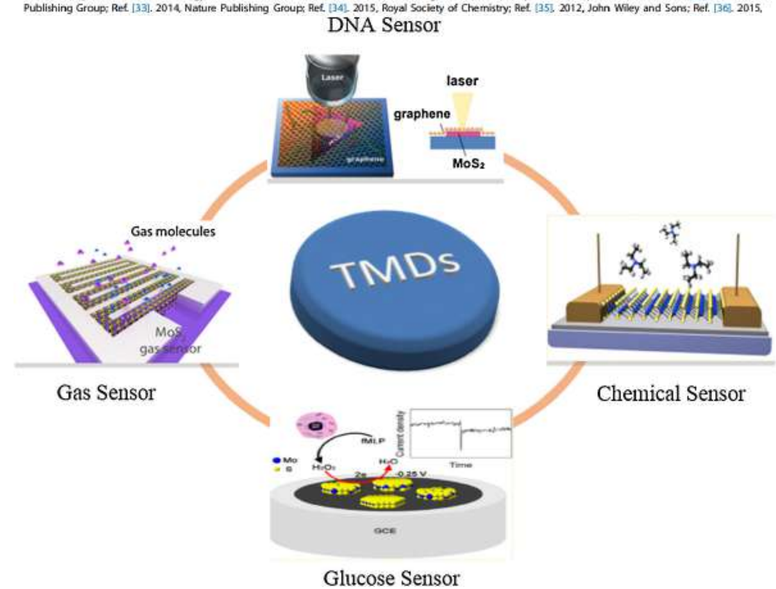


FIGURE 2
Electronic, opto-electronic and energy devices based on 2D transition metal dichalcogenides (TMDs). (Reprinted with permission from Ref. [32]. 2015, Nature Publishing Group; Ref. [33]. 2014, Nature Publishing Group; Ref. [34]. 2015, Royal Society of Chemistry; Ref. [35]. 2012, John Wiley and Sons; Ref. [36]. 2015,



Nanoscale

PAPER

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Monolayer 2D $ZrTe_2$ transition metal dichalcogenide as nanoscatter for random laser action

Pablo I.R. Pincheira[a*], Manoel L. da Silva[b] - Neto, Melissa Maldonado[c], Cid B. de Araújo[b,c], Ali M. Jawaid[d], Robert Busch[d], Allyson J. Ritter[d], Richard A. Vaia[d] and Anderson S. L. Gomes[c*]

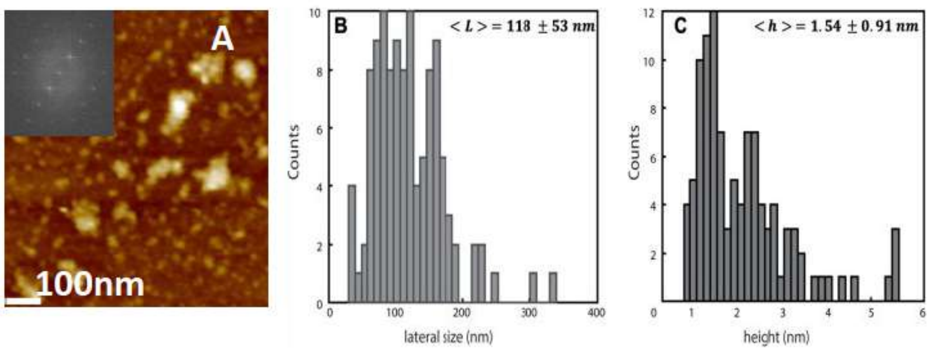


FIG. 1 Morphology of exfoliated zrte$_2$ flakes. AFM (a) of monolayer selected $ZrTe_2$ flakes. inset in (a) shows the FFT from sem. lateral size (b) and height (c) distributions of $ZrTe_2$ flakes. note, the average height reported via AFM analysis is typically larger than the absolute particle size due to substrate-flake interactions.

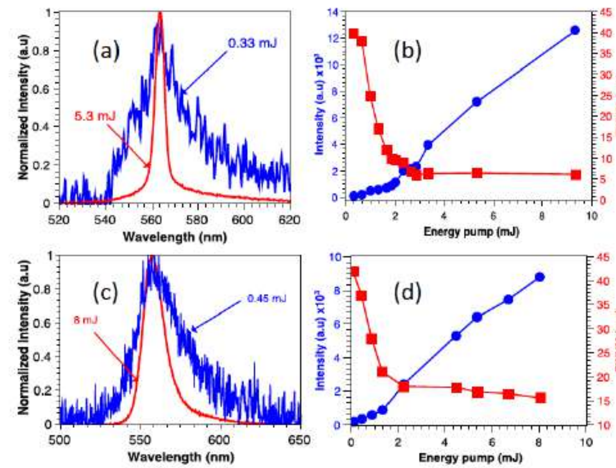


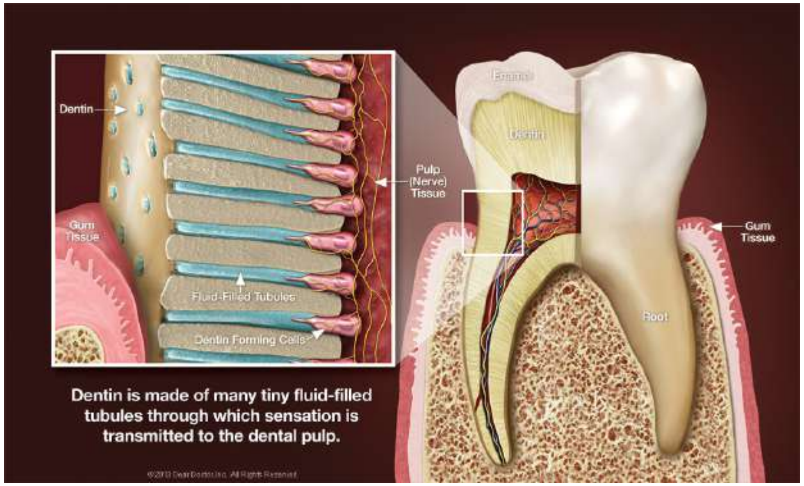
Fig. 3 RL characterization of the 3D $ZrTe_2$ and 2D $ZrTe_2$. (3a,c) shows the emission spectra for low energy and over the threshold for the 3D and 2D case respectively. (3a,d) shows FWHM and peak intensity of the emitted spectra as a function of the excitation energy for the 3D and 2D case respectively.

Imagem

Journal of Biomedical Optics 17(6), 066003 (June 2012)

In situ gold nanoparticles formation: contrast agent for dental optical coherence tomography

Ana K. S. Braz,[a,b] Renato E. de Araujo,[b] Tymish Y. Ohulchanskyy,[c] Shoba Shukla,[c] Earl J. Bergey,[c] Anderson S. L. Gomes,[d] and Paras N. Prasad[c]



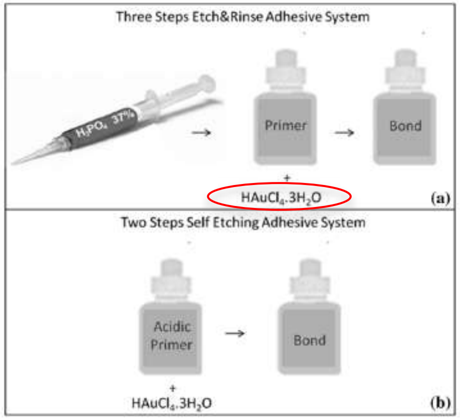


Fig. 1 DBA preparation with (a) a three-step etch and rinse adhesive system, Adper Scotchbond Multi-Purpose, and (b) a two-steps self etching adhesive system, Adhese.

\+

- *In situ* photothermal reduction
- Spherical gold nanoparticles inside dentinal layers and tubules

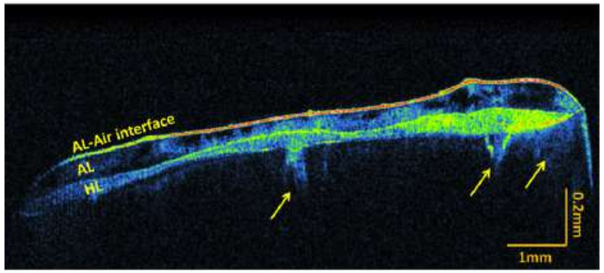


Fig. 3 OCT images of the adhesion process on dentin using DBAs prepared with gold nanoparticles. The adhesion process regions are identified: adhesive layer (AL), hybrid layer (HL), and resin tags (arrows).

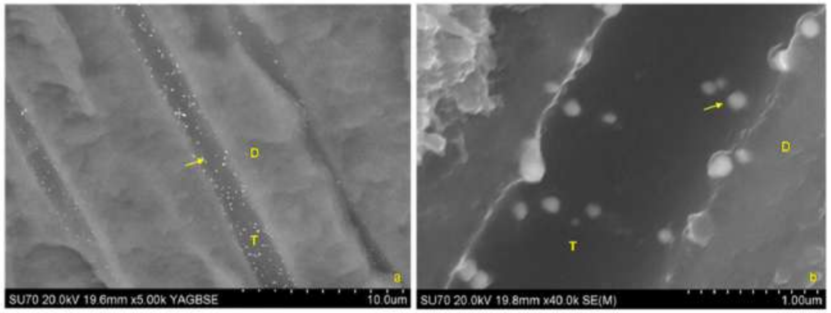


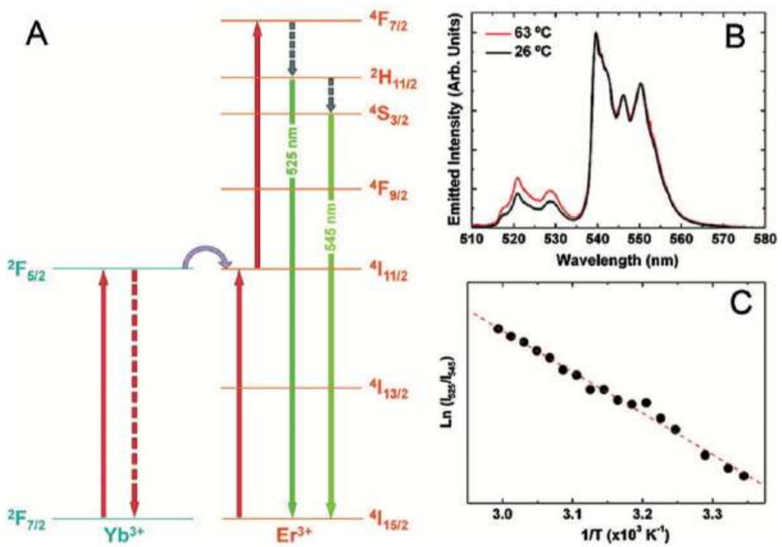
Fig. 2 SEM images of gold nanoparticles (arrows) showing penetration into dentinal tubules. Dentin (*D*) and tubules (*T*) are identified.

ChemPubSoc Europe
DOI: 10.1002/cphc.201500753
CHEMPHYSCHEM Minireviews

Very Important Paper

Nanothermometry: From Microscopy to Thermal Treatments

Haiying Zhou,[a] Monica Sharma,[a] Oleg Berezin,[c] Darryl Zuckerman,[a] and Mikhail Y. Berezin*[a, b]



NP: $NaYF_4:Er^{3+},Yb^{3+}$

Vetrone et al, ACS Nano 2010, 4, 3254 – 3258

See also:

Chem Soc Rev
ROYAL SOCIETY OF CHEMISTRY
REVIEW ARTICLE
View Article Online
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Cite this: *Chem. Soc. Rev.*, 2015, 44, 1680

Light upconverting core–shell nanostructures: nanophotonic control for emerging applications

Guanying Chen,*ab Hans Ågren,c Tymish Y. Ohulchanskyya and Paras N. Prasad*ad

FULL PAPER

Particle
www.particle-journal.com

Noninvasive Temperature Measurement in Dental Materials Using Nd^{3+}, Yb^{3+} Doped Nanoparticles Emitting in the Near Infrared Region

Artem Yakovliev, Tymish Y. Ohulchanskyy, Roman Ziniuk, Tereza Dias, Xin Wang, Hao Xu, Guanying Chen, Junle Qu,* and Anderson S. L. Gomes**

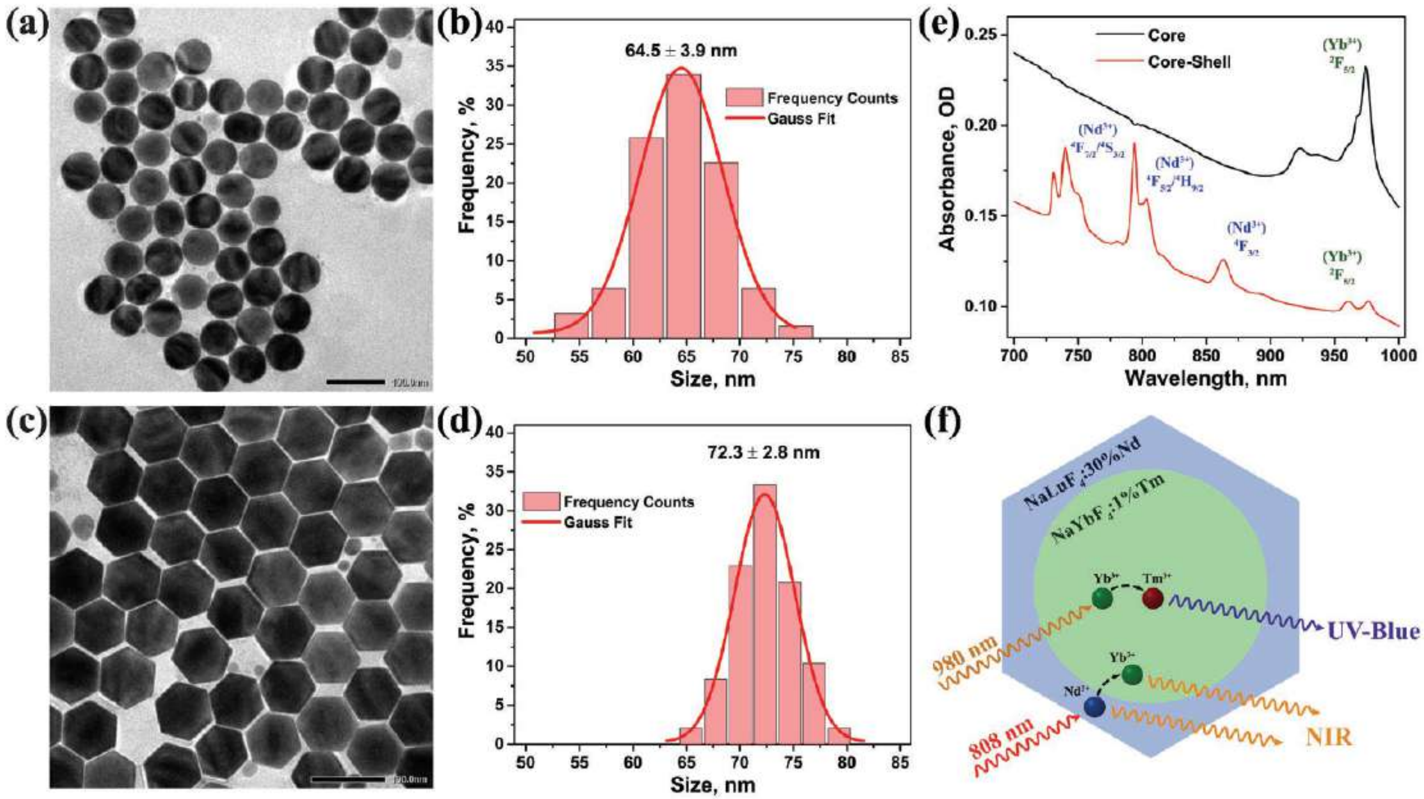


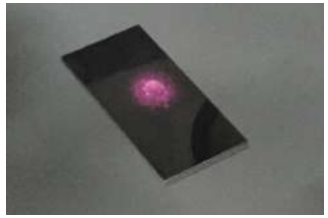
Figure 1. Characterization of RENPs. a) TEM and b) corresponding size distribution of β-$NaYbF_4$:1%Tm^{3+} core nanoparticles. c) TEM and d) corresponding size distribution of $NaYbF_4$:1%Tm^{3+}@$NaLuF_4$:30%Nd^{3+} core–shell nanoparticles. e) Absorbance spectra of β-$NaYbF_4$:1%Tm^{3+} core and $NaYbF_4$:1%Tm^{3+}@$NaLuF_4$:30%Nd^{3+} core–shell nanoparticles. f) Schematic representation of excitation dynamics in the RENPs.

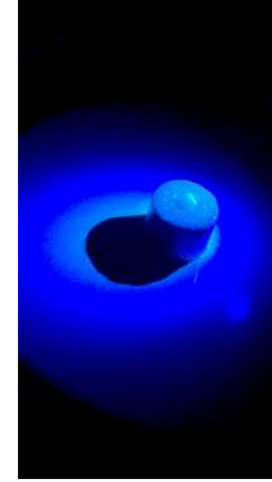
FULL PAPER

Particle

Noninvasive Temperature Measurement in Dental Materials Using Nd^{3+}, Yb^{3+} Doped Nanoparticles Emitting in the Near Infrared Region

Artem Yakovliev, Tymish Y. Ohulchanskyy, Roman Ziniuk, Tereza Dias, Xin Wang, Hao Xu, Guanying Chen, Junle Qu,* and Anderson S. L. Gomes**





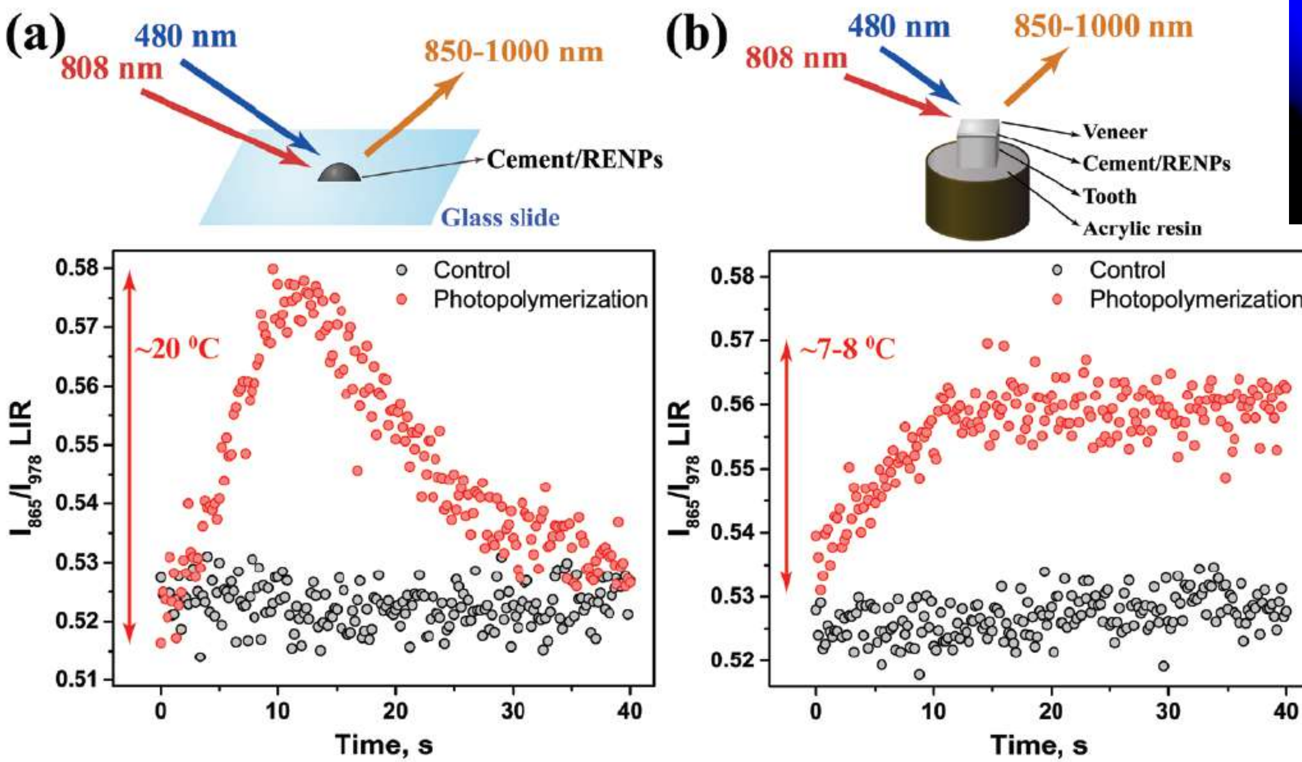
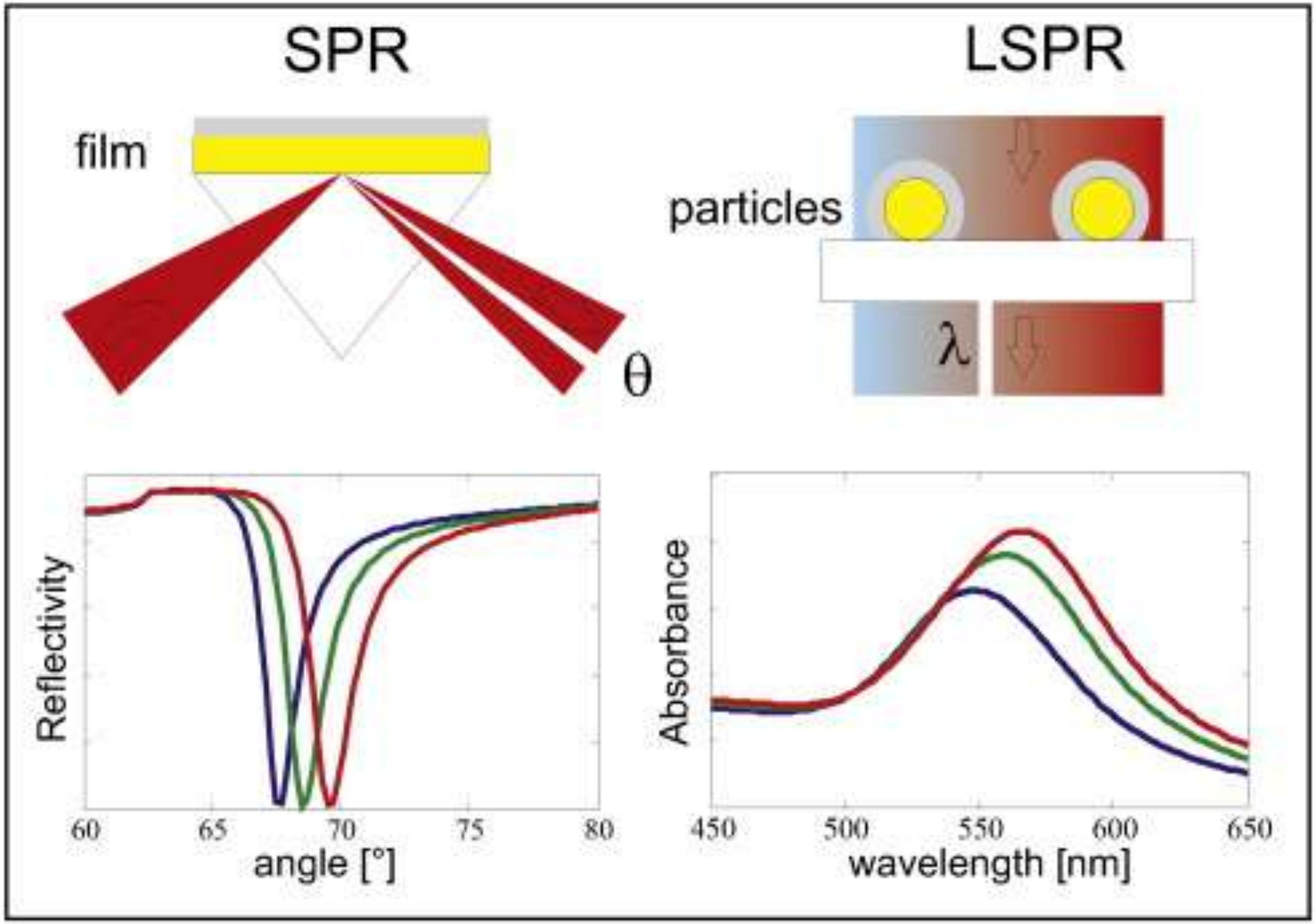


Figure 3. Temperature sensing during photopolymerization process. a) Temperature rise monitoring (red dots) of the cement/RENPs photopolymerization upon treating with blue light. Black dots are the control data obtained without blue illumination. b) Temperature rise monitoring (red dots) of the cement/RENPs photopolymerization under veneer upon treating with blue light. Black dots are the control data obtained without blue illumination.

NANOFOTÔNICA + PLASMÔNICA = NANOPLASMÔNICA



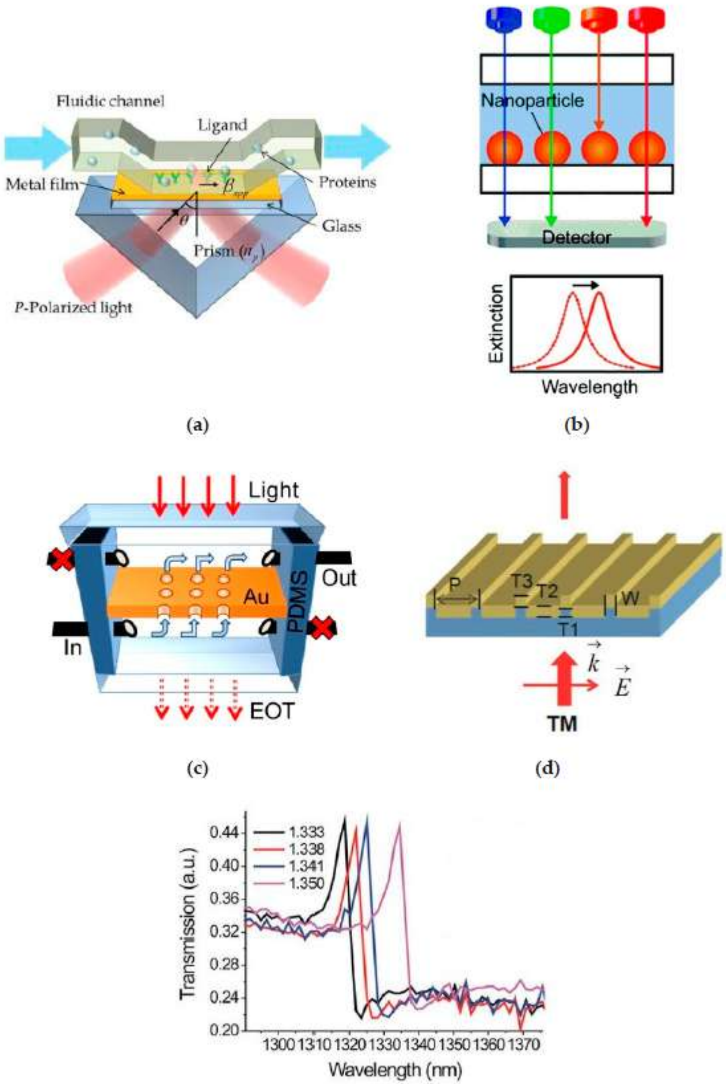


Figure 2. Schematic of plasmonic sensors. (**a**) Surface plasmon resonance (SPR) sensor requiring prism coupling. Reprinted from [93] under CC BY 3.0. (**b**) Localized surface plasmon resonance (LPSR) based sensor composed of an array of metallic nanoparticles. Reprinted with permission from [110] under CC BY-NC 3.0. Copyright © The Royal Society of Chemistry (RSC) (2014). (**c**) An array of metallic nanoholes operating on the principle of extraordinary optical transmission (EOT). Reprinted with permission from [111]. Copyright © SPIE (2010). (**d**) Schematic of plasmonic structures having Fano resonance. (**e**) Fano resonance shift by change of refractive indices. (**d,e**) Reprinted from [103] under CC BY 4.0.

sensors

MDPI

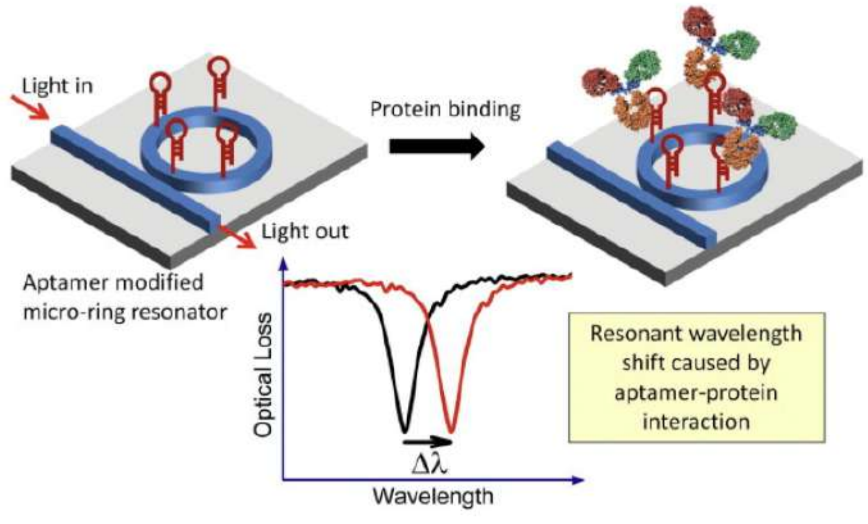
Review

Towards Portable Nanophotonic Sensors

Abdul Shakoor [1,*], James Grant [2], Marco Grande [3] and David. R. S. Cumming [2]

1 Optoelectronics Research Centre, University of Southampton, Southampton SO17 1BJ, UK
2 School of Engineering, University of Glasgow, Glasgow G12 8LT, UK; james.grant@glasgow.ac.uk (J.G.); david.cumming.2@glasgow.ac.uk (D.R.S.C.)
3 Dipartimento di Ingegneria Elettrica e dell'Informazione, Politecnico di Bari, 70125 Bari, Italy; marco.grande@poliba.it

On Chip Semiconductor/Dielectric Nanophotonic Sensors



(a)

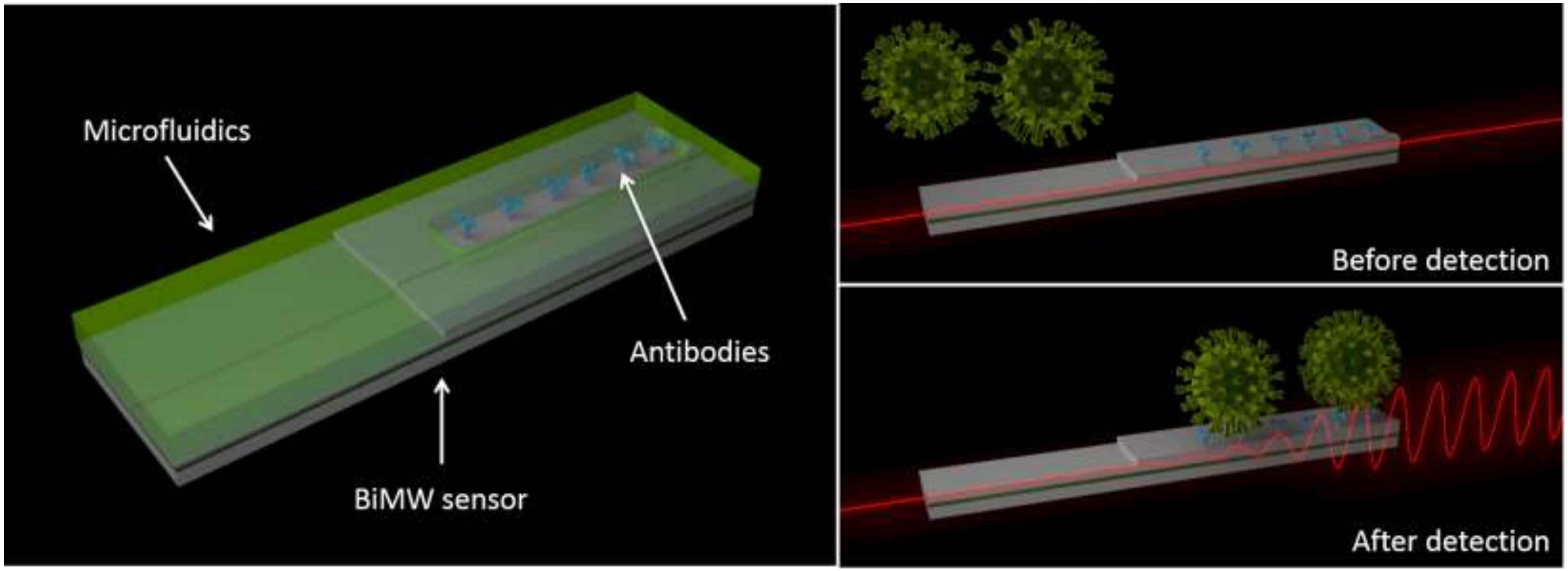
ADVANCED NANOPHOTONIC BIOSENSOR PLATFORMS FOR COVID-19 FAST DIAGNOSTICS AT THE POINT-OF-NEED: CONVAT PROJECT

Friday, July 17, 2020 - 12:00

Place: Online seminar, Donostia International Physics Center

Who: Laura M. Lechuga, ICN2, Spain

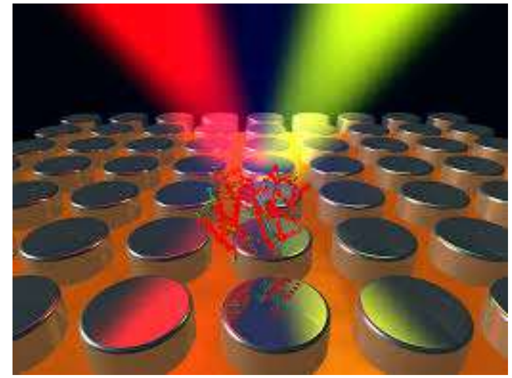
Source Name: DIPC



Em resumo...

O que é nanofotônica?

É o estudo do *comportamento da luz em escala nanométrica*, e de *sua interação com objetos em escala nanométrica.*



Além do que falei.....

Fig 4
Photovoltaic Solar Panel Array
Courtesy of University of St Andrews

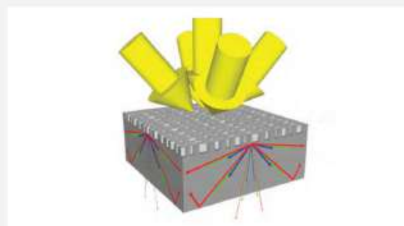


Fig 5
Solar cell with nanostructured surface to increase light absorption
Courtesy of University of St Andrews

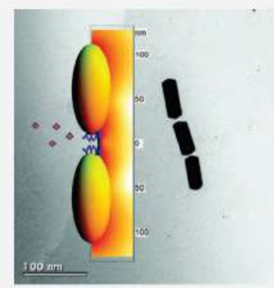


Fig 7
Nanophotonic Biosensor
source: www.bioplasmonics.ethz.ch

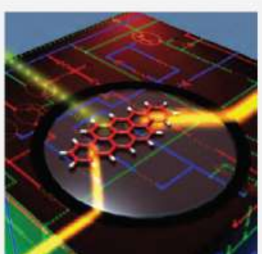


Fig 6
A single-molecule optical transistor
Courtesy of MPI Science for Light

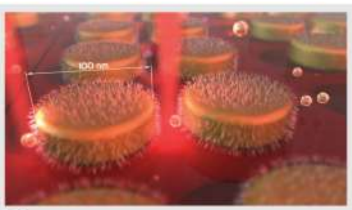
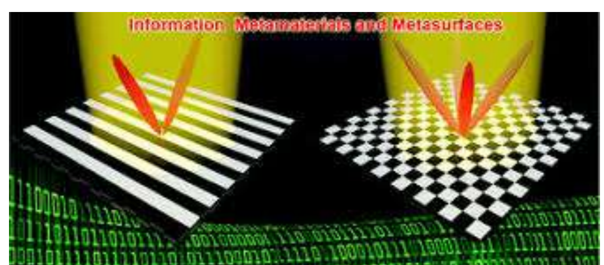


Fig 2
Nanomaterial Growth
Courtesy of ICFO. Picture by Dyvision



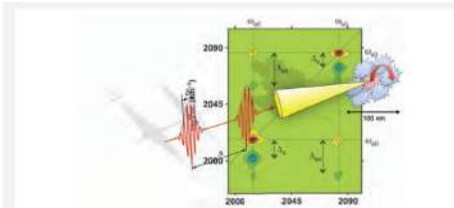


Fig 3
Schematic of a Nanophotonic Antenna for Advanced Nanoscopy
Courtesy of LENS, figure adapted from David M. Jonas, "Two-dimensional femtosecond spectroscopy," Annual Review of Physical Chemistry 54, 425 (2003)

Yana Chirkina, RED BALLET, Moscow

Melissa Gomes, Brazil

Obrigado......

anderson.lgomes@ufpe.br