

Manipulating light, heat *and forces* at the nanoscale with metallic nanoparticles

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Grupo de Fotónica de Nanomateriales

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En colaboración con:

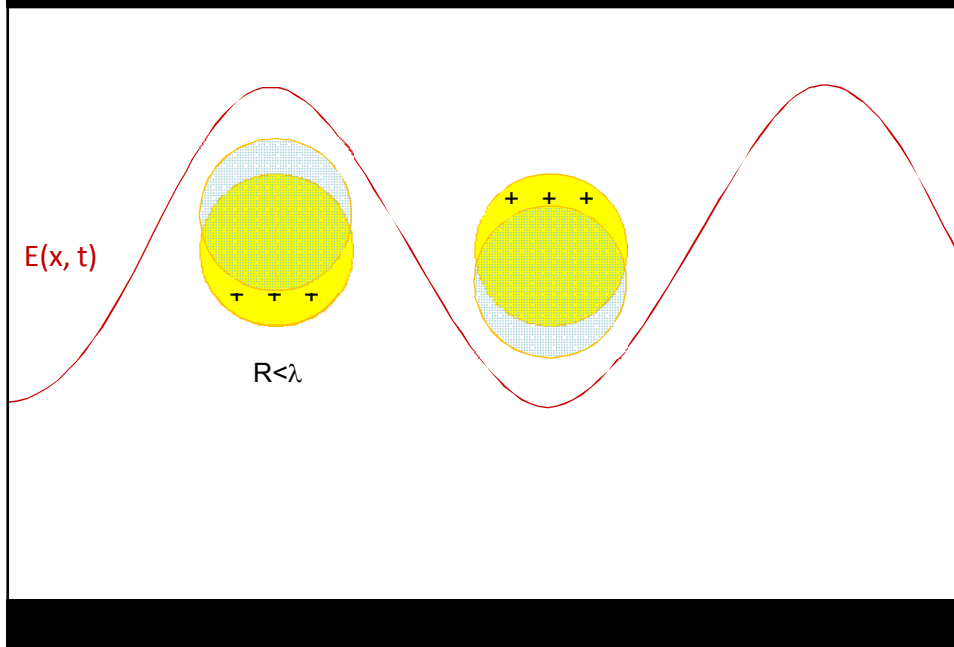


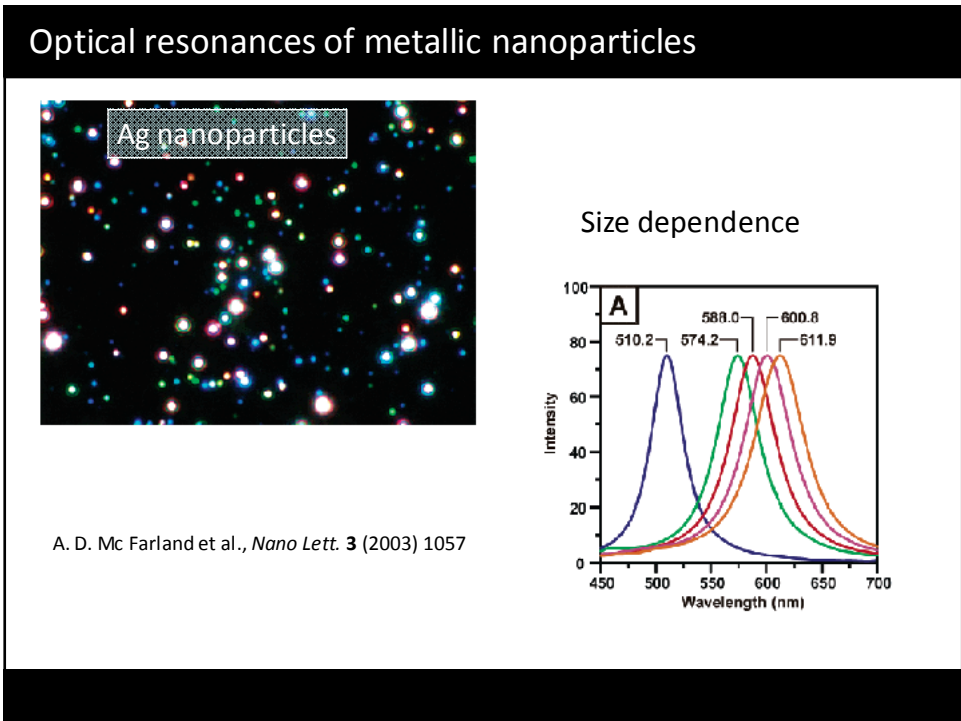
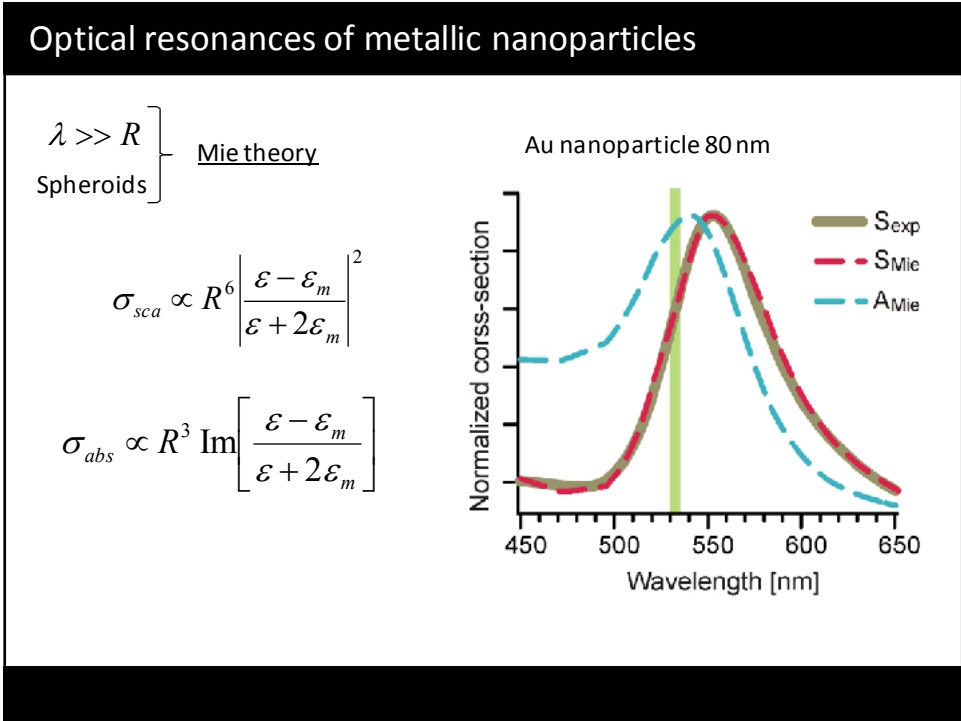
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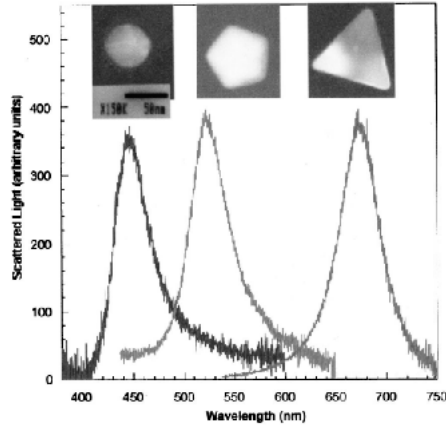
<http://nanomaterials-photonics.df.uba.ar/>

Optical properties of metallic nanoparticles





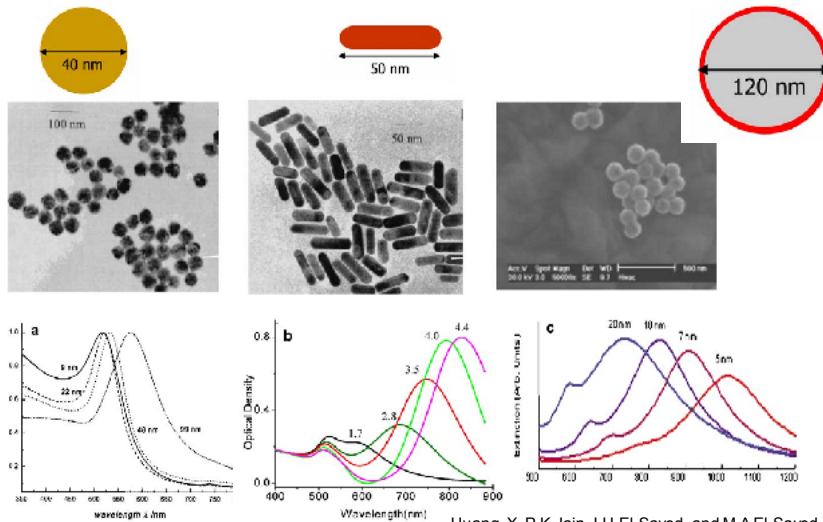
Optical resonances of metallic nanoparticles



Shape dependence

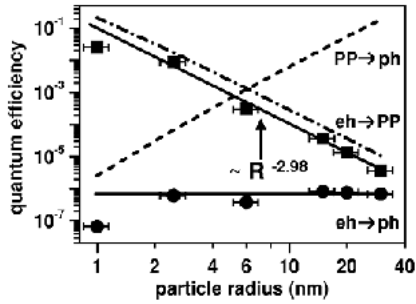
J.J. Mock et al., *J. Chem. Phys.*, **116** (2002) 6755

Optical resonances of metallic nanoparticles

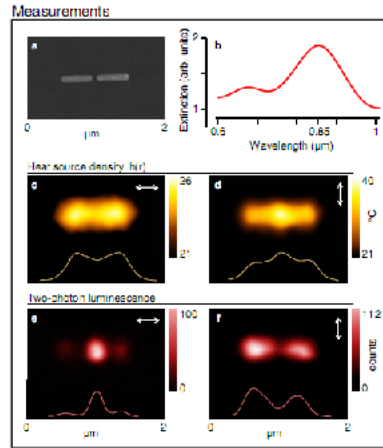


Huang, X, P K Jain, I H El-Sayed, and M A El-Sayed.
 "Plasmonic photothermal therapy (PPT) using gold nanoparticles."
Lasers in Medical Science 23 (2008): 217-228.

Heat generation

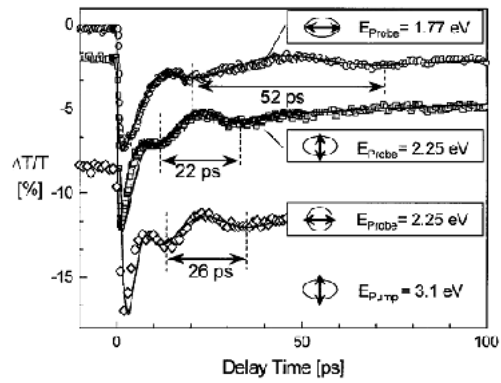
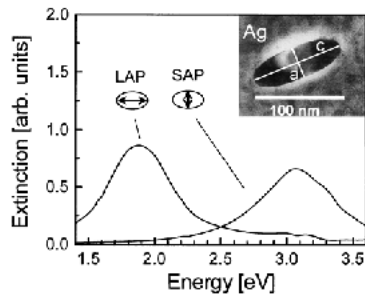


Dulkeith, E. et al.
 "Plasmon emission in photoexcited gold nanoparticles."
Physical Review B **70** (2004) 205424.



G.Baffou, C. Girard and R.Quidant.
 "Mapping Heat Origin in Plasmonic Structures."
Physical Review Letters (2010) 136805.

Ultrafast relaxation



Perner, M. et al.
 "Observation of Hot-Electron Pressure in the Vibration Dynamics of Metal Nanoparticles."
Physical Review Letters **85** (2000): 792-795.

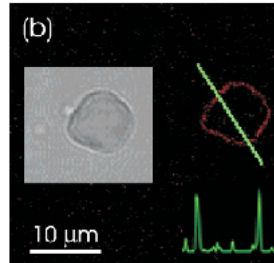
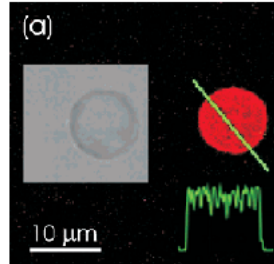
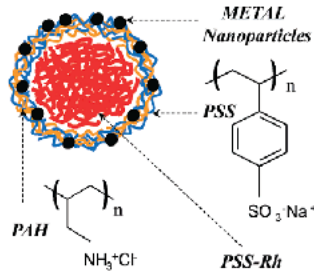
Nanoscale plasmonic heating applications

NANO LETTERS

2005
Vol. 5, No. 7
1371–1377

The Role of Metal Nanoparticles in Remote Release of Encapsulated Materials

Andre G. Skirtach,^{1*} Christophe Dejucqnat,¹ Dieter Braun,¹ Andrei S. Susna,³ Andray L. Rogach,³ Wolfgang J. Parak,² Helmut Mthwald,¹ and Gleb B. Sukhorukov¹



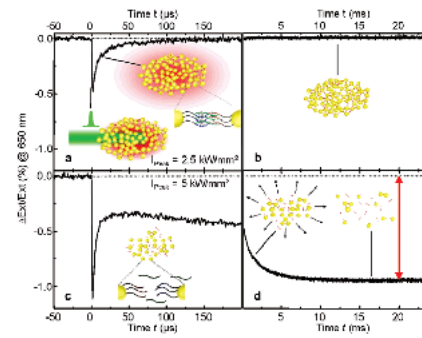
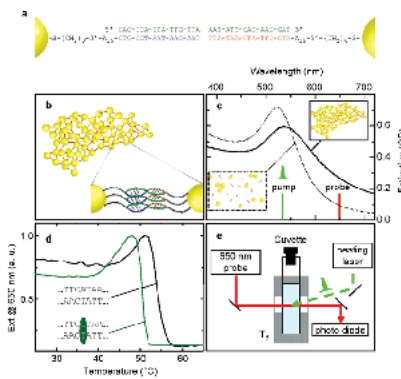
Nanoscale plasmonic heating applications

NANO LETTERS

2008
Vol. 8, No. 2
619–623

Gold NanoStoves for Microsecond DNA Melting Analysis

Joachim Stahr,¹ Calin Hrelescu,¹ Ralph A. Sperling,^{1,4} Gunnar Raschke,¹ Michael Wunderlich,³ Alfons Nicht,³ Dieter Heindl,³ Konrad Kuzinger,³ Wolfgang J. Parak,² Thomas A. Klar,^{1,1} and Jochen Feldmann^{1*}



Nanoscale plasmonic heating applications

Nanoshell-mediated near-infrared thermal therapy of tumors under magnetic resonance guidance

L. R. Hirsch*, R. J. Stafford¹, J. A. Bankson¹, S. R. Sershen*, B. Rivera², R. E. Price³, J. D. Hazle¹, N. J. Halas⁵, and J. L. West**

PNAS | November 11, 2003 | vol. 100 | no. 23 | 13549–13554

Laser only

a

Nanoshells + Laser

b

Fluorescein-Dextran

c

Fluorescein-Dextran

d

Manipulating heat at the nanoscale

80 kW/cm² ~ 1 mW / 1mm

Why?

- New microscopy techniques reveal structures and pathways of nano (bio)systems with great detail
- Still, full understanding of functions Require in some cases energetic information too.

Remotely controlled nanoscopic heat sources

↓

Thermodynamic experiments at the nanoscale

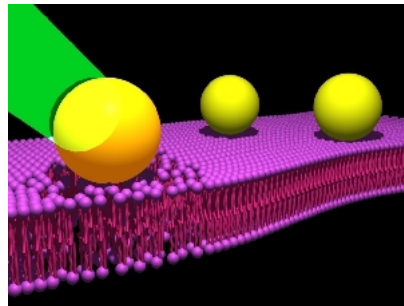
Manipulating heat at the nanoscale

**NANO
LETTERS**

2009
Vol. 9, No. 8
2903-2908

Controlled Nanometric Phase Transitions of Phospholipid Membranes by Plasmonic Heating of Single Gold Nanoparticles

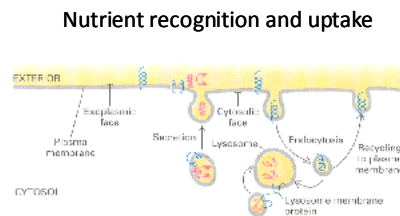
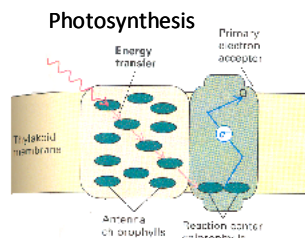
A. S. Urban,[†] M. Fedoruk,[†] M. R. Horton,[‡] J. O. Rädler,[‡] F. D. Stefani,^{†*} and J. Feldmann^{†‡}



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Membrane processes

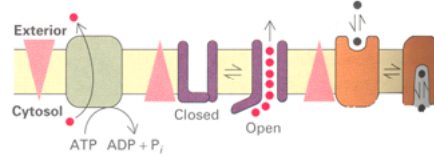


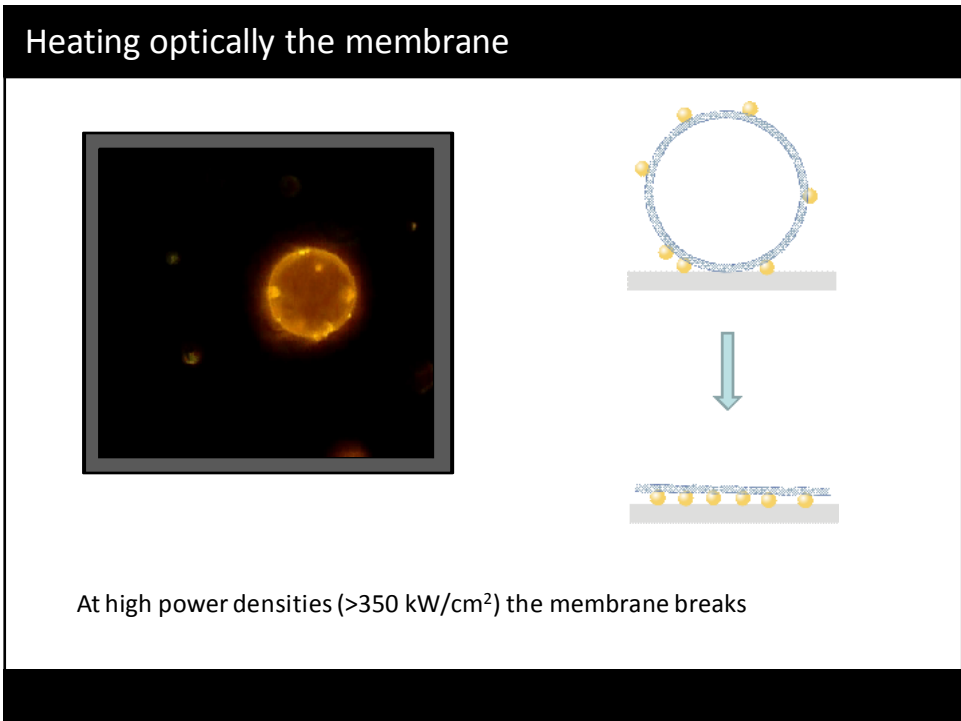
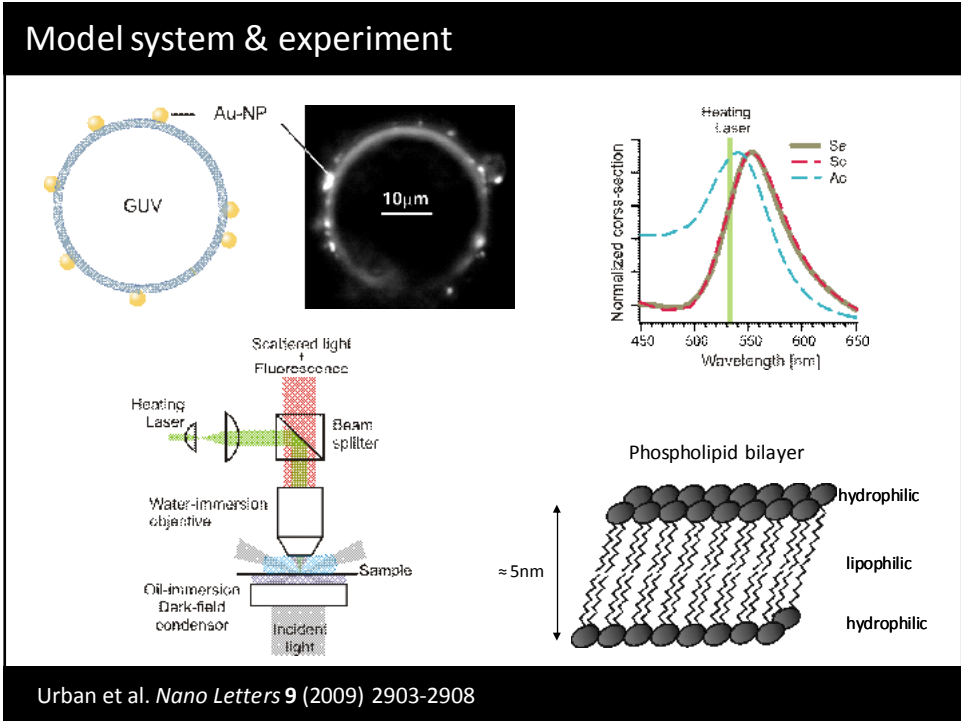
Remotely controlled nanoscopic sources of heat



Investigation + manipulation of thermal processes at the nanoscale

Ion transport, signaling





Membrane physics: fluid – gel phase transition

Melting temperature dependent on phospholipid

gel phase \longleftrightarrow T_m fluid phase

$T_m = -21^\circ\text{C}$ $T_m = 42^\circ\text{C}$ $T_m = 24^\circ\text{C}$

Upon melting, the membrane properties change:

- It becomes more flexible
- Self diffusion of lipids increases (up to 10^3 -fold)

Optically induced melting of the membrane

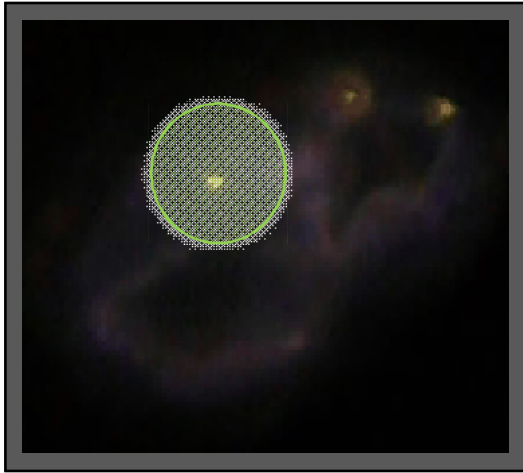
~ 1 minute

10 μm

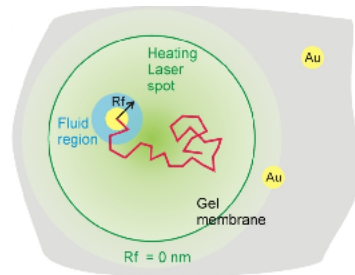
The hot particles melt the membrane \longrightarrow the latter relaxes to a sphere

Urban et al. *Nano Letters* 9 (2009) 2903-2908

Local nanoscale heating the membrane

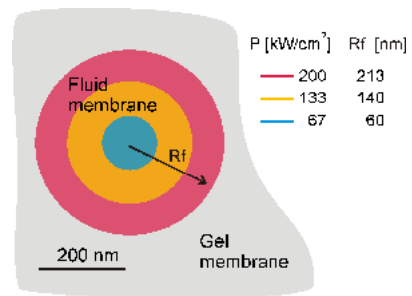
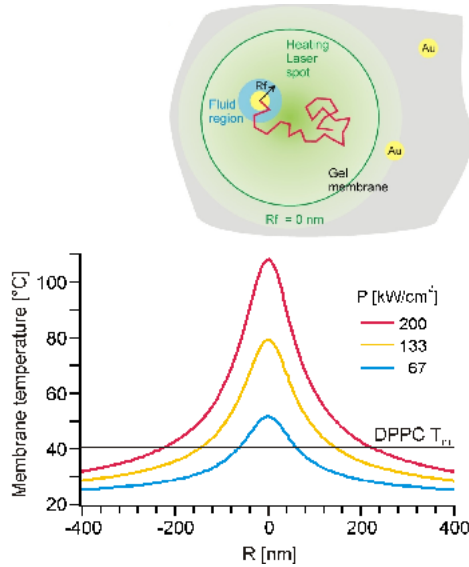


The hot particle melts the nearby membrane and opens its way across the rigid gel membrane



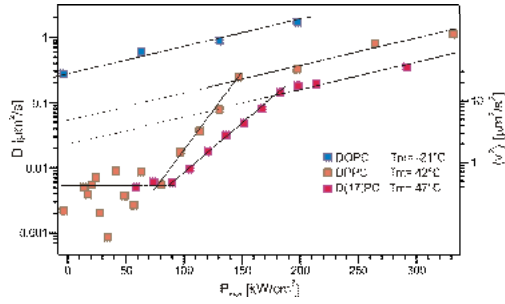
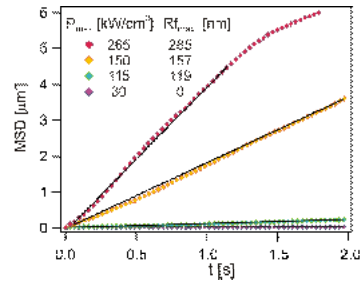
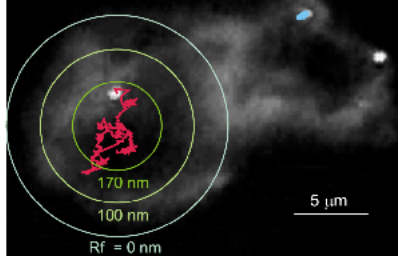
Urban et al. *Nano Letters* 9 (2009) 2903-2908

Nanometric phase transitions



Urban et al. *Nano Letters* 9 (2009) 2903-2908

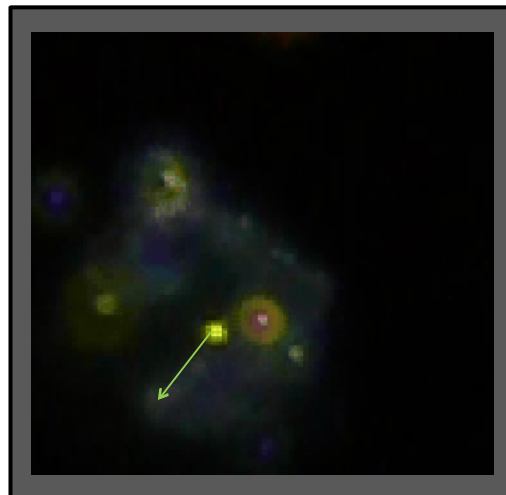
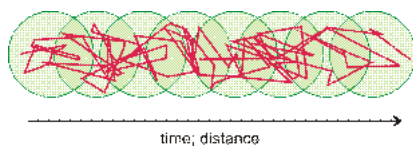
Corralled diffusion of the hot nanoparticle



We can induce and characterize the nanoscale phase transition

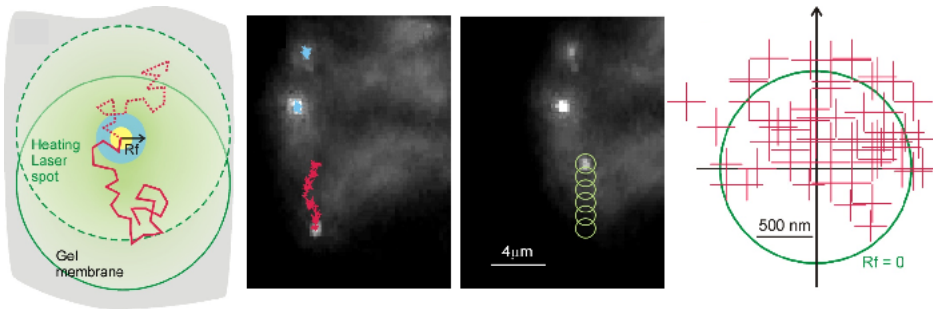
Urban et al. *Nano Letters* 9 (2009) 2903-2908

Guiding the hot nanoparticle



Urban et al. *Nano Letters* 9 (2009) 2903-2908

Guiding the hot nanoparticle



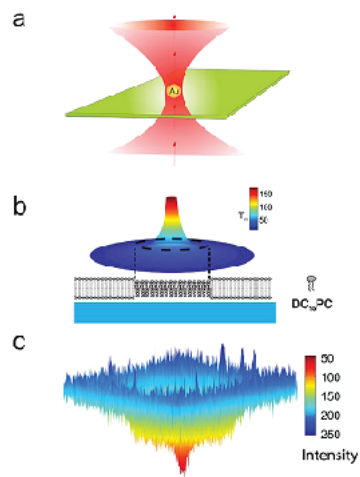
The hot nanoparticle can be directed to specific locations on the membrane

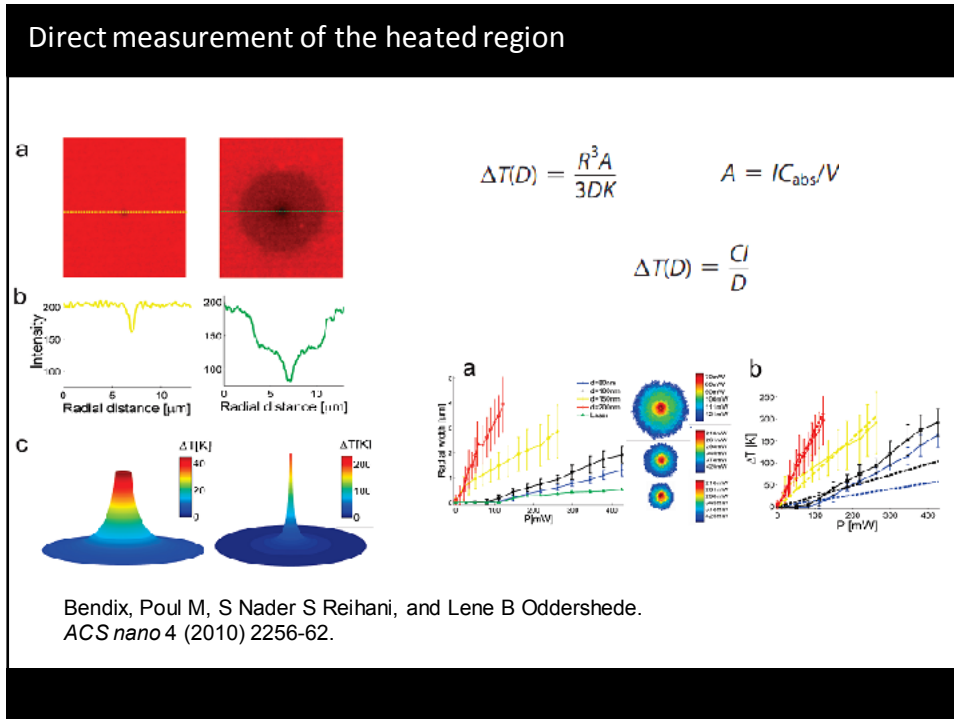
Urban et al. *Nano Letters* 9 (2009) 2903-2908

Direct Measurements of Heating by Electromagnetically Trapped Gold Nanoparticles on Supported Lipid Bilayers

Poul M. Bendix, S. Nader S. Reihani,[†] and Lene B. Oddershede^{*}
[†]4516-1416, University of Copenhagen, 2300 Copenhagen, Denmark; *Corresponding author: lbo@bio.ku.dk

ACS NANO VOL. 4 2256-2262 • 2010





Nano heat generators on phospholipid membranes

Adapting the heating beam:
 specific location + controlled heat deposition

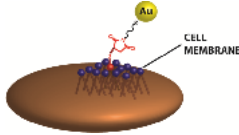
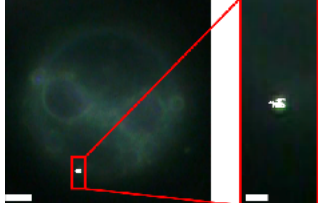
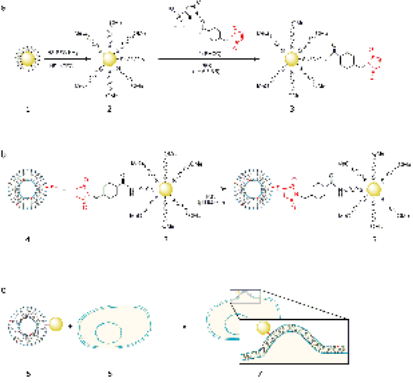
Potential: membrane physics
 trigger protein function
 map energetic obstacles for protein diffusion.

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NANO LETTERS pubs.acs.org/nano.lett

Immobilization of Gold Nanoparticles on Living Cell Membranes upon Controlled Lipid Binding

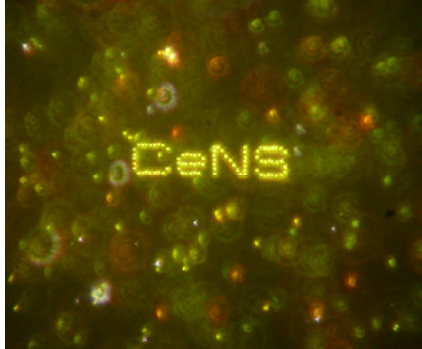
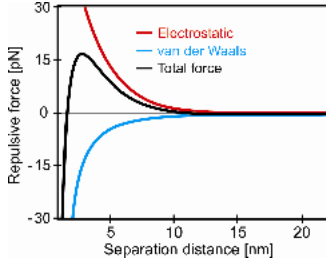

Haojin Ba, Jessica Rodriguez-Fernández,* Fernando D. Stefani,[†] and Jochen Feldmann

NANO LETTERS pubs.acs.org/nano.lett


Laser Printing Single Gold Nanoparticles

Alexander S. Urban,[†] Andrey A. Lutich,^{*†} Fernando D. Stefani,^{*††} and Jochen Feldmann^{*†}

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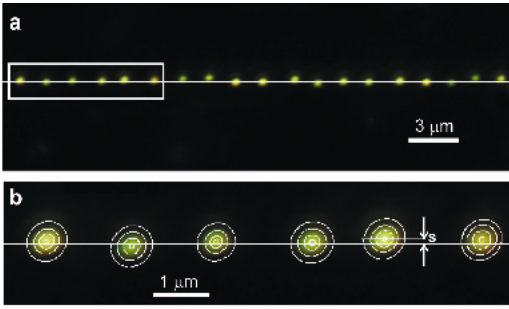


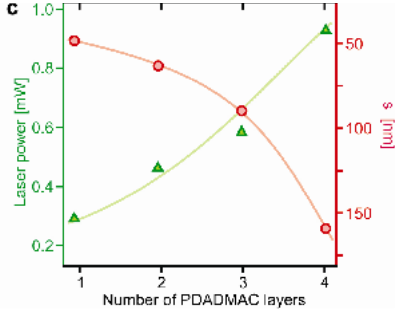

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Printing accuracy





Number of PDADMAC layers	Laser power [mW]	Exposure time [μs]
1	0.9	150
2	0.8	100
3	0.65	50
4	0.25	25

There is no fundamental limit!

- Increase solution viscosity
- Tighter focusing
- Microinjection

In addition:

- Orientation control by polarization

Urban et al. *Submitted* (2010)