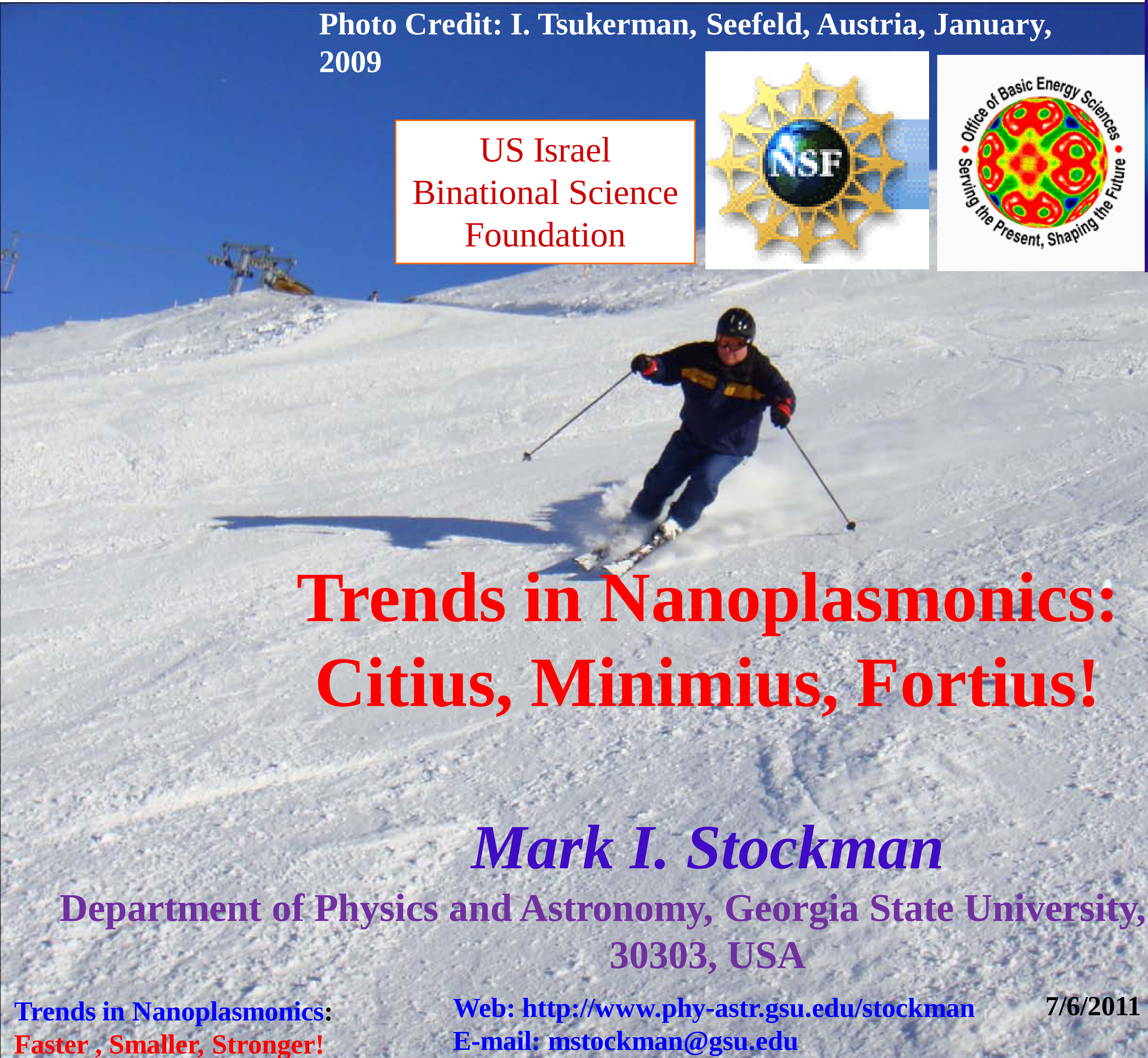

Photo Credit: I. Tsukerman, Seefeld, Austria, January, 2009

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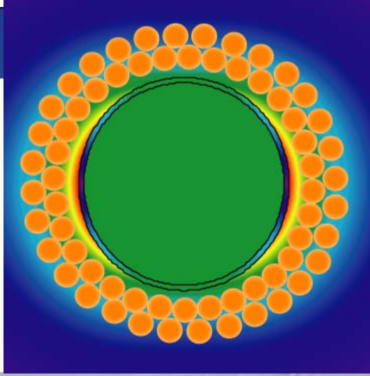

Trends in Nanoplasmonics: Citius, Minimius, Fortius!

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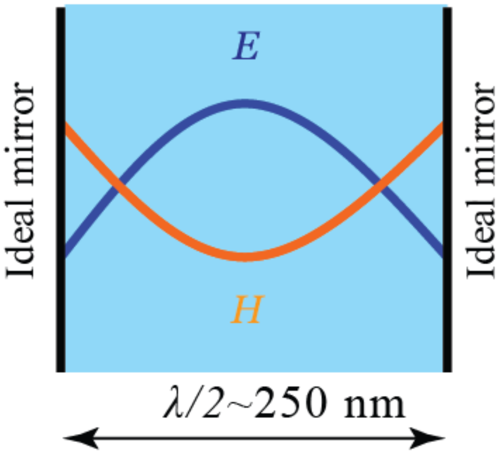
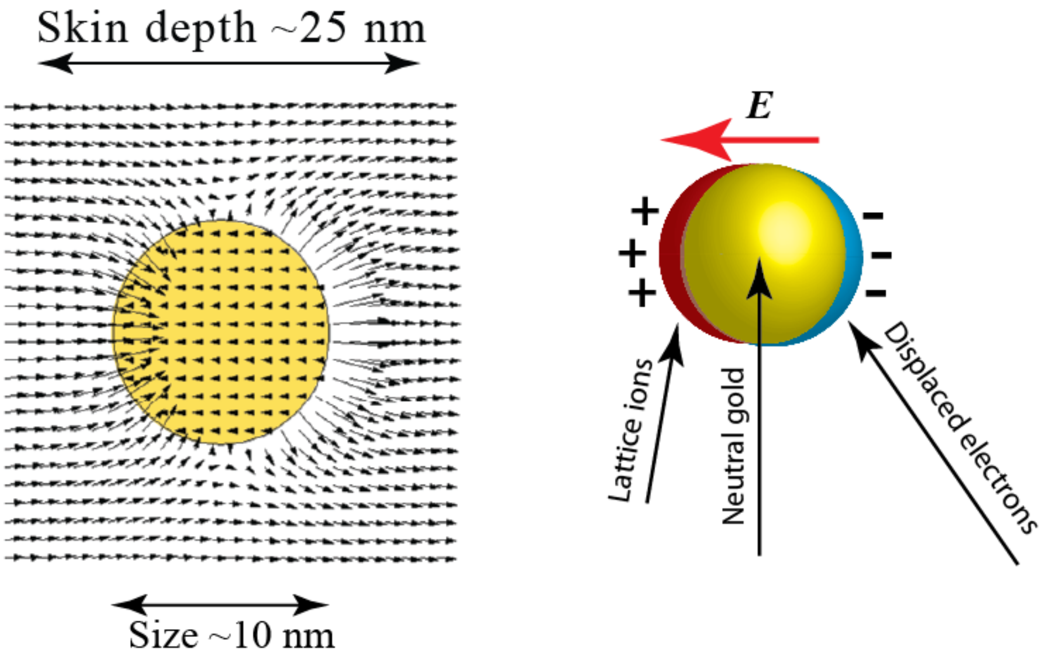
Nanoplasmonics in a nano-nutshell

Concentration of optical energy on the nanoscale



Photon



Surface Plasmon

Lycurgus Cup (4th Century AD): Roman Nanotechnology

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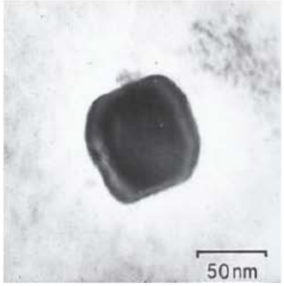
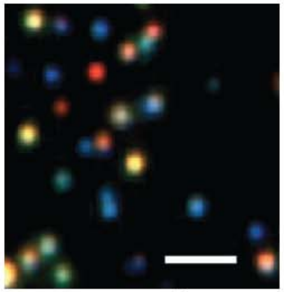


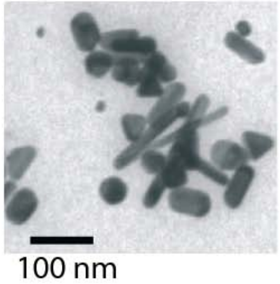
I. Freestone, N. Meeks, M. Sax, and C. Higgitt, *The Lycurgus Cup - a Roman Nanotechnology*, Gold Bull. **40**, 270-277 (2007)

Nanoplasmonic colors are very bright. Scattering and absorption of light by them are very strong. This is due to the fact that all of the millions of electrons move in unison in plasmonic oscillations

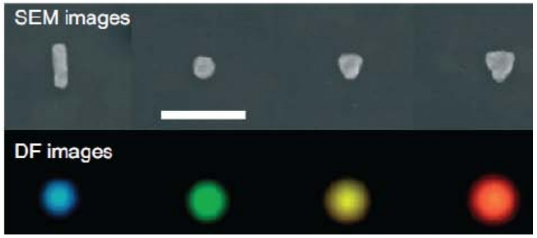
Nanoplasmonic colors are also eternal: metal nanoparticles are stable in glass: they do not bleach and do not blink. Gold is stable under biological conditions and is not toxic *in vivo*

Colors of Silver Nanocrystals and Gold Nanoshapes





C. Orendorff, T. Sau, and C. Murphy, *Shape-Dependent* …, Small **2**, 636-639 (2006)

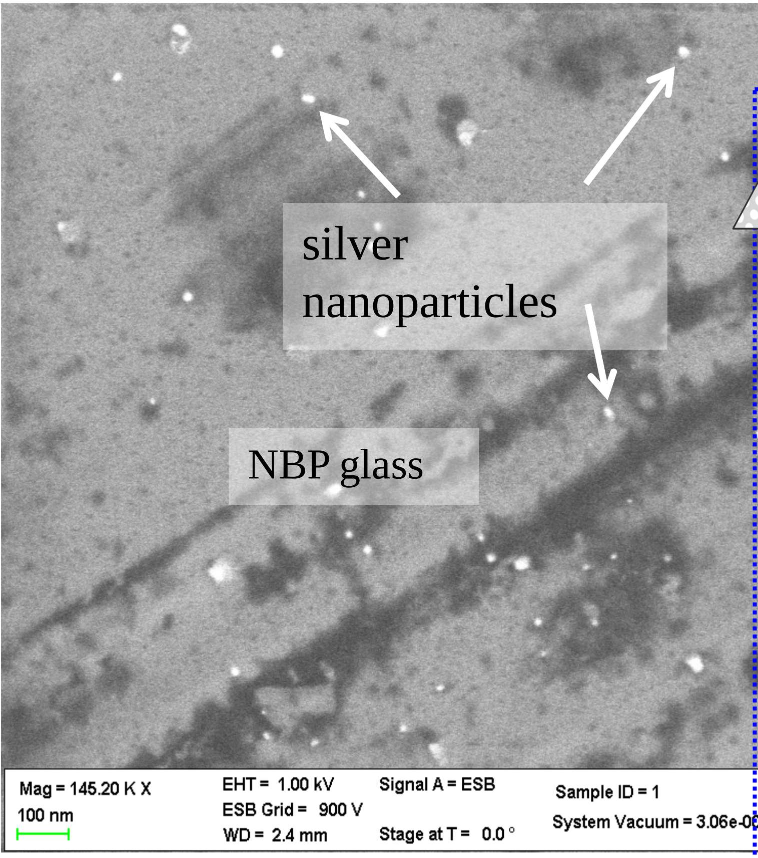


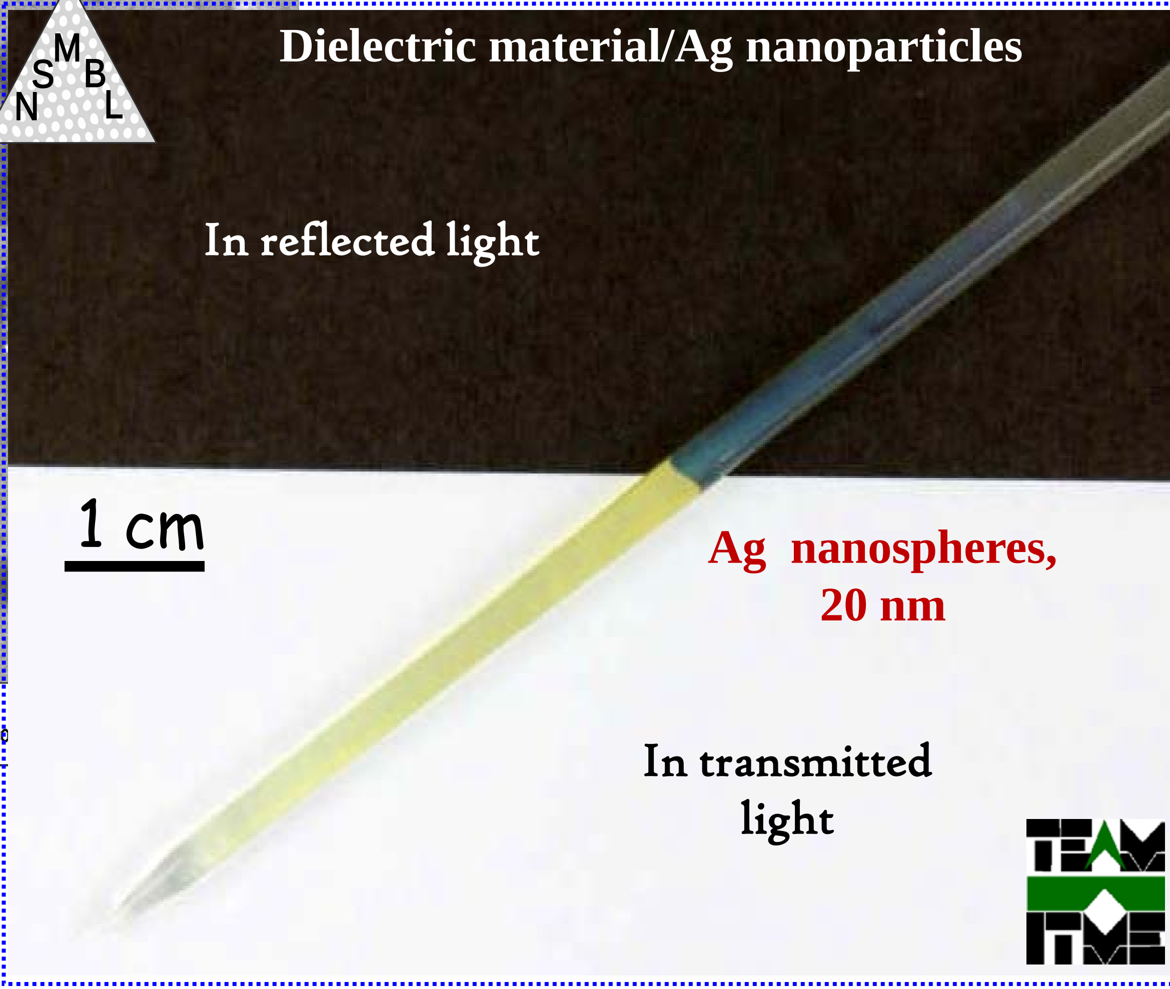
Scanning electron microscopy

Dark field optical microscopy

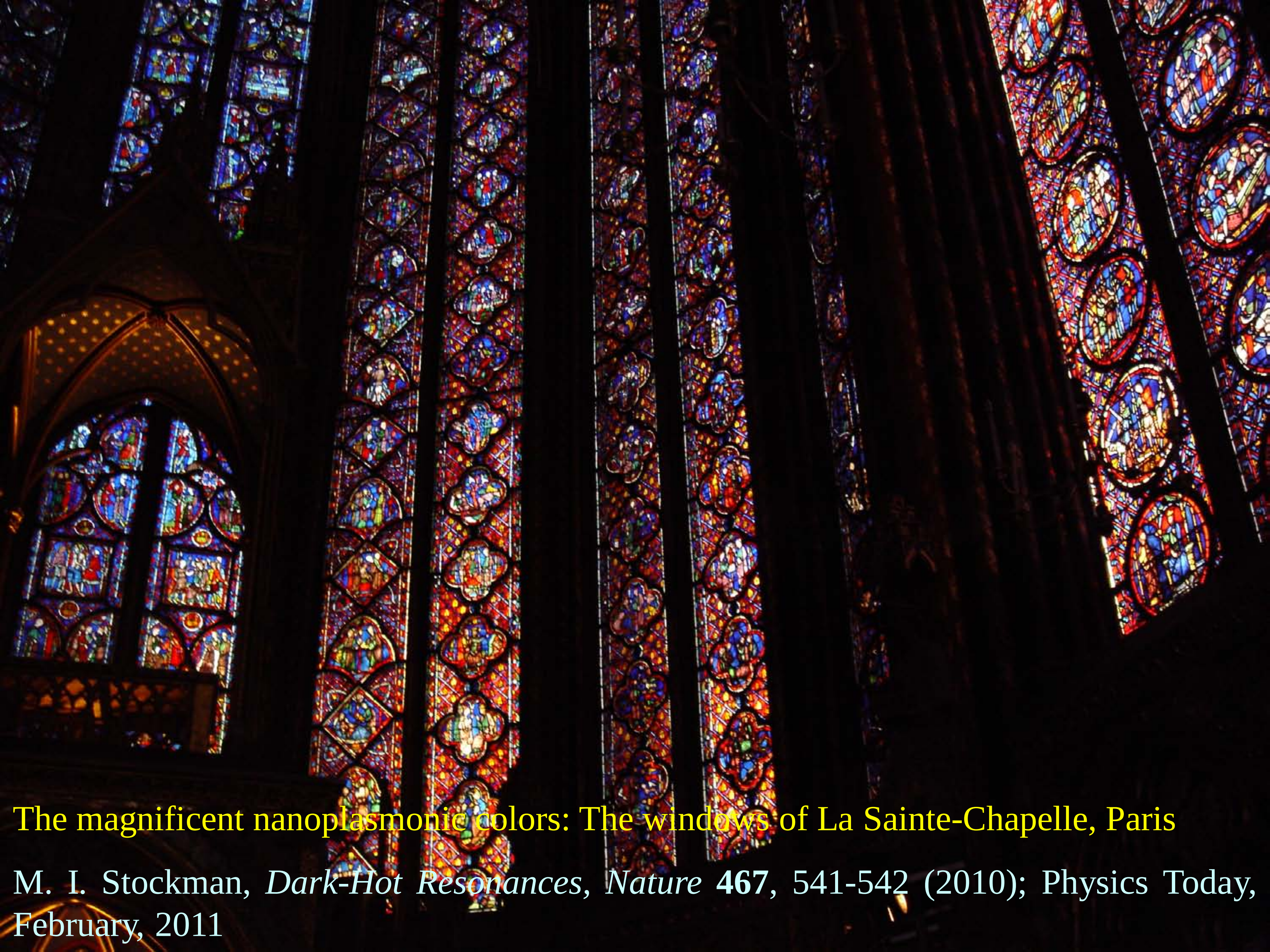
W. A. Murray and W. L. Barnes, *Plasmonic Materials*, Adv. Mater. **19**, 3771-3782 (2007) [Scale bar: 300 nm]

SEM-ESB: Energy Selective Backscattered





D. A. Pawlak et al., Institute of Electronic Materials Technology, Warsaw, Poland



The magnificent nanoplasmonic colors: The windows of La Sainte-Chapelle, Paris

M. I. Stockman, *Dark-Hot Resonances*, *Nature* **467**, 541-542 (2010); Physics Today, February, 2011

Applications of Nanoplasmonics:

1. Ultrasensitive and express sensing and detection using both SPPs and SPs (LSPRs): see, e.g., J. N. Anker, W. P. Hall, O. Lyandres, N. C. Shah, J. Zhao, and R. P. Van Duyne, *Biosensing with Plasmonic Nanosensors*, Nature Materials 7, 442-453 (2008); Biacore (GE) SPP sensors: http://www.biacore.com/
2. Near-filed scanning microscopy (or, nanoscopy): NSOM (SNOM)
3. Nanoantennas: Coupling of light to nanosystems. Extraction of light from LEDs and lasers [N. F. Yu, J. Fan, Q. J. Wang, C. Pflugl, L. Diehl, T. Edamura, M. Yamanishi, H. Kan, and F. Capasso, *Small-Divergence Semiconductor Lasers by Plasmonic Collimation*, Nat. Phot. 2, 564-570 (2008)]; nanostructured antennas for photodetectors and solar cells; heat-assisted magnetic memory [W. A. Challener *et al.*, Nat. Photon. 3, 220 (2009)]
4. Photo- and chemically stable labels and probes for biomedical research and medicine
5. Nanoplasmonic-based immunoassays and tests. Home pregnancy test (dominating the market), PSA test (clinic), troponin heart-attack test, and HIV tests (in trials)
6. Near perspective: Generation of EUV and XUV pulses
7. Thermal cancer therapy: L. R. Hirsch, R. J. Stafford, J. A. Bankson, S. R. Sershen, B. Rivera, R. E. Price, J. D. Hazle, N. J. Halas, and J. L. West, *Nanoshell-Mediated Near-Infrared Thermal Therapy of Tumors under Magnetic Resonance Guidance*, Proc. Natl. Acad. Sci. USA 100, 13549-13554 (2003). C. Loo, A. Lowery, N. Halas, J. West, and R. Drezek, *Immunotargeted Nanoshells for Integrated Cancer Imaging and Therapy*, Nano Lett. 5, 709-711 (2005)

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Plasmonic Hot Spots 15th Anniversary

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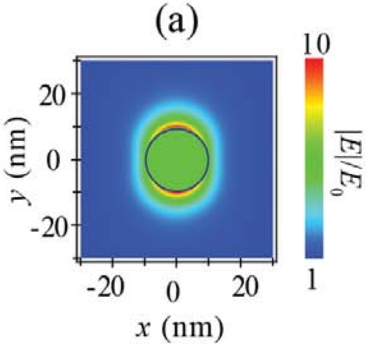
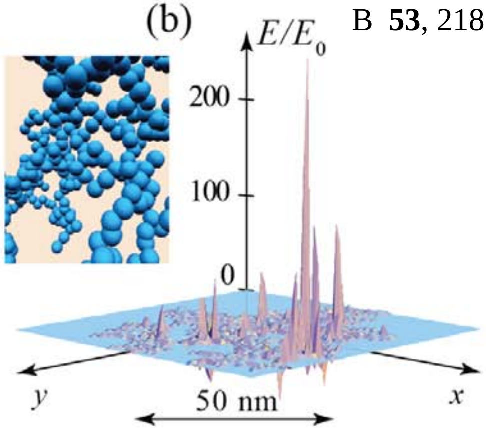
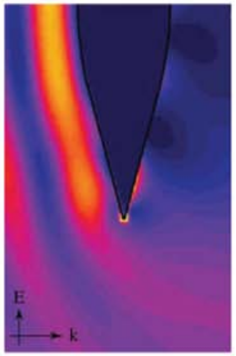
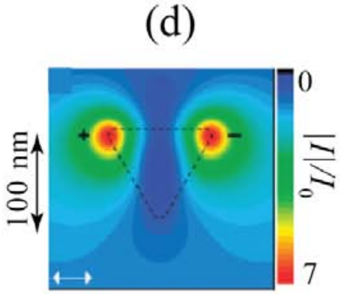


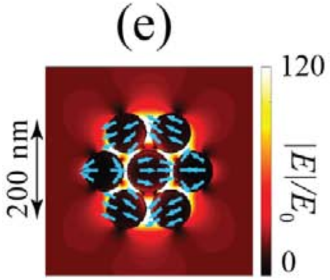




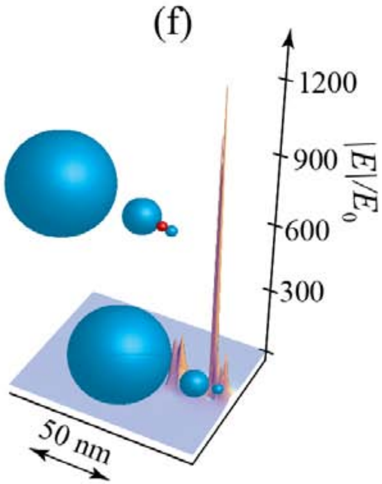
L. Novotny and S. J. Stranick, Annual Rev. Phys. Chem. **57**, 303-331 (2006)



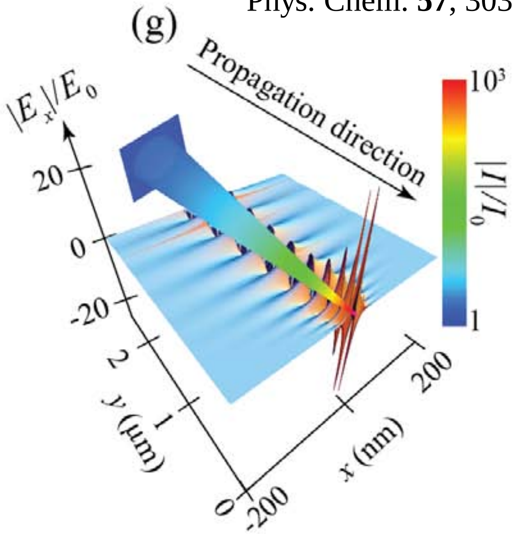
M. Rang et al., Nano Lett. **8**, 3357 (2008)



- J. A. Fan et al., Science **328**, 1135 (2010)
- M. Hentschel et al., Nano Lett. **10**, 2721 (2010)



K. Li, M. I. Stockman, and D. J. Bergman, Phys. Rev. Lett. **91**, 227402 (2003)



M. I. Stockman, Phys. Rev. Lett. **93**, 137404 (2004)

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- Conclusions
- Bonus: Ultrafast Nanoscale Coherent Control
- Bonus: Attosecond Plasmonic Field Nanoscope

Enhancement factors for small nanoparticles (size $R < l_s \sim 25\,\mathrm{nm}$)

Plasmonic quality factor: $Q = \dfrac{-\operatorname{Re}\varepsilon_m}{\operatorname{Im}\varepsilon_m} \sim 10-100$

Radiative rate enhancement for dipole mode frequency: $\sim Q^2$

Excitation rate enhancement: $\sim Q^2$

SERS enhancement: $\sim Q^4$

The above-listed enhancement factors do not depend on size *R*

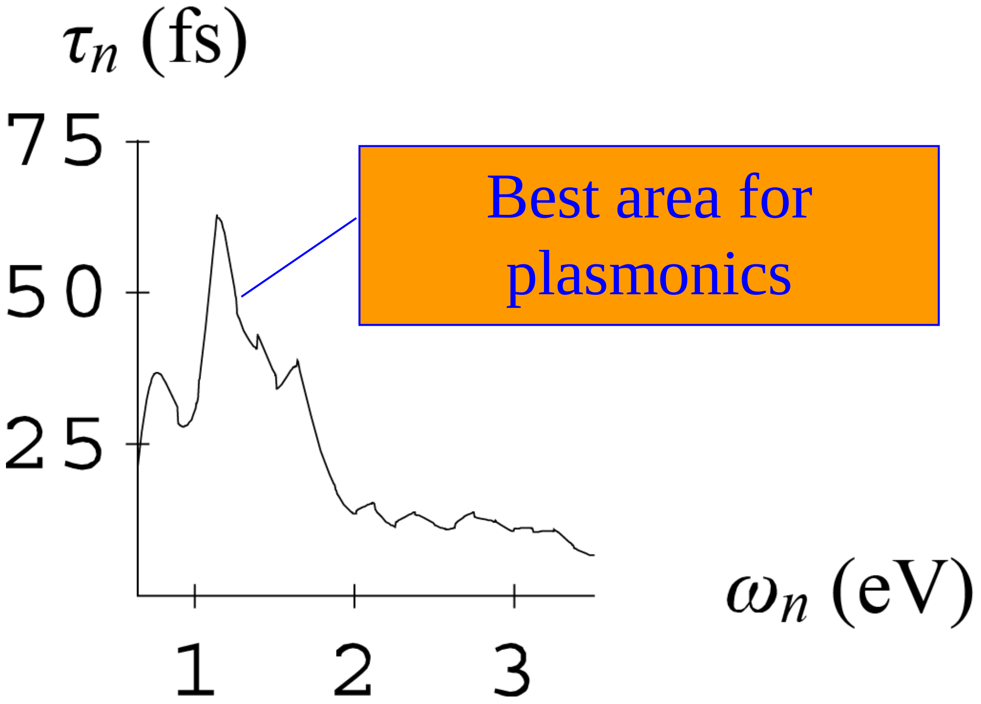
Emission rate of SPs into a mode: $\propto \dfrac{Q}{R^3}$

This with respect to free photons: $\sim \dfrac{\bar{\lambda}^3 Q}{R^3}$ (Purcell factor)

This enhancement factor is *inversely* proportional to *R*^{3}

This is of fundamental importance for spasers (plasmonic nanolasers)

Nanoplasmonics is intrinsically ultrafast:



Best area for plasmonics

Surface plasmon relaxation times are in ~10-100 fs range

Spectrally, surface plasmon resonances in complex systems occupy a very wide frequency band; for gold and silver:

$$\Delta\omega \approx \omega_p / \sqrt{2} \approx 4\,\text{eV}$$

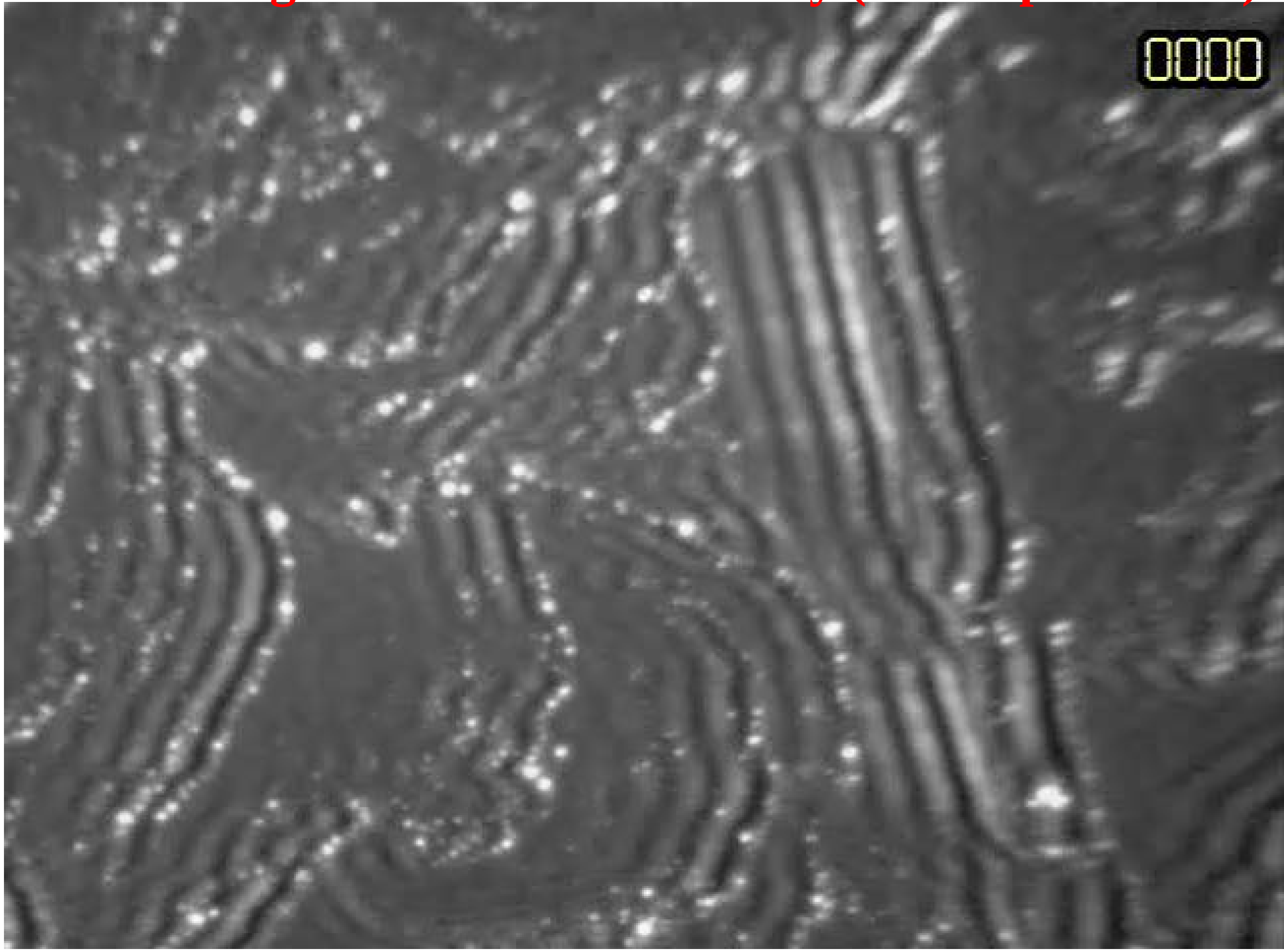
Including aluminum with plasmon responses in the ultraviolet, this spectral width increases to ~10 eV.

Corresponding rise time of plasmonic responses ~ 100 as

Localized SP hot spots and SPPs coexist in space and time on nanostructured surfaces

A. Kubo, K. Onda, H. Petek, Z. Sun, Y. S. Jung, and H. K. Kim, *Femtosecond Imaging of Surface Plasmon Dynamics in a Nanostructured Silver Film*, Nano Lett. 5, 1123 (2005).

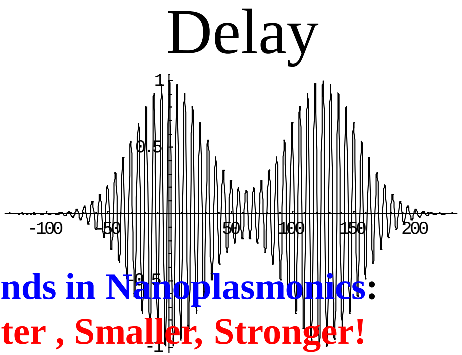
PEEM Image as a Function of Delay (250 as per frame)



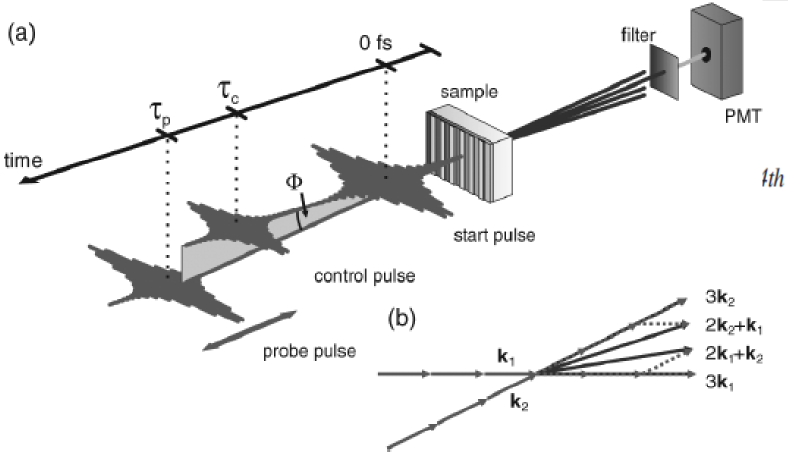
200 nm

30 femtoseconds from life of a nanoplasmonic system

Localized SP hot spots are deeply subwavelength as seen in PEEM (photoemission electron microscope)



PRL **104,** 113903 (2010) PHYSICAL REVIEW LETTERS week ending 19 MARCH 2010



All-Optical Control of the Ultrafast Dynamics of a Hybrid Plasmonic System

Tobias Utikal,[1,2] Mark I. Stockman,[1,2,3] Albert P. Heberle,[1] Markus Lippitz,[1,2] and Harald Giessen[1]

4th Physics Institute and Research Center SCoPE, University of Stuttgart, Pfaffenwaldring 57, 70550 Stuttgart, Germany
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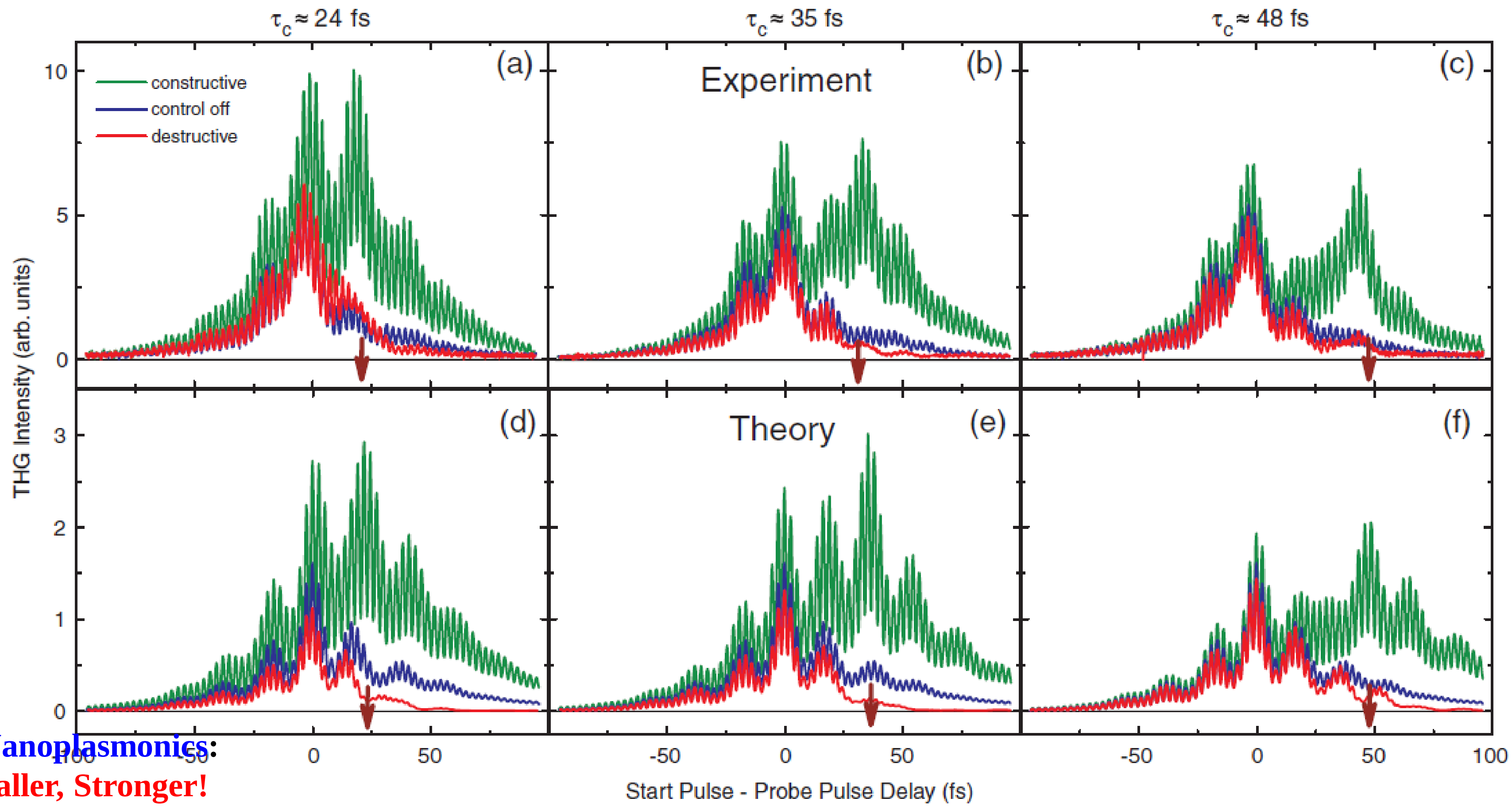
[3]*Department of Physics and Astronomy, Georgia State University, Atlanta, Georgia 30303, USA*

Constructive control by the second pulse

Destructive control by the second pulse

No control pulse (free induction decay)



Trends in Nanoplasmonics:

Faster , Smaller, Stronger!

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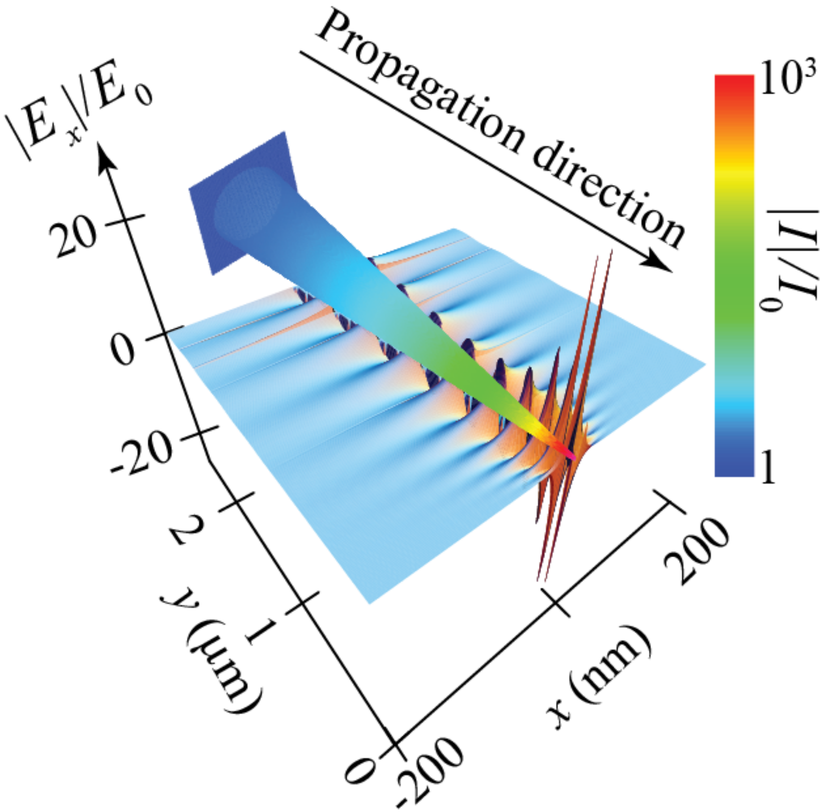
- Bonus: Attosecond Plasmonic Field Nanoscope

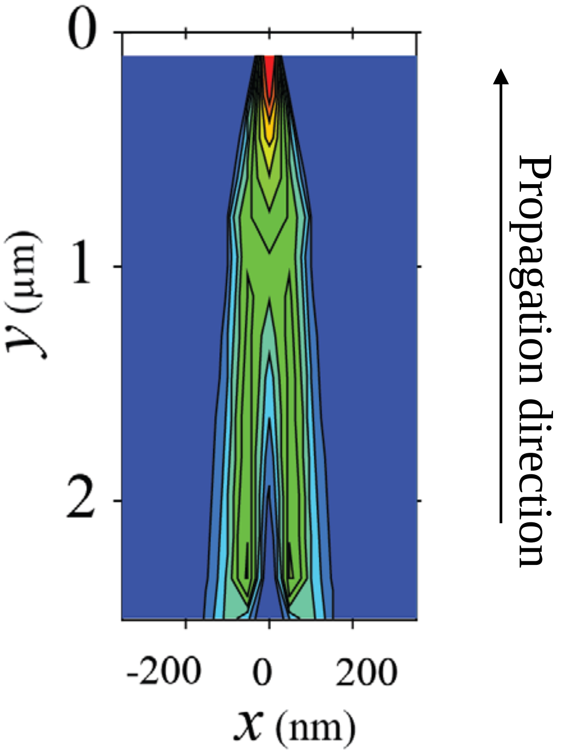
Adiabatic Compression

Field enhancement :

$$\sim \frac{L_s}{R} \text{ (for 2d compression)}, \; L_s \approx 25\,\text{nm}$$

$$\sim \left(\frac{L_s}{R}\right)^{3/2} \text{ (for 3d compression)}$$



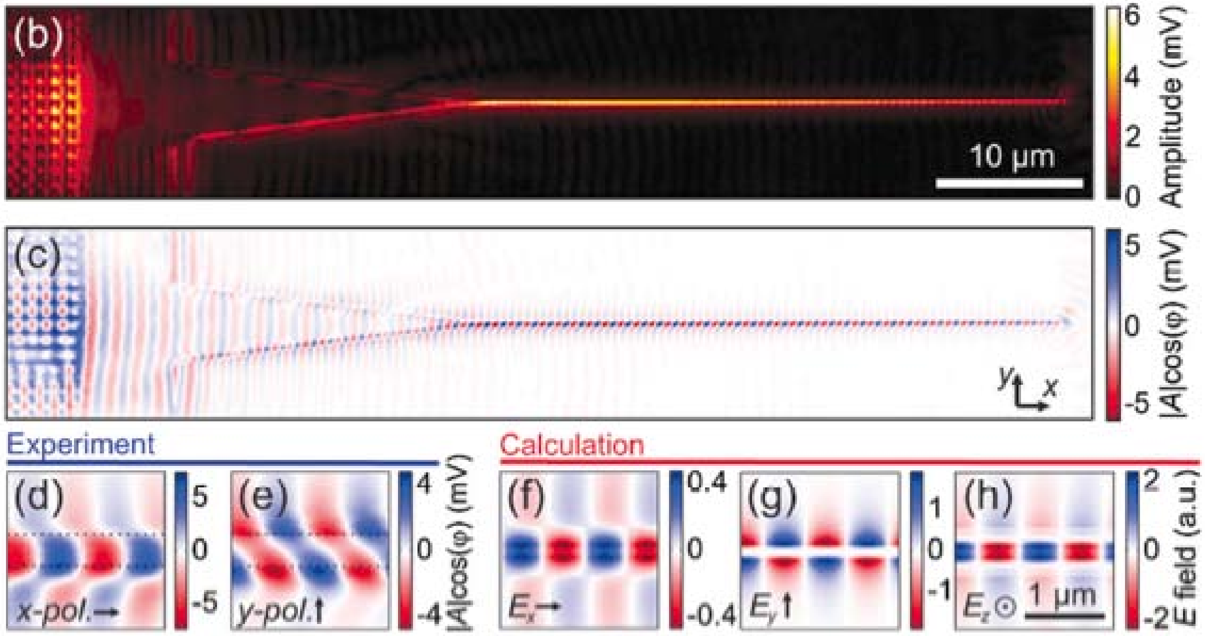


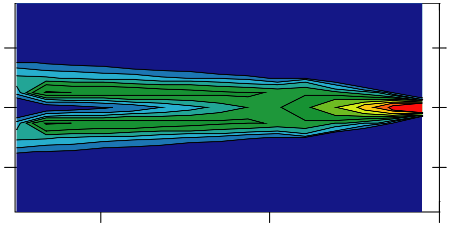
M. I. Stockman, *Nanofocusing of Optical Energy in Tapered Plasmonic Waveguides*, Phys. Rev. Lett. **93**, 137404-1-4 (2004).

PRL **102,** 203904 (2009) PHYSICAL REVIEW LETTERS

Nanowire Plasmon Excitation by Adiabatic Mode Transformation

Ewold Verhagen,[*] Marko Spasenović, Albert Polman, and L. (Kobus) Kuipers





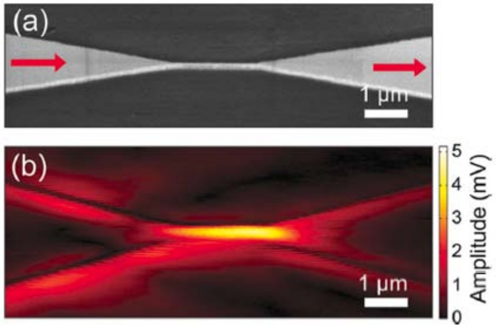


FIG. 4 (color). (a) Secondary electron micrograph of a 2 μm long nanowire connected by tapered waveguide sections for input and output coupling. (b) Near-field amplitude of forward-propagating waves in the structure at $\lambda = 1550$ nm. The intensity transmission of the complete structure is 20 ± 6%.

NANO LETTERS
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Near-Field Localization in Plasmonic Superfocusing: A Nanoemitter on a Tip

DOI: 10.1021/nl903574a | *Nano Lett.* **2010**, *10*, 592-596

Catalin C. Neacsu,[†,#] Samuel Berweger,[†,#] Robert L. Olmon,[†,‡,#] Laxmikant V. Saraf,[‖]
Claus Ropers,[⊥] and Markus B. Raschke[*,†,§]

[†]Department of Chemistry, [‡]Department of Electrical Engineering, [§]Department of Physics, University of
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Laboratory, Richland, Washington 9935
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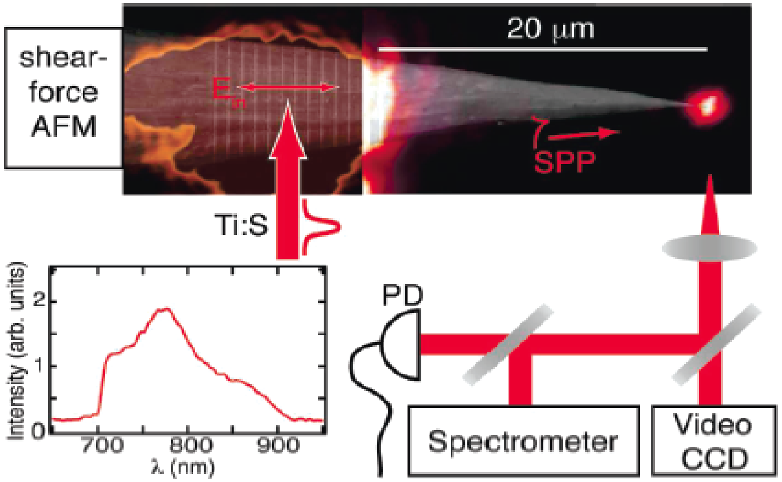


FIGURE 1. Grating coupling of surface plasmons on a tip. Overlay of SEM and optical far-field image of a Au tip with grating written by FIB for surface plasmon coupling of incident near-IR light from a Ti:Sapphire laser (spectrum shown). The grating with period $a_0 \sim 770$ nm is illuminated with polarization parallel with respect to the tip axis and an incident focus size of ~8 μm. The nonradiative SPP propagation leads to energy transfer and focusing and finally reemission near the tip apex with radius ≲15 nm.

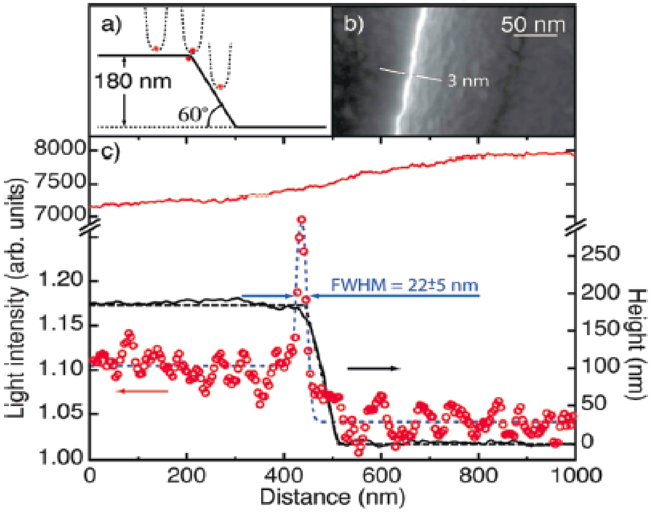


FIGURE 3. Determination of tip emitter size. (a) Schematic of scanning the nanofocusing tip across a silicon step edge with radius 3 ± 1 nm. (b) Top view SEM image of step edge. The wall and lower terrace are on the right-hand side. The edge serves as a local scatterer of the optical near-field of the apex. (c) The optical signal of a lateral scan across the step edge provides a measure of the spatial field confinement and thus the emitter size at the apex. Solid black line: AFM topography of the step. Red circles: plasmonic edge-scattered light intensity of the apex. The optical intensity peaks at the step edge and displays a width of 22 ± 5 nm, demonstrating the near-field localization at the apex. Solid red: Signal obtained under direct illumination of the apex under otherwise identical conditions.

nature nanotechnology

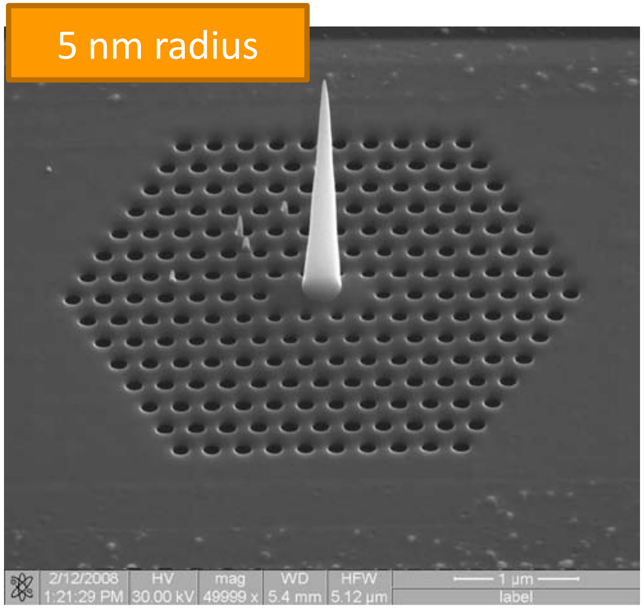
ARTICLES

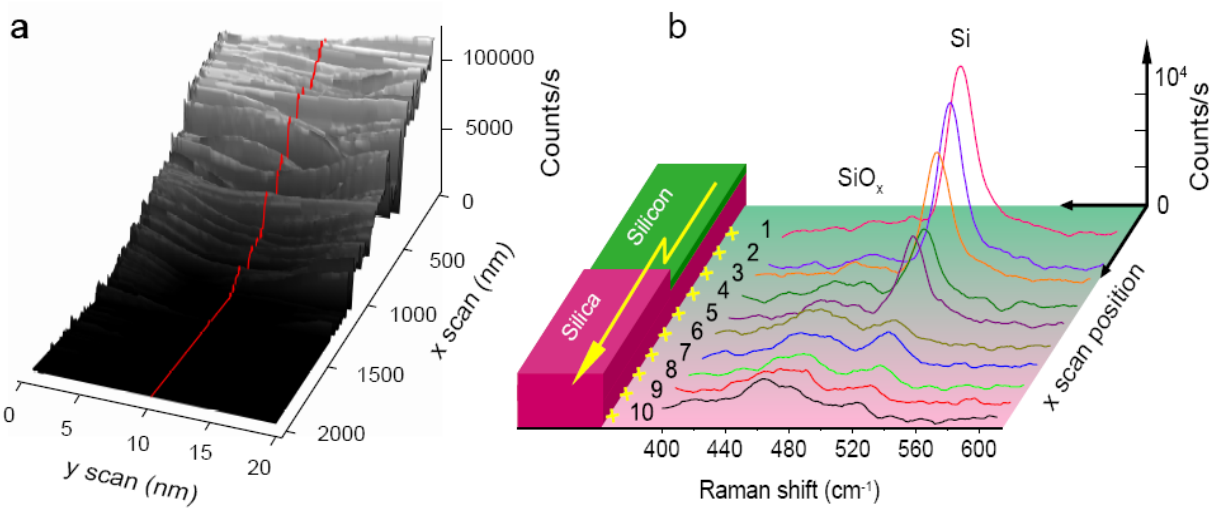
PUBLISHED ONLINE: 22 NOVEMBER 2009 | DOI: 10.1038/NNANO.2009.348

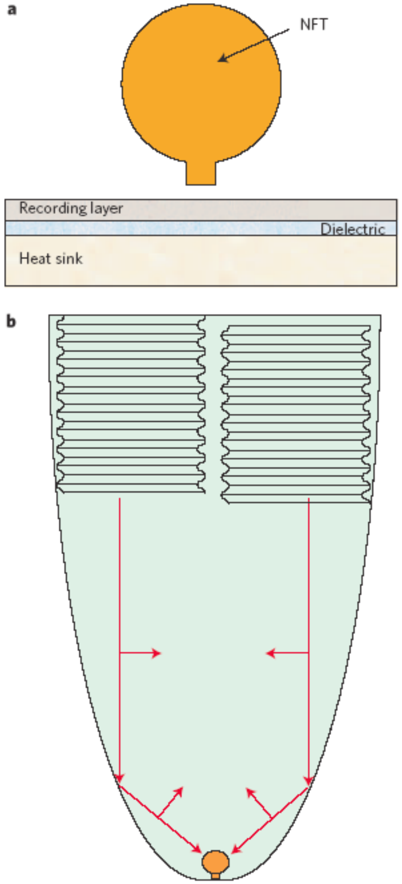
Nanoscale chemical mapping using three-dimensional adiabatic compression of surface plasmon polaritons

Francesco De Angelis[1,2], Gobind Das[1], Patrizio Candeloro[2], Maddalena Patrini[3], Matteo Galli[3], Alpan Bek[4], Marco Lazzarino[4,5], Ivan Maksymov[3], Carlo Liberale[2], Lucio Claudio Andreani[3] and Enzo Di Fabrizio[1,2]*

5 nm radius



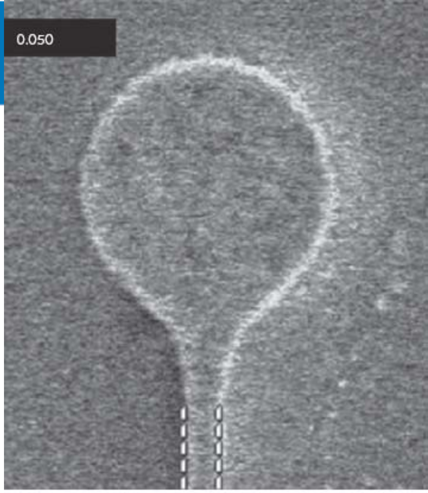


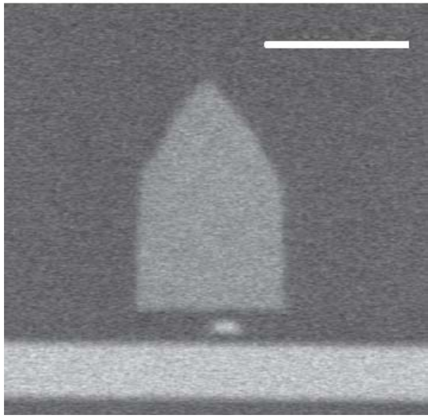


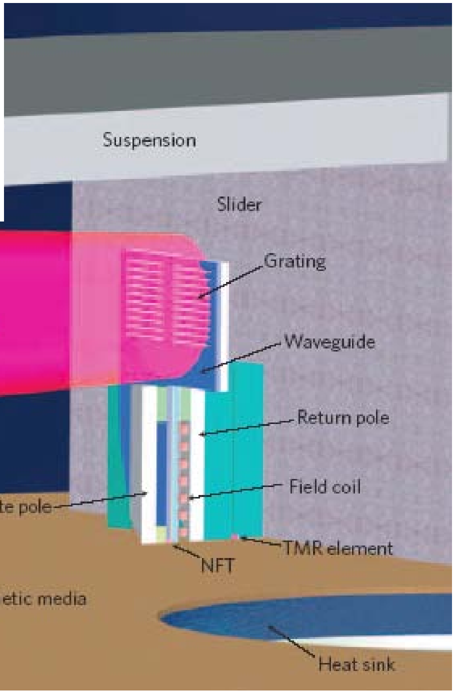
nature photonics
ARTICLES
PUBLISHED ONLINE: 22 MARCH 2009 | DOI: 10.1038/NPHOTON.2009.26

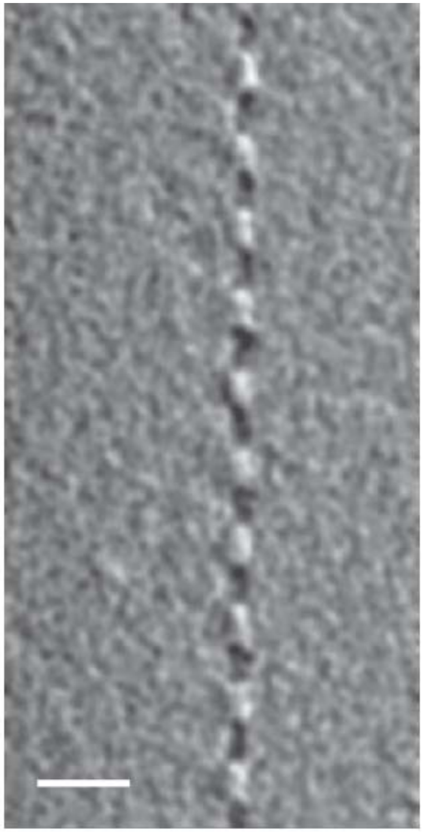
Heat-assisted magnetic recording by a near-field transducer with efficient optical energy transfer

W. A. Challener*, Chubing Peng, A. V. Itagi, D. Karns, Wei Peng, Yingguo Peng, XiaoMin Yang, Xiaobin Zhu, N. J. Gokemeijer, Y.-T. Hsia, G. Ju, Robert E. Rottmayer, Michael A. Seigler and E. C. Gage





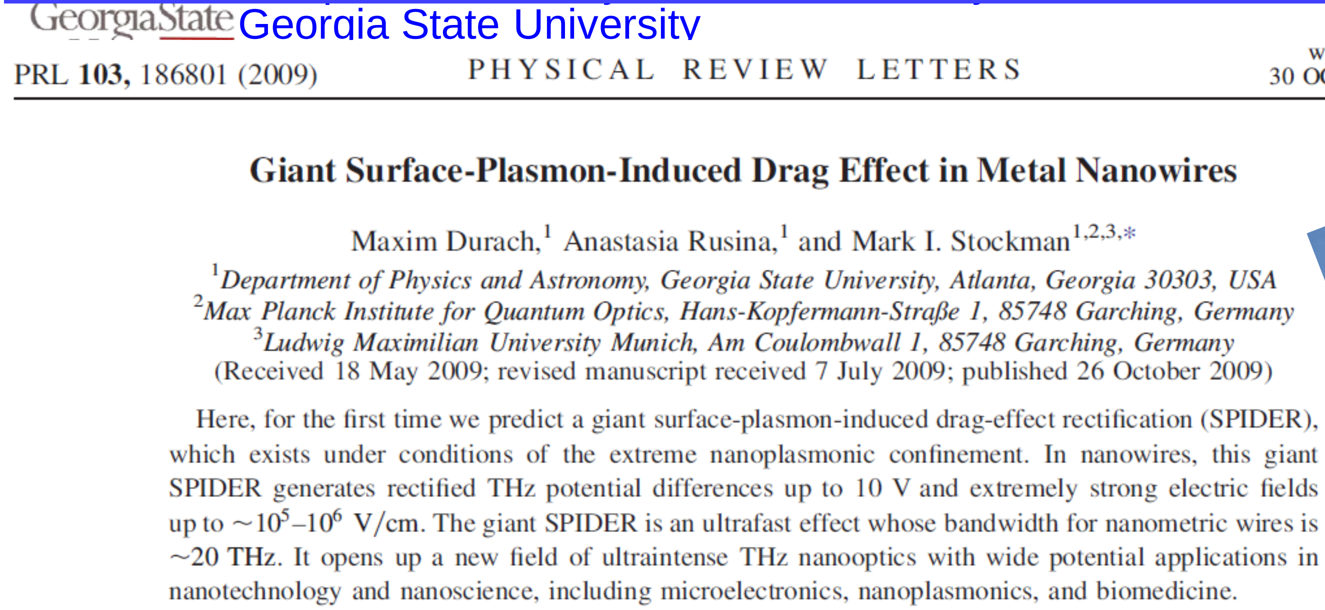




MFM image of a recorded track. The track width is ~70 300 nm.

Giant SPIDER – Surface-Plasmon-Induced Drag-Effect Rectification

Georgia State University



PRL **103,** 186801 (2009) PHYSICAL REVIEW LETTERS week ending 30 OCTOBER 2009

Giant Surface-Plasmon-Induced Drag Effect in Metal Nanowires

Maxim Durach,[1] Anastasia Rusina,[1] and Mark I. Stockman[1,2,3,*]

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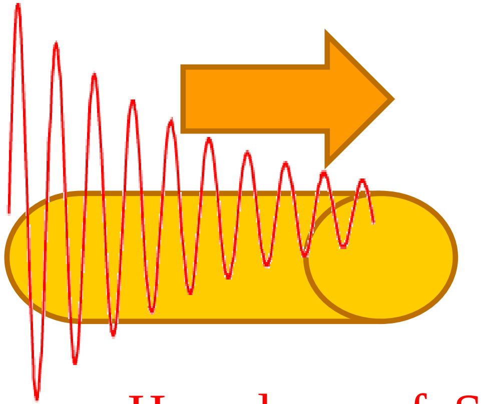
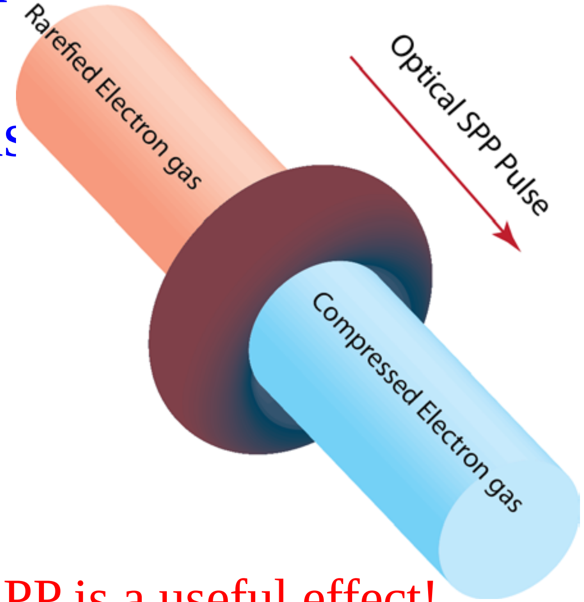
(Received 18 May 2009; revised manuscript received 7 July 2009; published 26 October 2009)

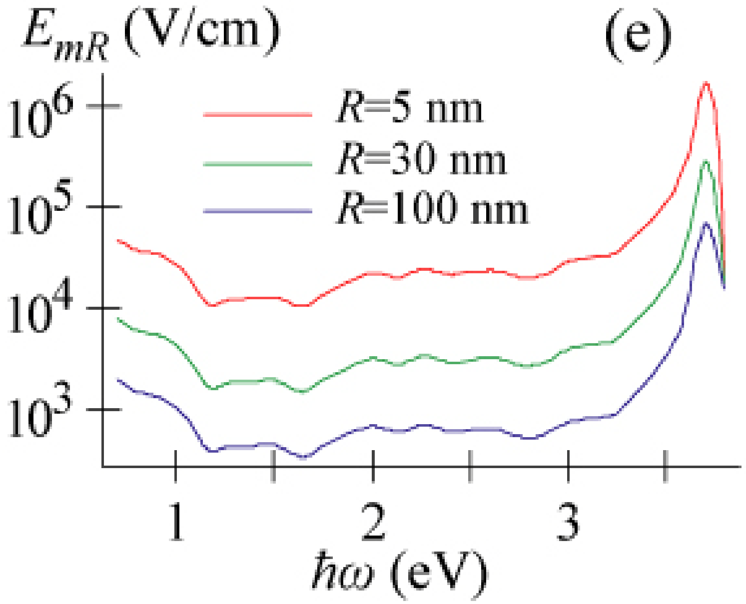
Here, for the first time we predict a giant surface-plasmon-induced drag-effect rectification (SPIDER), which exists under conditions of the extreme nanoplasmonic confinement. In nanowires, this giant SPIDER generates rectified THz potential differences up to 10 V and extremely strong electric fields up to $\sim 10^5$–10^6 V/cm. The giant SPIDER is an ultrafast effect whose bandwidth for nanometric wires is $\sim$20 THz. It opens up a new field of ultraintense THz nanooptics with wide potential applications in nanotechnology and nanoscience, including microelectronics, nanoplasmonics, and biomedicine.

Gradient Force and Pressure Force exerted on electrons





Maximum THz Field by SPIDER



Here decay of SPP is a useful effect!

CONTENTS

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- Bonus: Attosecond Plasmonic Field Nanoscope

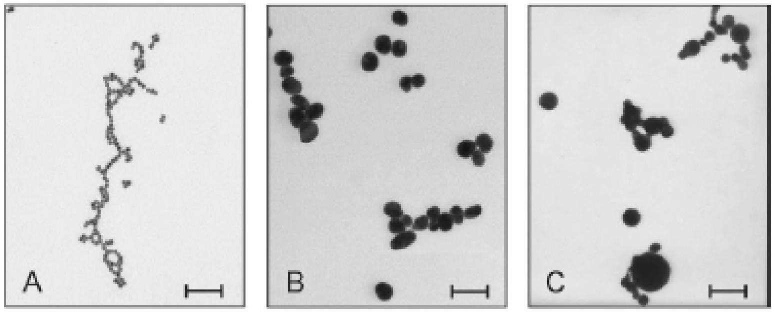
Anal. Chem. 2008, 80, 4247–4251

Correspondence

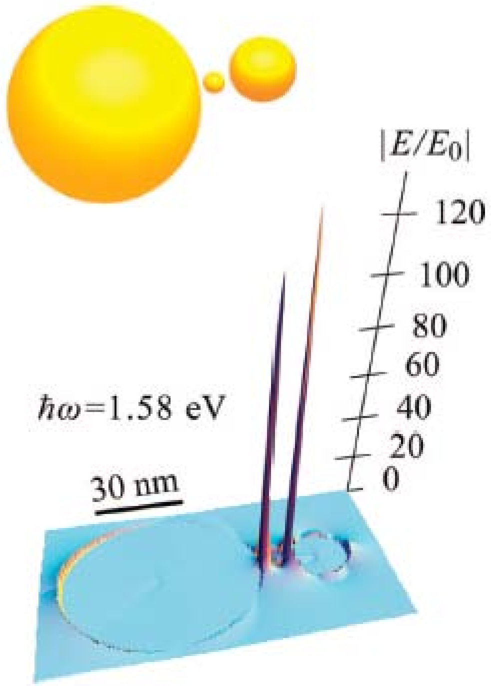
Different types of aggregates of gold nanospheres

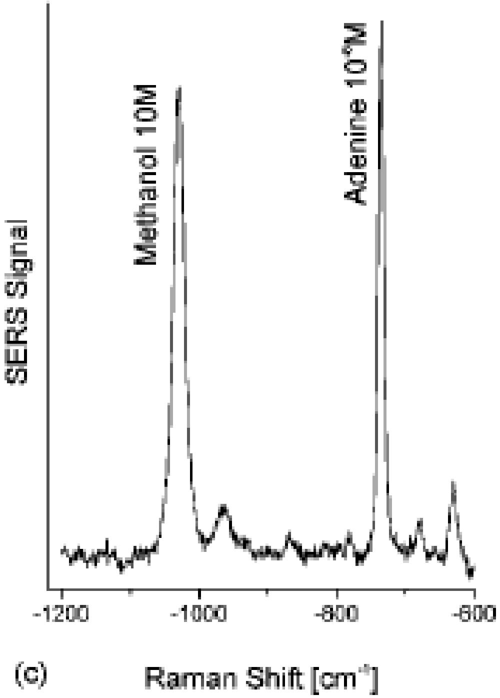
Gold Nanolenses Generated by Laser Ablation-Efficient Enhancing Structure for Surface Enhanced Raman Scattering Analytics and Sensing

**Janina Kneipp,[*,†,‡] Xiangting Li,[§] Margaret Sherwood,[†] Ulrich Panne,[‡] Harald Kneipp,[†]
Mark I. Stockman,[§] and Katrin Kneipp[†,∥]**



Scale bar:
100 nm





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2. M. I. Stockman, *Spasers Explained*, Nat. Phot. **2**, 327-329 (2008) .
3. M. I. Stockman and D. J. Bergman, *Surface Plasmon Amplification by Stimulated Emission of Radiation (SPASER)*, USA Patent No. 7,569,188 (August 4, 2009)
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2. P. M. Bolger, W. Dickson, A. V. Krasavin, L. Liebscher, S. G. Hickey, D. V. Skryabin, and A. V. Zayats, *Amplified Spontaneous Emission of Surface Plasmon Polariton*, Opt. Lett. **35**, 1197-1199 (2010).
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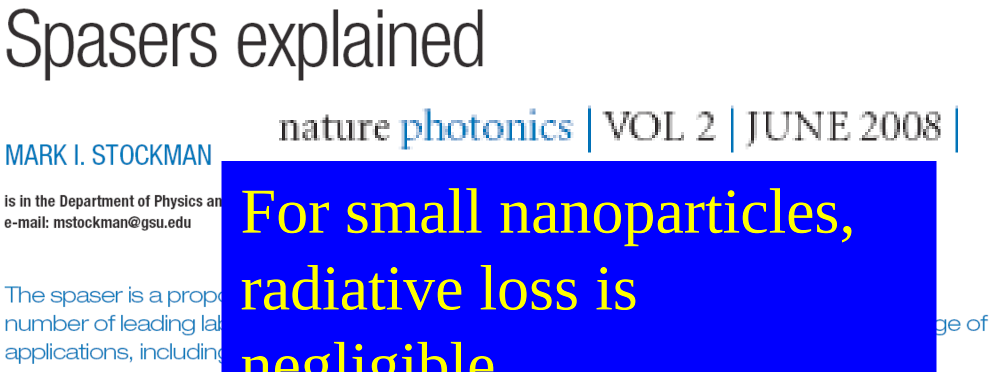
Spaser is the ultimately smallest quantum nano-generator and nano-amplifier



Spasers explained

nature photonics | VOL 2 | JUNE 2008 |

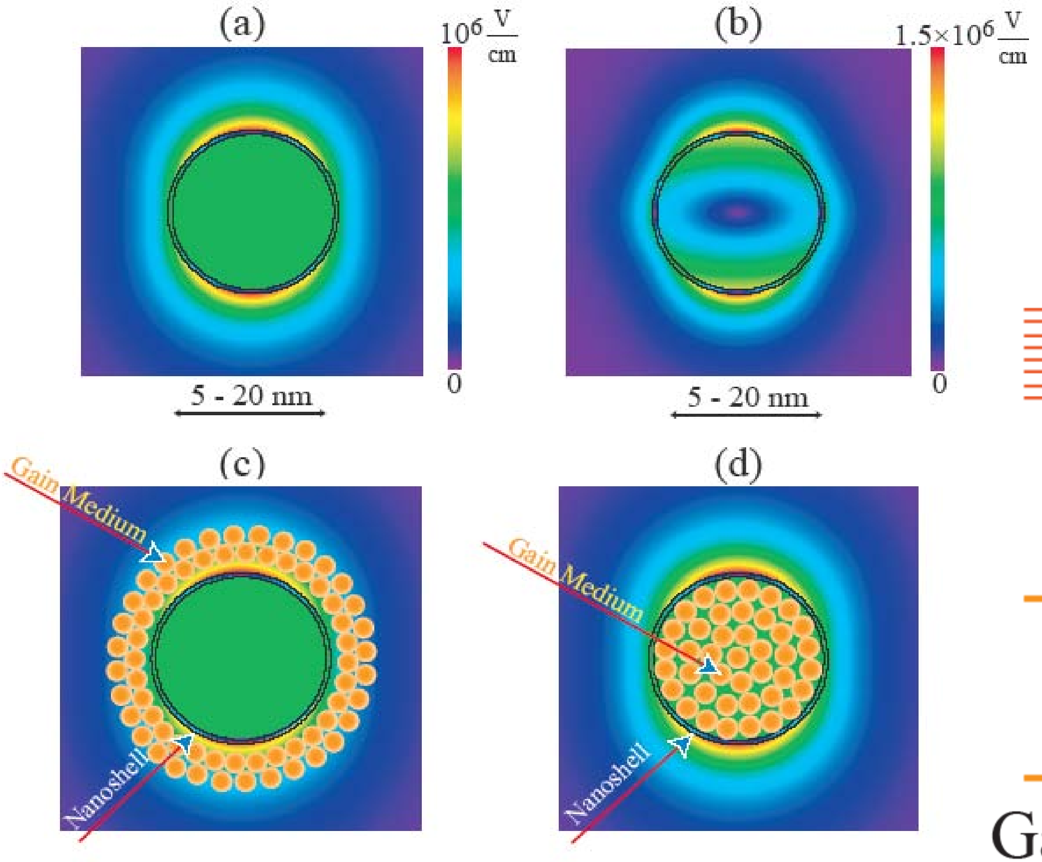
MARK I. STOCKMAN

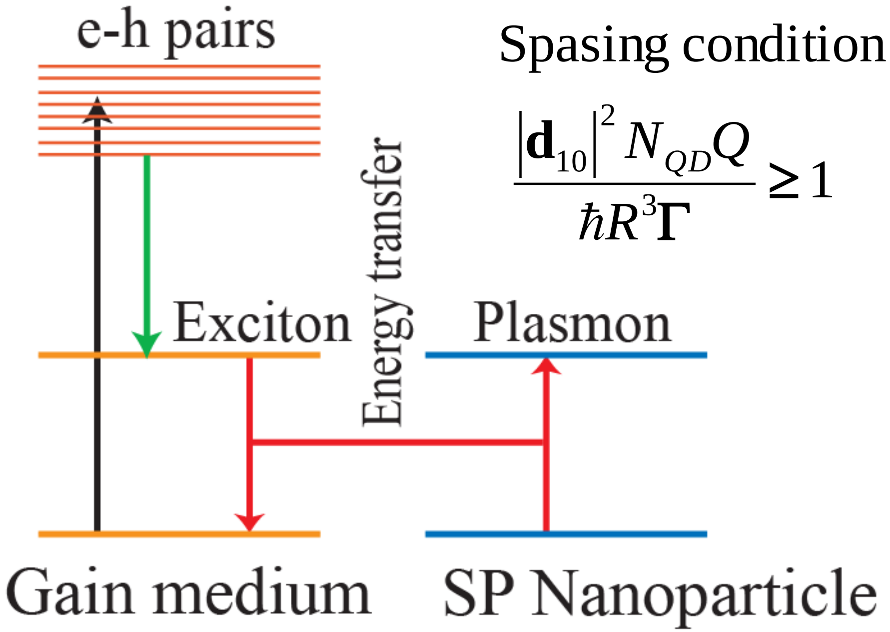
is in the Department of Physics an
e-mail: mstockman@gsu.edu

The spaser is a propo
number of leading lab
applications, including
ge of

For small nanoparticles, radiative loss is negligible.

Spaser is quasistatic and fully scalable





Spasing condition :

$$\frac{\left|\mathbf{d}_{10}\right|^2 N_{QD} Q}{\hbar R^3 \Gamma} \geq 1$$

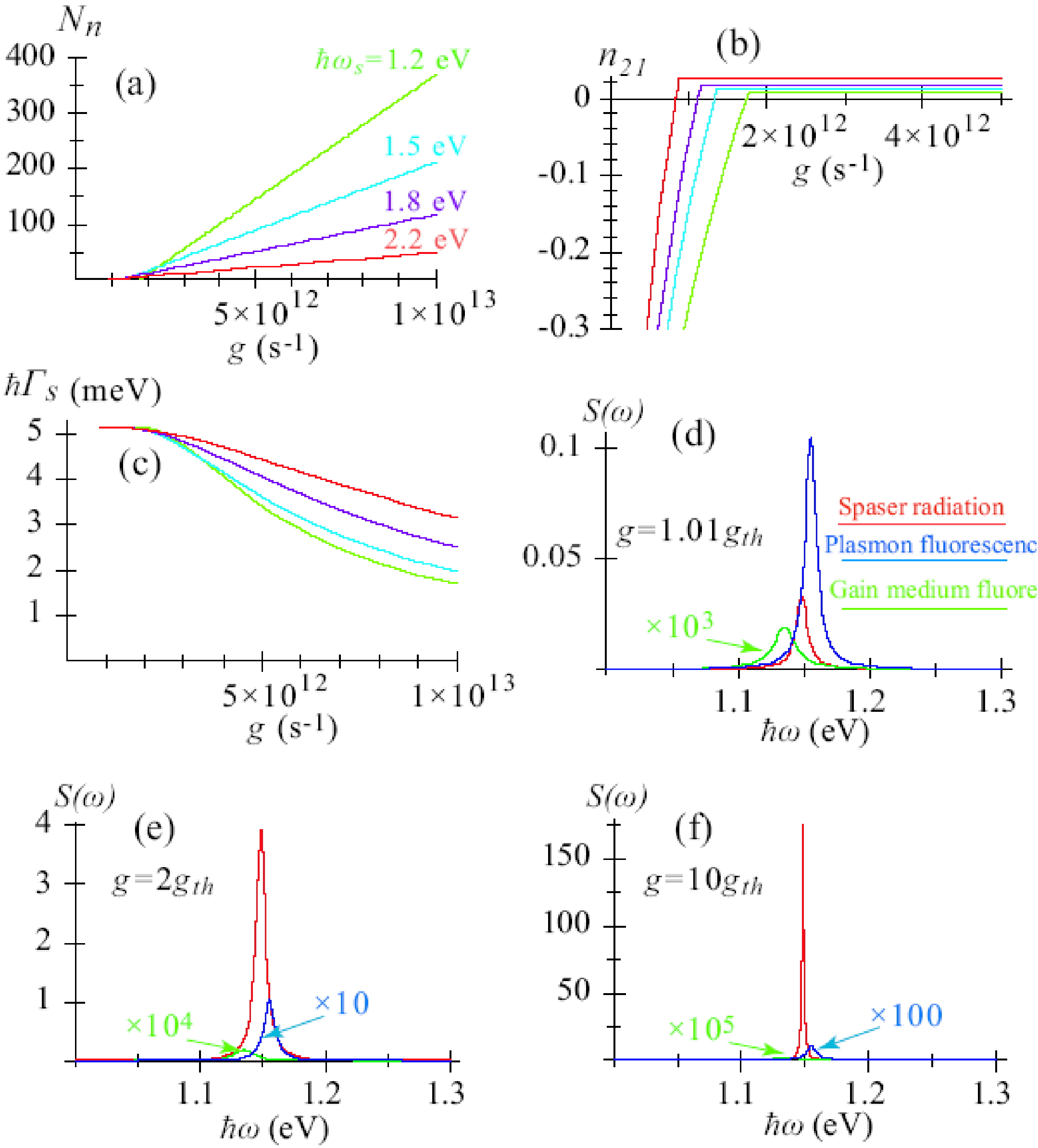
Stationary (CW) spaser regime

This quasilinear dependence $N_n(g)$ is a result of the very strong feedback in spaser due to the small modal volume

arXiv:0908.3559
Journal of Optics, **12**, 024004-1-13 (2010).

Plasmon number

Inversion vs. pumping rate

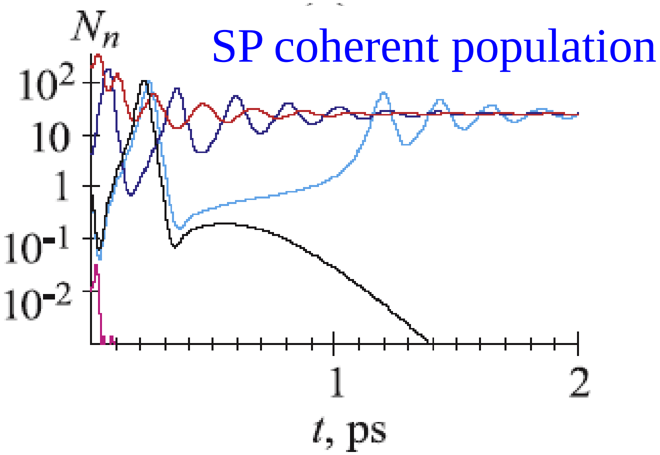


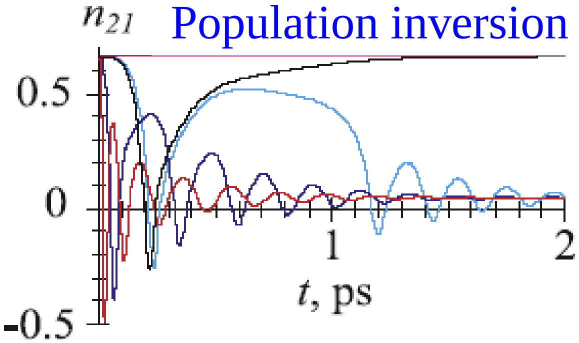
Bandwidth ~ 10-100 THz

Very high resistance to ionizing radiation

Amplification in Spaser with a Saturable Absorber (1/3 of the gain chromophores)

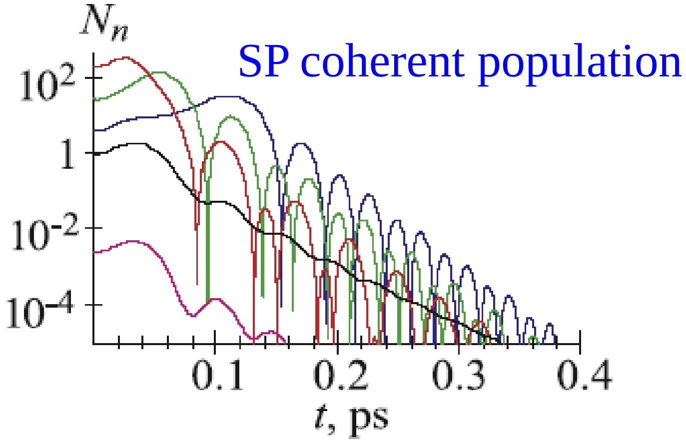
Stationary pumping

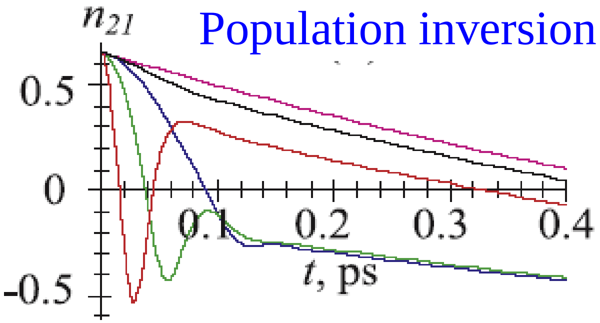

SP coherent population

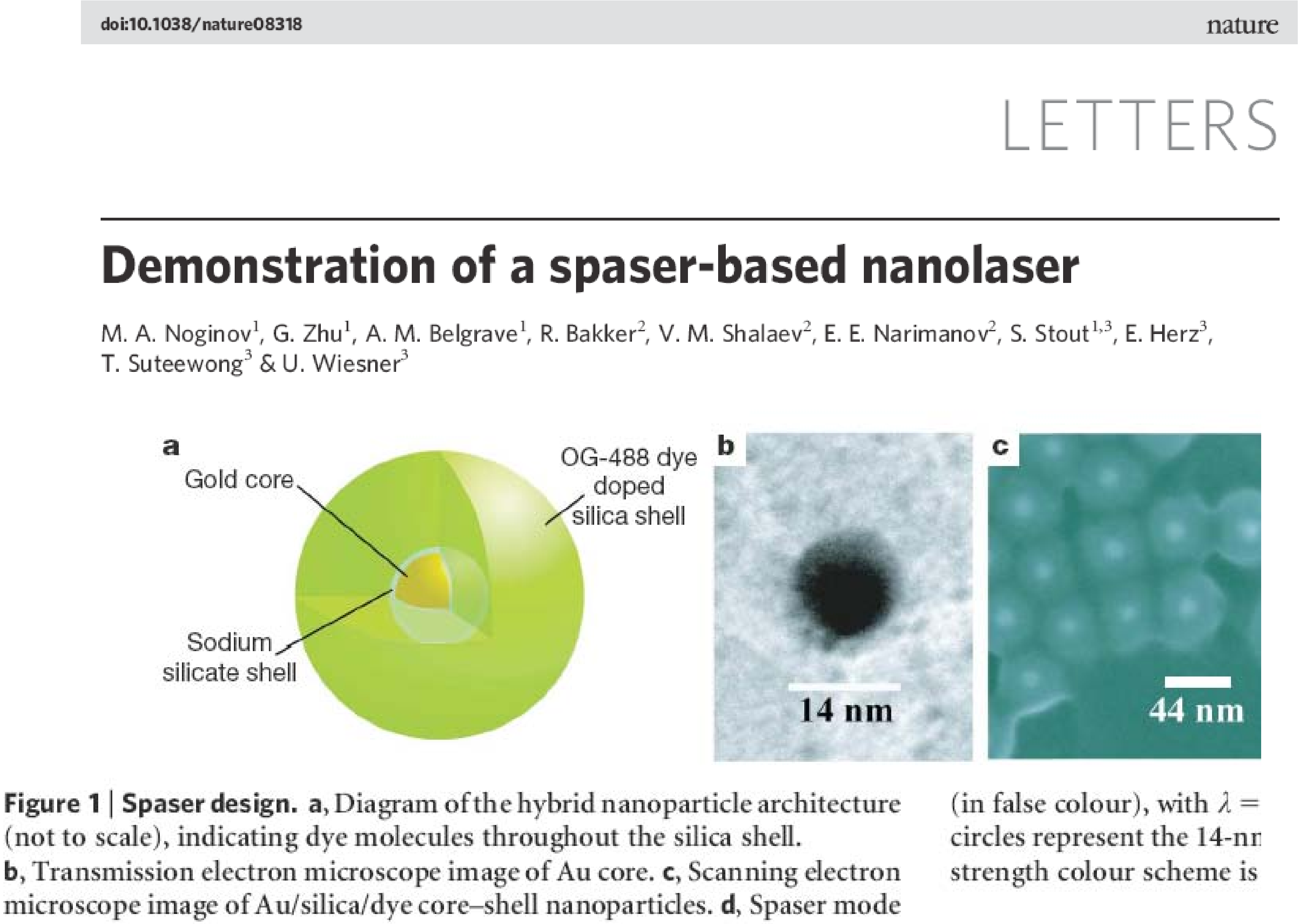

Population inversion

This very high speed of the spaser is due to the small modal volume

Pulse pumping


SP coherent population


Population inversion



doi:10.1038/nature08318 nature

LETTERS

Demonstration of a spaser-based nanolaser

M. A. Noginov[1], G. Zhu[1], A. M. Belgrave[1], R. Bakker[2], V. M. Shalaev[2], E. E. Narimanov[2], S. Stout[1,3], E. Herz[3], T. Suteewong[3] & U. Wiesner[3]

Figure 1 | Spaser design. a, Diagram of the hybrid nanoparticle architecture (not to scale), indicating dye molecules throughout the silica shell. **b**, Transmission electron microscope image of Au core. **c**, Scanning electron microscope image of Au/silica/dye core–shell nanoparticles. **d**, Spaser mode (in false colour), with $\lambda =$
circles represent the 14-n
strength colour scheme is

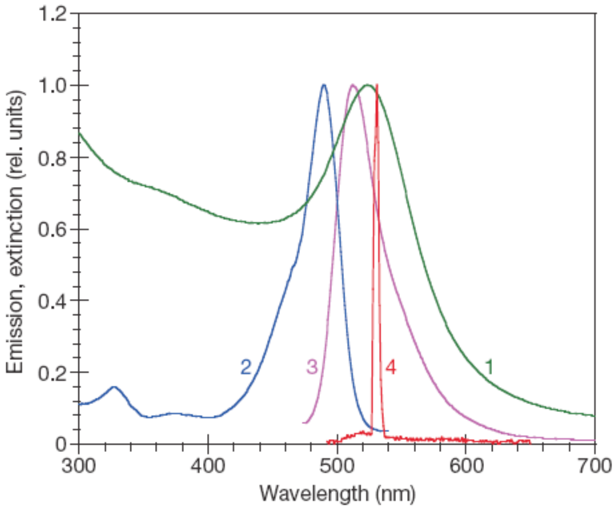


Figure 2 | Spectroscopic results. Normalized extinction (1), excitation (2), spontaneous emission (3), and stimulated emission (4) spectra of Au/silica/dye nanoparticles. The peak extinction cross-section of the nanoparticles is 1.1×10^{-12} cm^2. The emission and excitation spectra were measured in a spectrofluorometer at low fluence.

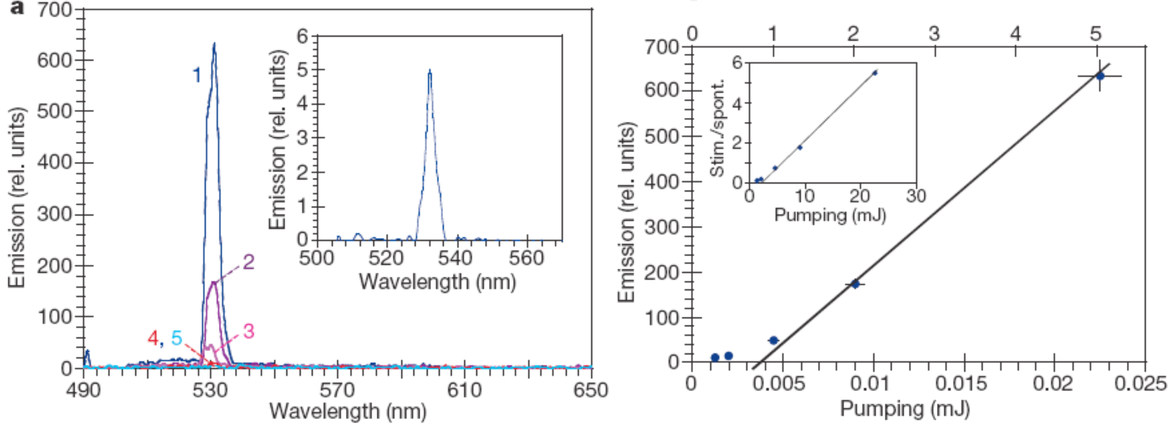
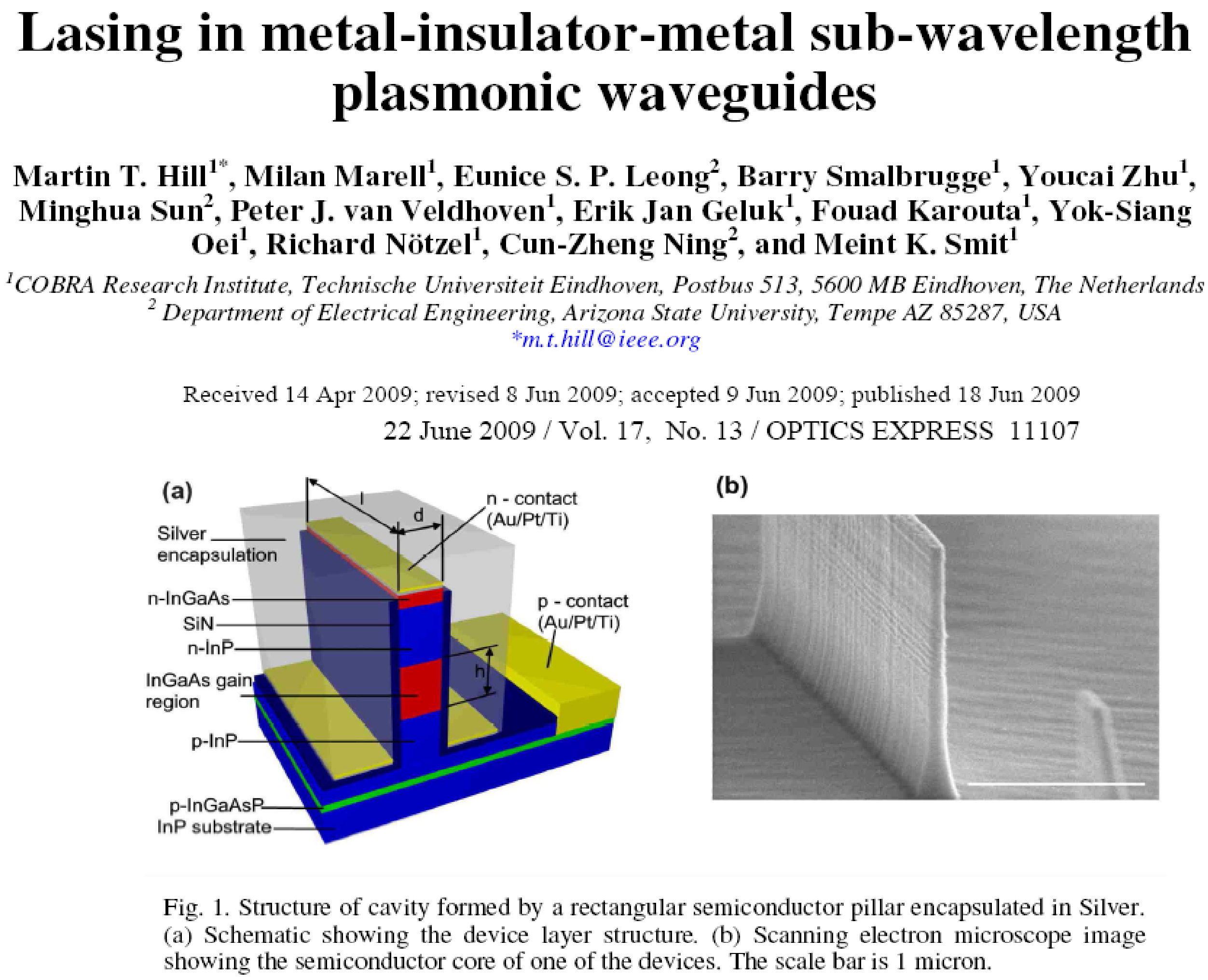


Figure 4 | Stimulated emission. **a**, Main panel, stimulated emission spectra of the nanoparticle sample pumped with 22.5 mJ (1), 9 mJ (2), 4.5 mJ (3), 2 mJ (4) and 1.25 mJ (5) 5-ns optical parametric oscillator pulses at $\lambda = 488$ nm. **b**, Main panel, corresponding input–output curve (lower axis, total launched pumping energy; upper axis, absorbed pumping energy per nanoparticle); for most experimental points, ~5% error bars (determined by the noise of the photodetector and the instability of the pumping laser) do not exceed the size of the symbol. Inset of **a**, stimulated emission spectrum at more than 100-fold dilution of the sample. Inset of **b**, the ratio of the stimulated emission intensity (integrated between 526 nm and 537 nm) to the spontaneous emission background (integrated at <526 nm and >537 nm).



Lasing in metal-insulator-metal sub-wavelength plasmonic waveguides

Martin T. Hill[1*], **Milan Marell**[1], **Eunice S. P. Leong**[2], **Barry Smalbrugge**[1], **Youcai Zhu**[1], **Minghua Sun**[2], **Peter J. van Veldhoven**[1], **Erik Jan Geluk**[1], **Fouad Karouta**[1], **Yok-Siang Oei**[1], **Richard Nötzel**[1], **Cun-Zheng Ning**[2], **and Meint K. Smit**[1]

[1] *COBRA Research Institute, Technische Universiteit Eindhoven, Postbus 513, 5600 MB Eindhoven, The Netherlands*
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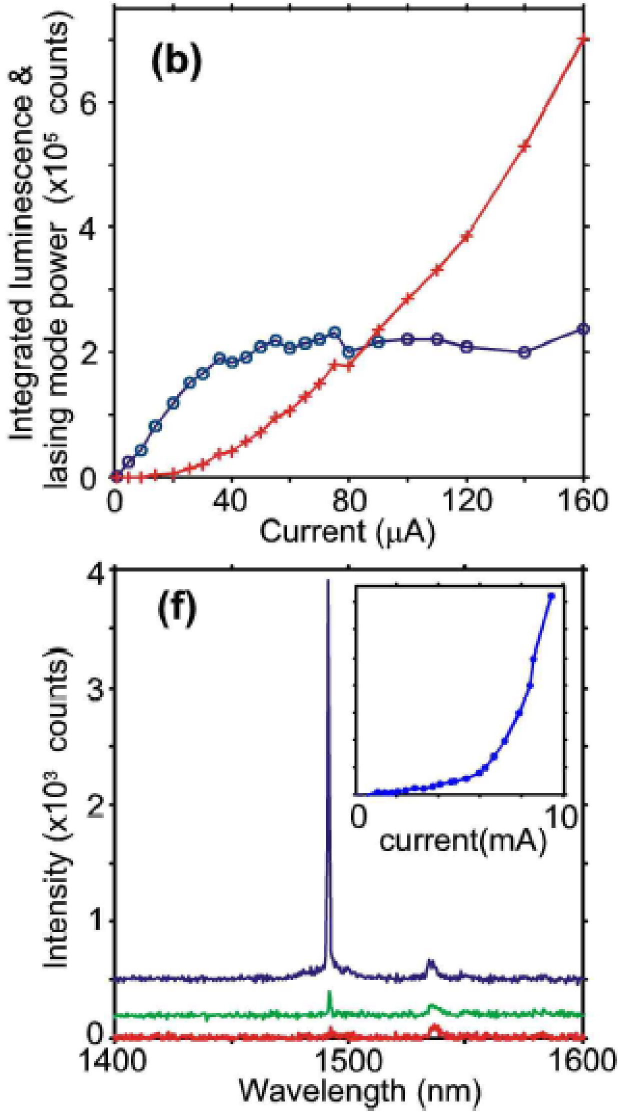
22 June 2009 / Vol. 17, No. 13 / OPTICS EXPRESS 11107

Fig. 1. Structure of cavity formed by a rectangular semiconductor pillar encapsulated in Silver. (a) Schematic showing the device layer structure. (b) Scanning electron microscope image showing the semiconductor core of one of the devices. The scale bar is 1 micron.

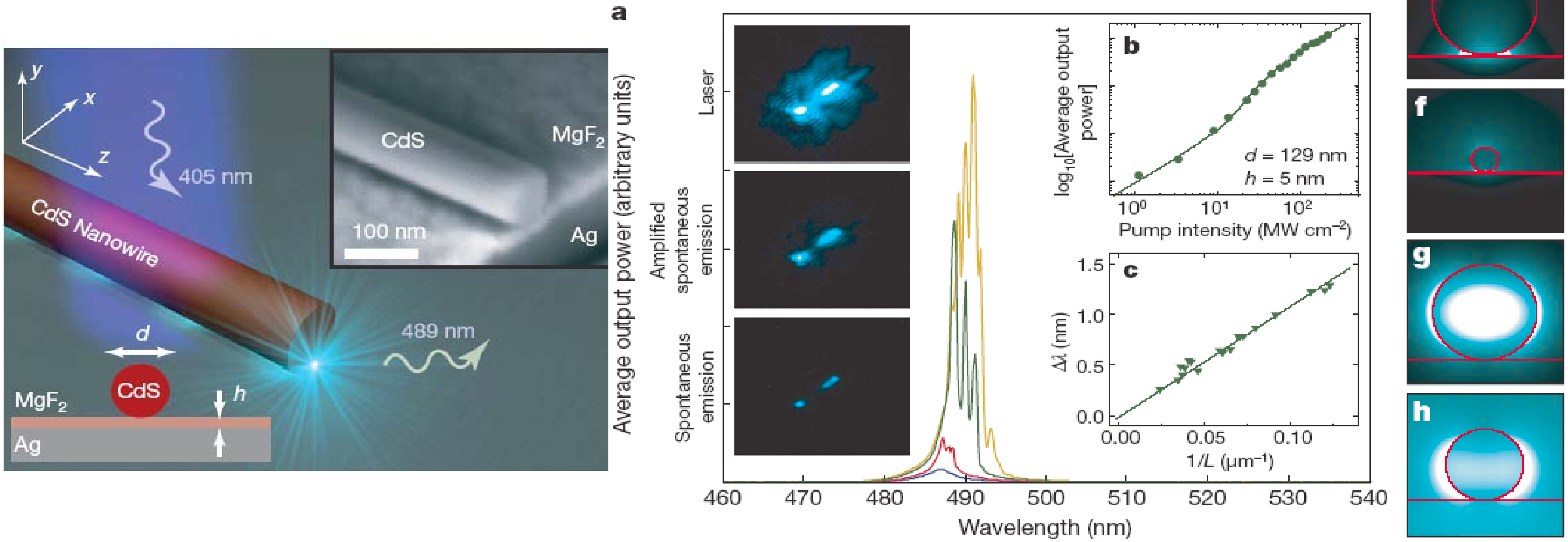


doi:10.1038/nature08364 nature

LETTERS

Plasmon lasers at deep subwavelength scale

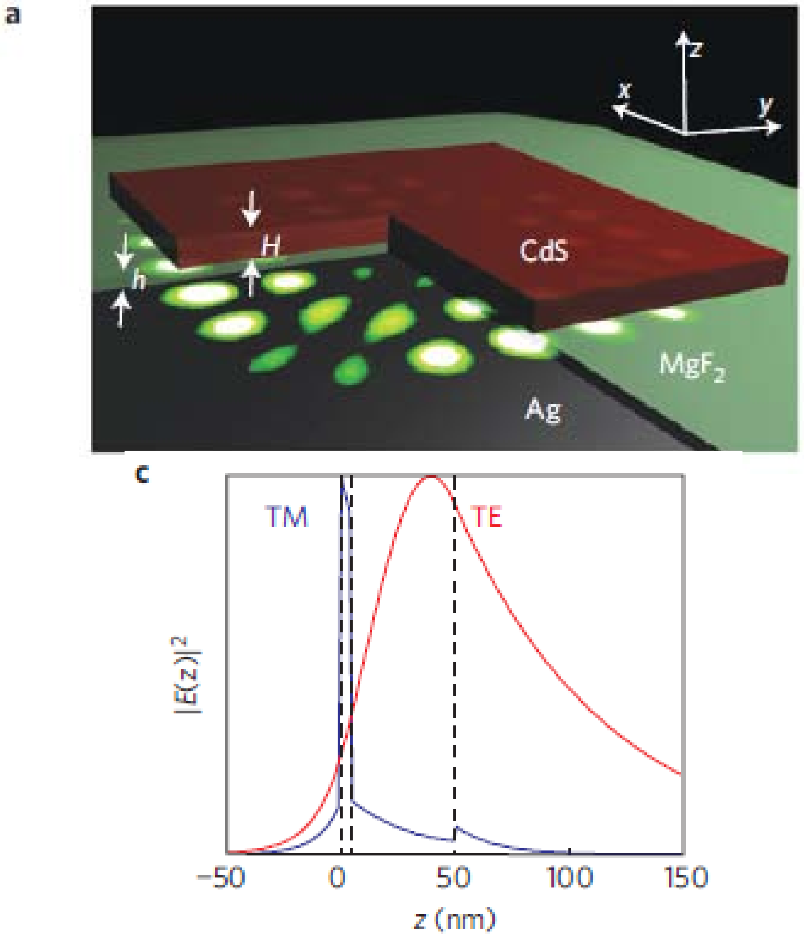
Rupert F. Oulton[1]*, Volker J. Sorger[1]*, Thomas Zentgraf[1]*, Ren-Min Ma[3], Christopher Gladden[1], Lun Dai[3], Guy Bartal[1] & Xiang Zhang[1,2]

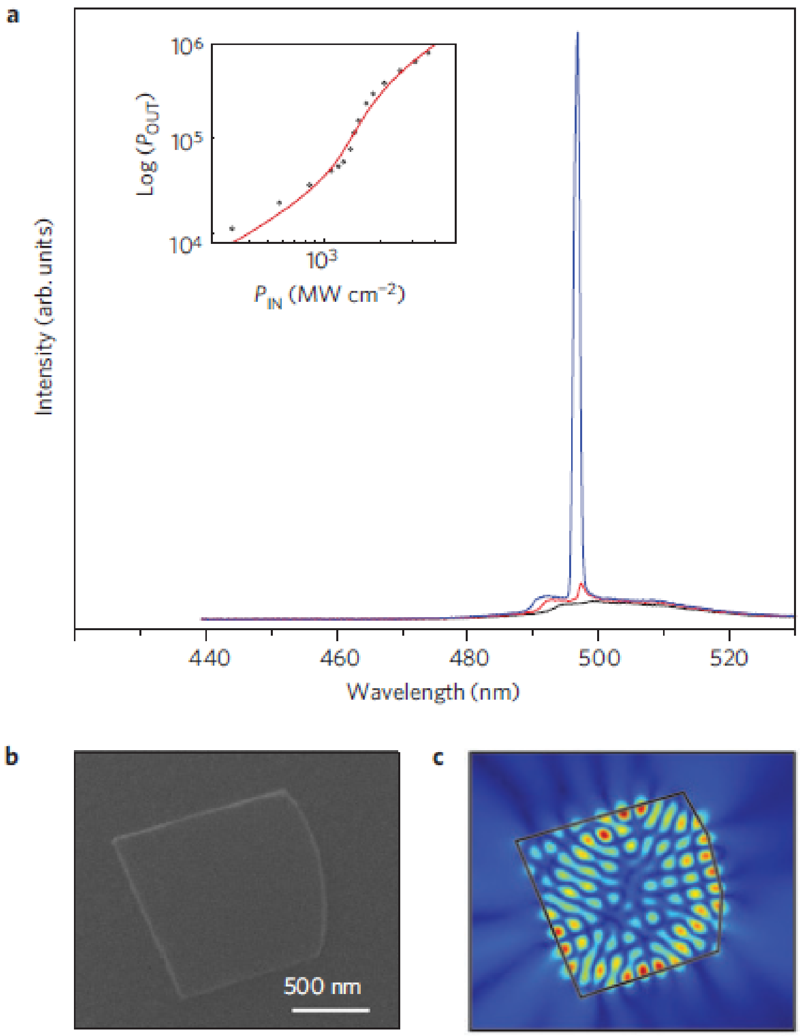


nature materials
LETTERS

Room-temperature sub-diffraction-limited plasmon laser by total internal reflection

Ren-Min Ma[1†], Rupert F. Oulton[1†], Volker J. Sorger[1], Guy Bartal[1] and Xiang Zhang[1,2]*





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- Conclusions
- Bonus: Ultrafast Nanoscale Coherent Control
- Bonus: Attosecond Plasmonic Field Nanoscope

BRIEF CONCLUSIONS

1. Nanoplasmonics is based on nanolocalization of optical fields due to SPs
2. Enhancement in nanoplasmonics is due to quality factor of SP modes and geometric concentration
3. Plasmonic hot spots is universal phenomena due to the scale-invariance of the nanoplasmonic phenomena
4. Adiabatic concentration is a non-resonant, wide-band, and non-radiative root to nanofocusing with extremely high throughput. There are demonstrated applications to nanoscopy and chemical nano-imaging.
5. Nanolenses are highly efficient enhancers of local field and SERS
6. SPASER is an efficient nanoscale generator and ultrafast quantum amplifier with a switch time ~100 fs for silver and ~10 fs for gold. It has the same size as MOSFET and can perform the same functions but is ~1000 times faster.
7. SPASERs have been observed in a number of experiments
8. The most promising applications of the SPASER are an ultrafast nanoamplifier, local optical energy source, active nano-label, and an element of metamaterials with compensated loss.

The End

CONTENTS

- M. I. Stockman, S. V. Faleev, and D. J. Bergman, *Coherent Control of Femtosecond Energy Localization in Nanosystems*, Phys. Rev. Lett. **88**, 67402-1-4 (2002).
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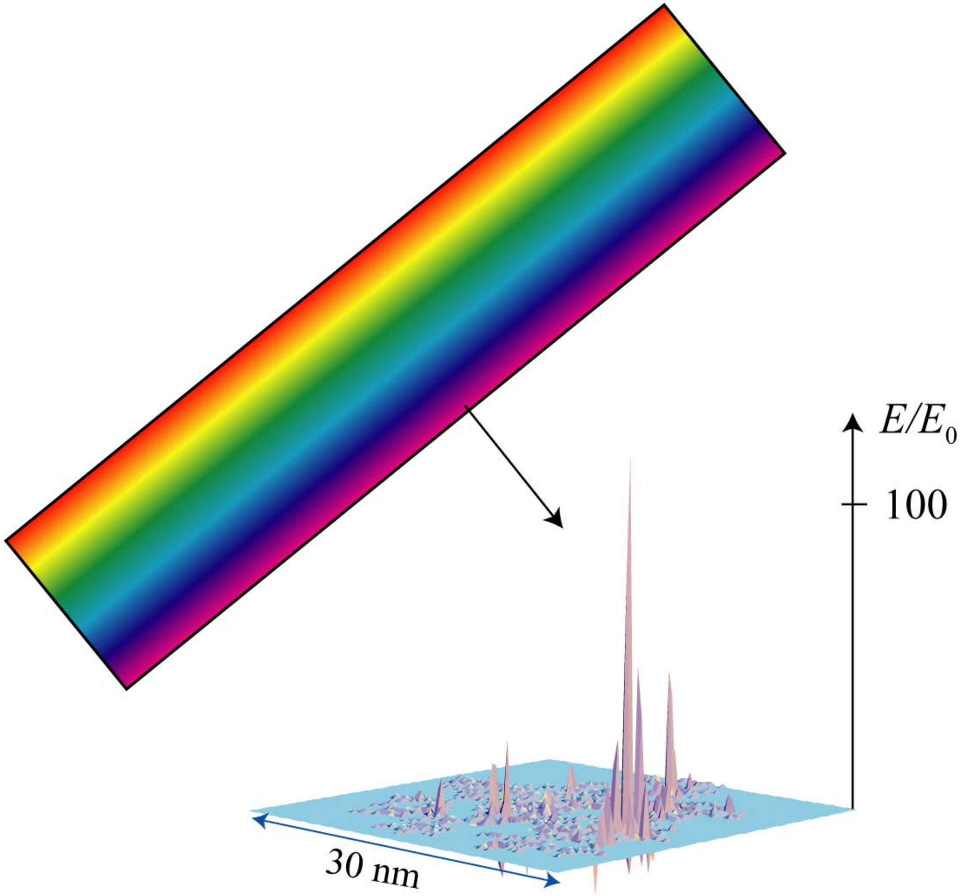
Schematic of Coherent Control by Phase Modulation

Different spectral components of the excitation pulse excite resonant surface plasmon modes.

These excitations dynamically interfere creating time-dependent hot spots of local fields during their coherence time

This interference can be directed by choosing phases and amplitudes of the different frequency components of the excitation pulse (pulse shaping)

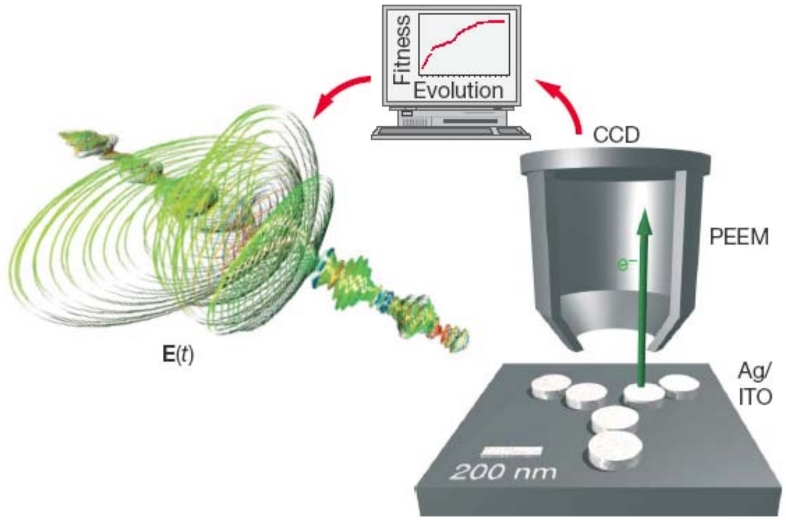


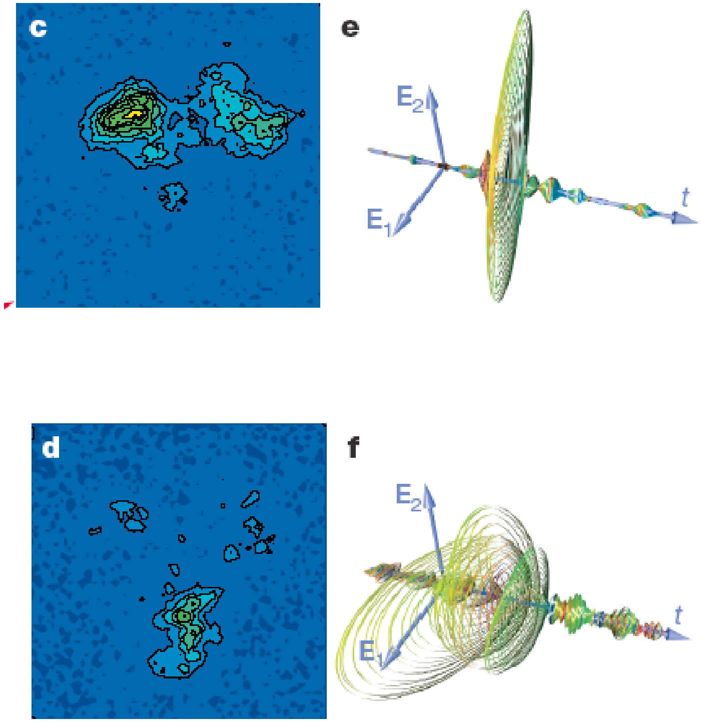
Vol 446|15 March 2007|doi:10.1038/nature05595 nature

LETTERS

Adaptive subwavelength control of nano-optical fields

Martin Aeschlimann[1], Michael Bauer[2], Daniela Bayer[1], Tobias Brixner[3], F. Javier García de Abajo[4], Walter Pfeiffer[5], Martin Rohmer[1], Christian Spindler[3] & Felix Steeb[1]





Nanoplasmonic Energy Localization, Time Reversal, and Coherent Control

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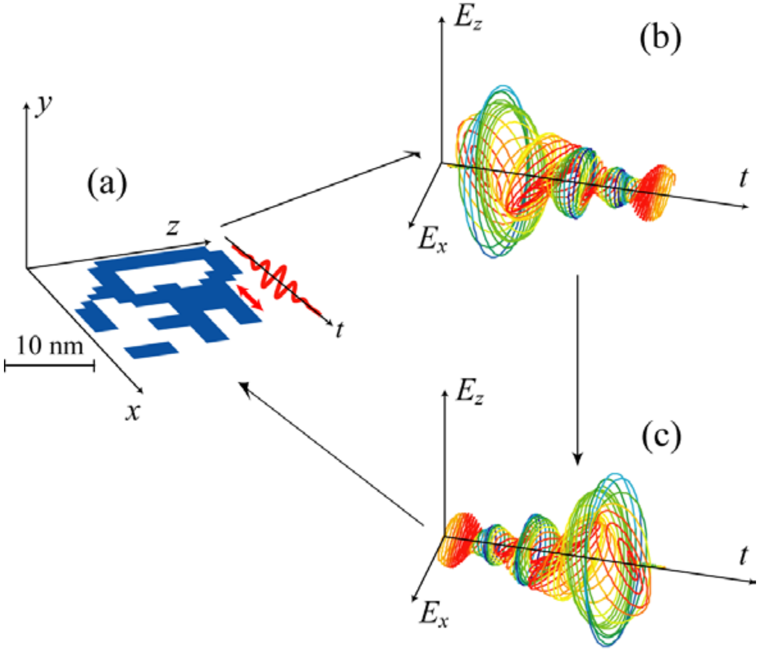

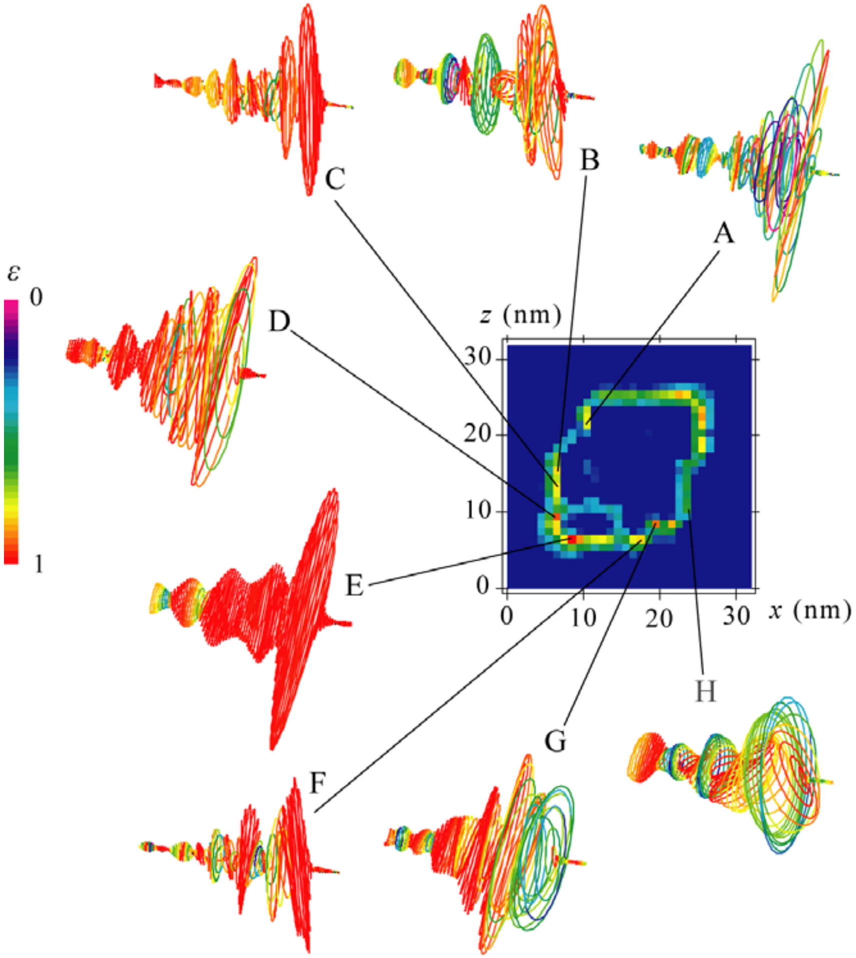
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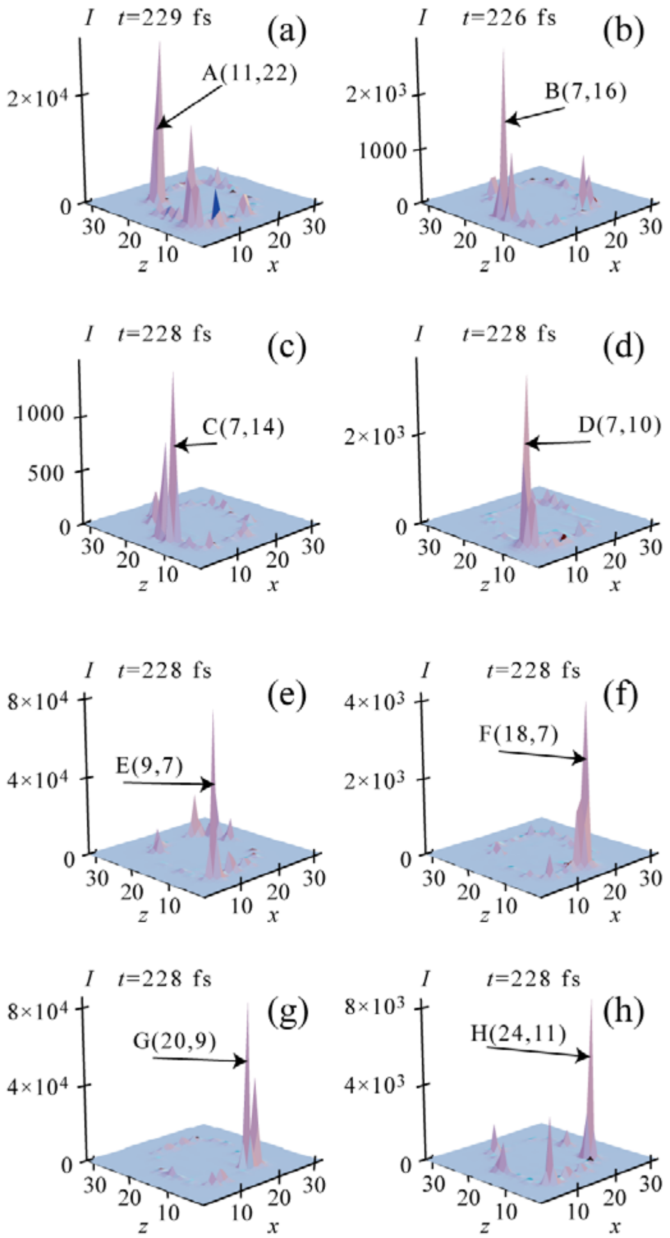
I t=229 fs (a)
2×10⁴
A(11,22)
0
30 20 10 z
10 20 30 x
I t=226 fs (b)
2×10³
1000
B(7,16)
0
I t=228 fs (c)
1000
500
C(7,14)
0
I t=228 fs (d)
2×10³
D(7,10)
0
I t=228 fs (e)
8×10⁴
4×10⁴
E(9,7)
0
I t=228 fs (f)
4×10³
2×10³
F(18,7)
0
I t=228 fs (g)
8×10⁴
4×10⁴
G(20,9)
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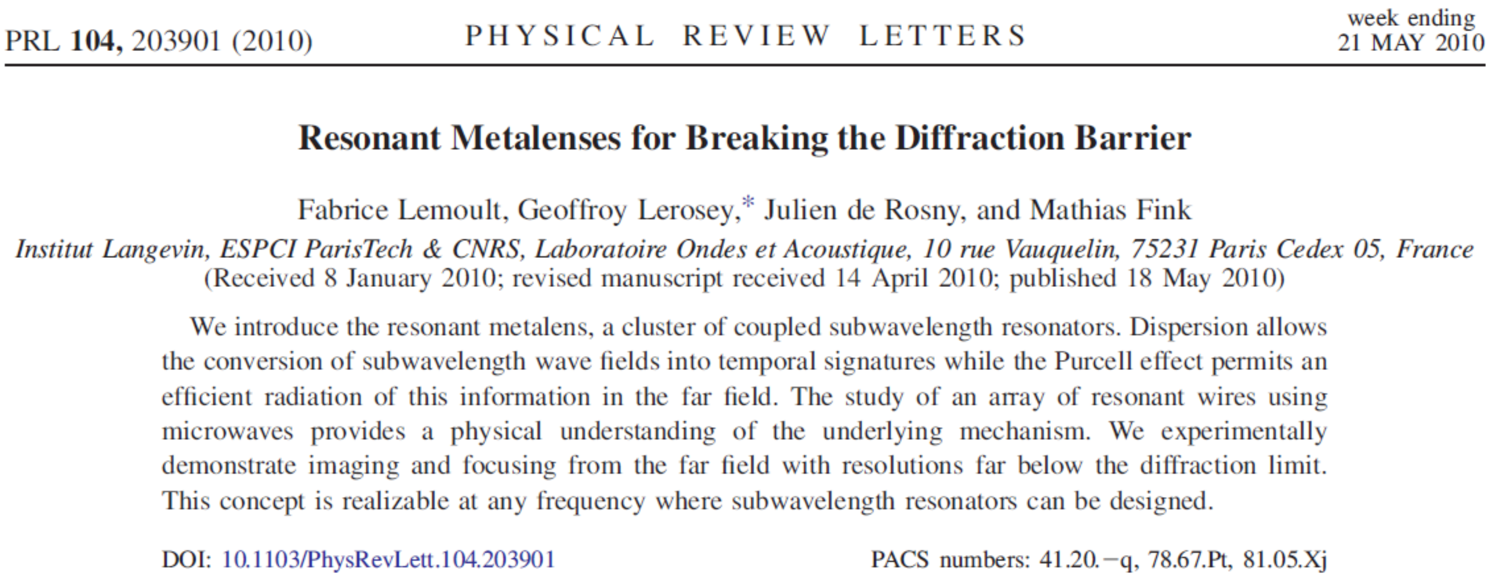
8×10³
4×10³
H(24,11)
0



PRL **104,** 203901 (2010) PHYSICAL REVIEW LETTERS week ending 21 MAY 2010

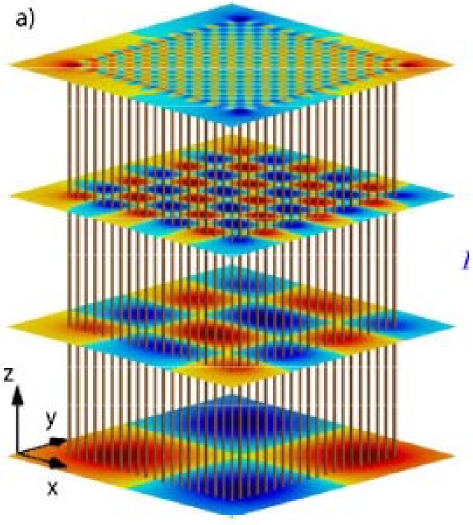
Resonant Metalenses for Breaking the Diffraction Barrier

Fabrice Lemoult, Geoffroy Lerosey,* Julien de Rosny, and Mathias Fink
Institut Langevin, ESPCI ParisTech & CNRS, Laboratoire Ondes et Acoustique, 10 rue Vauquelin, 75231 Paris Cedex 05, France

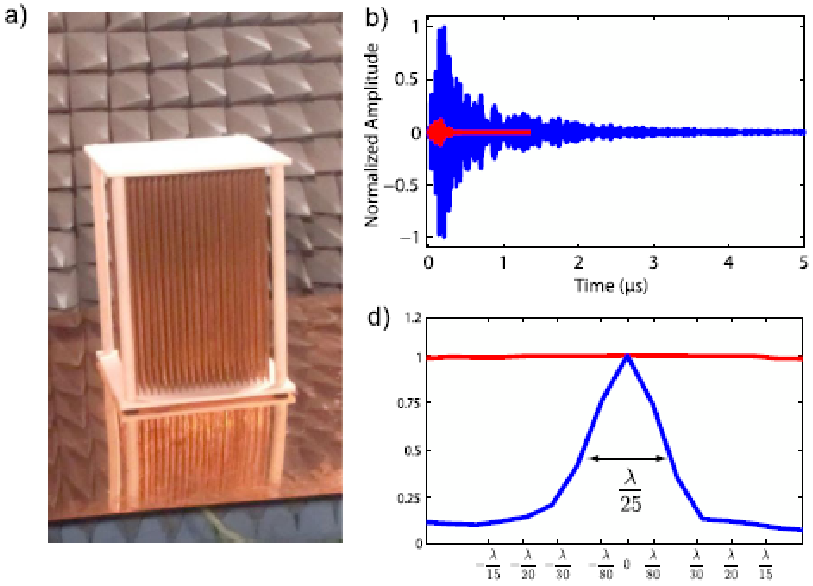
(Received 8 January 2010; revised manuscript received 14 April 2010; published 18 May 2010)

We introduce the resonant metalens, a cluster of coupled subwavelength resonators. Dispersion allows the conversion of subwavelength wave fields into temporal signatures while the Purcell effect permits an efficient radiation of this information in the far field. The study of an array of resonant wires using microwaves provides a physical understanding of the underlying mechanism. We experimentally demonstrate imaging and focusing from the far field with resolutions far below the diffraction limit. This concept is realizable at any frequency where subwavelength resonators can be designed.

DOI: 10.1103/PhysRevLett.104.203901 PACS numbers: 41.20.−q, 78.67.Pt, 81.05.Xj



amplitude of E_x TEM Bloch modes (1,1), (2,3), (5,6), and (19,19).



(d) Focal spot obtained after far field time reversal

NANO LETTERS

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Vol. 9, No. 10
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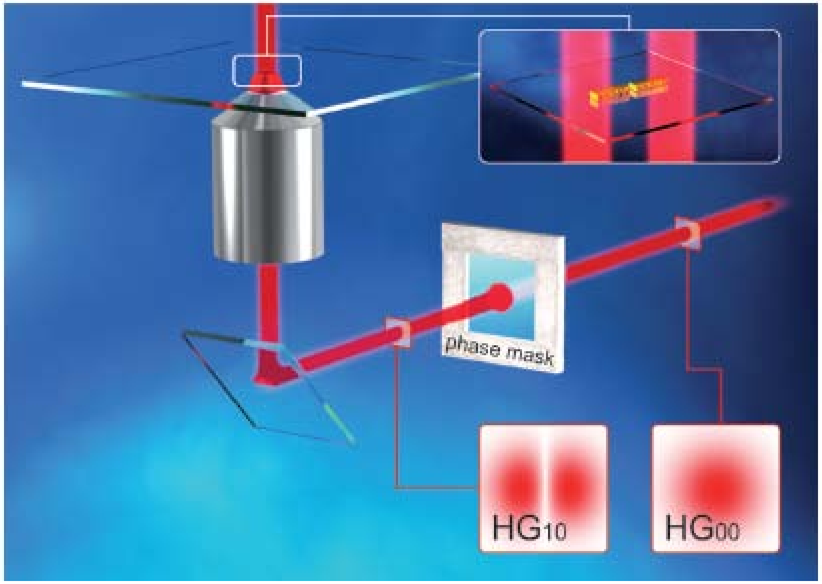
Controlling the Optical Near Field of Nanoantennas with Spatial Phase-Shaped Beams

Giorgio Volpe,[†] Sudhir Cherukulappurath,[†] Roser Juanola Parramon,[†]
Gabriel Molina-Terriza,[†,‡] and Romain Quidant[*,†,‡]

ICFO-Institut de Ciencies Fotoniques, Mediterranean Technology Park,
08860 Castelldefels, Barcelona, Spain, and ICREA-Institució Catalana de
Estudis Avançats, 08010 Barcelona, Spain



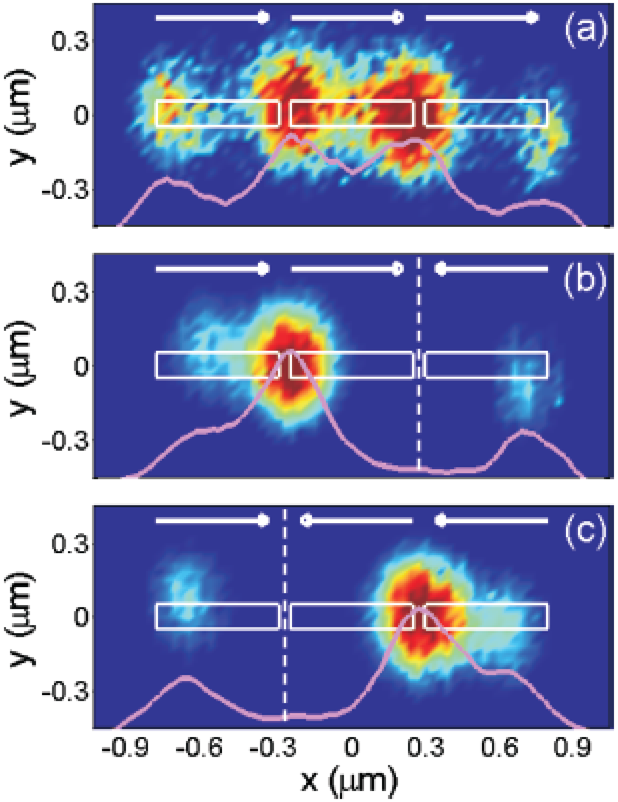


Figure 4. Experimental TPL maps recorded for (a) a Gaussian beam and (b, c) a HG_{10} beam whom phase shift (located by the vertical dashed line) coincides with (b) the right gap and (c) the left gap.

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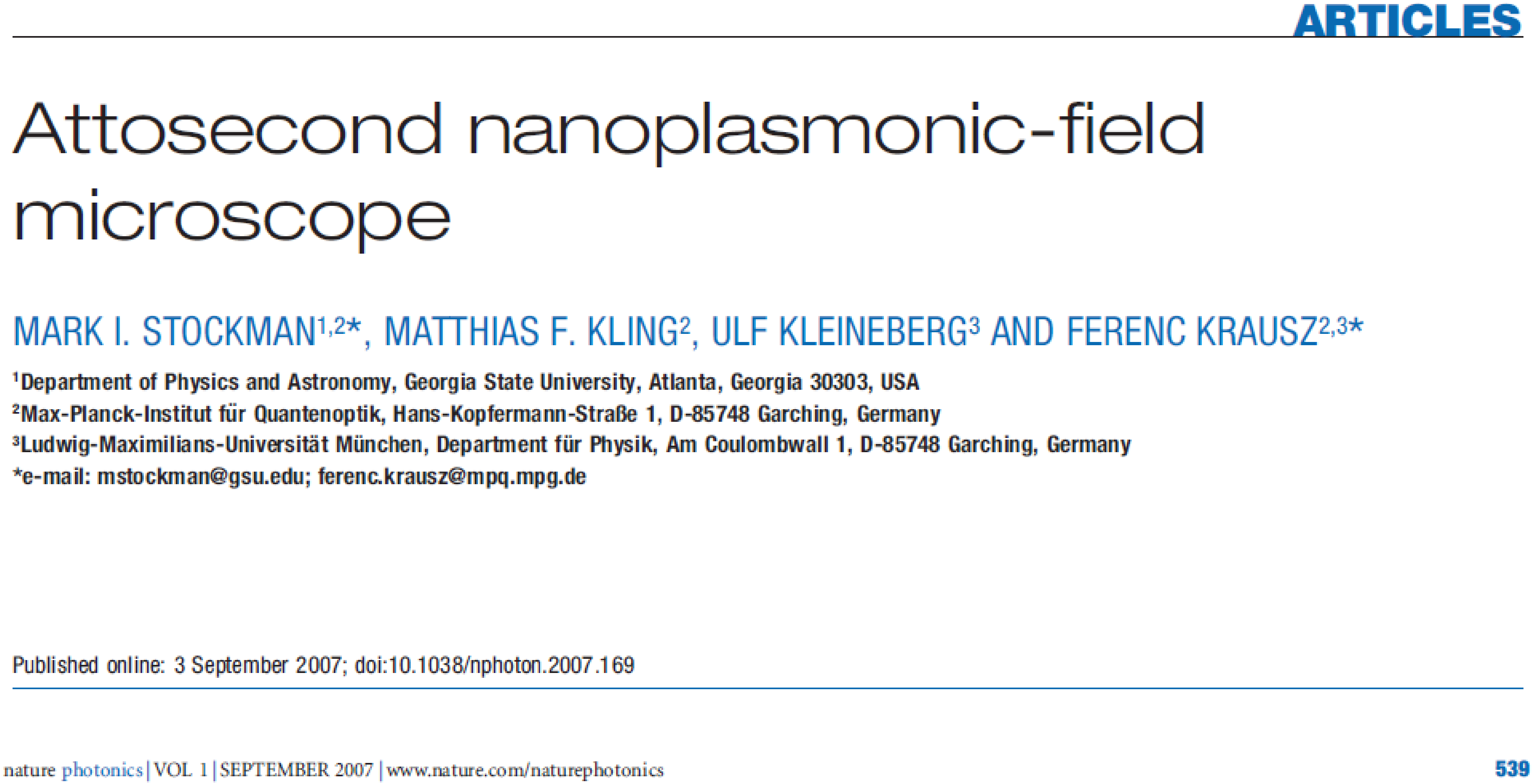

ARTICLES

Attosecond nanoplasmonic-field microscope

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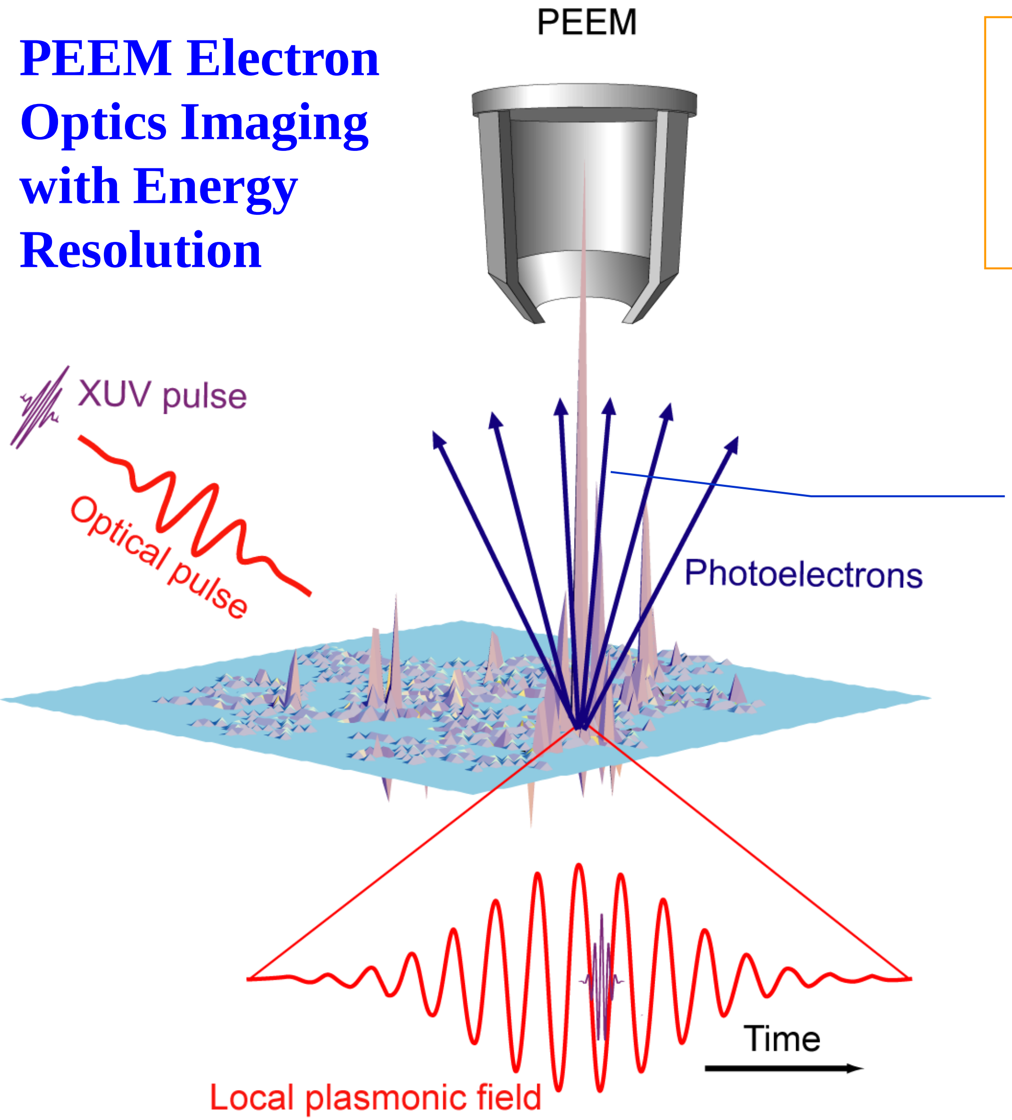
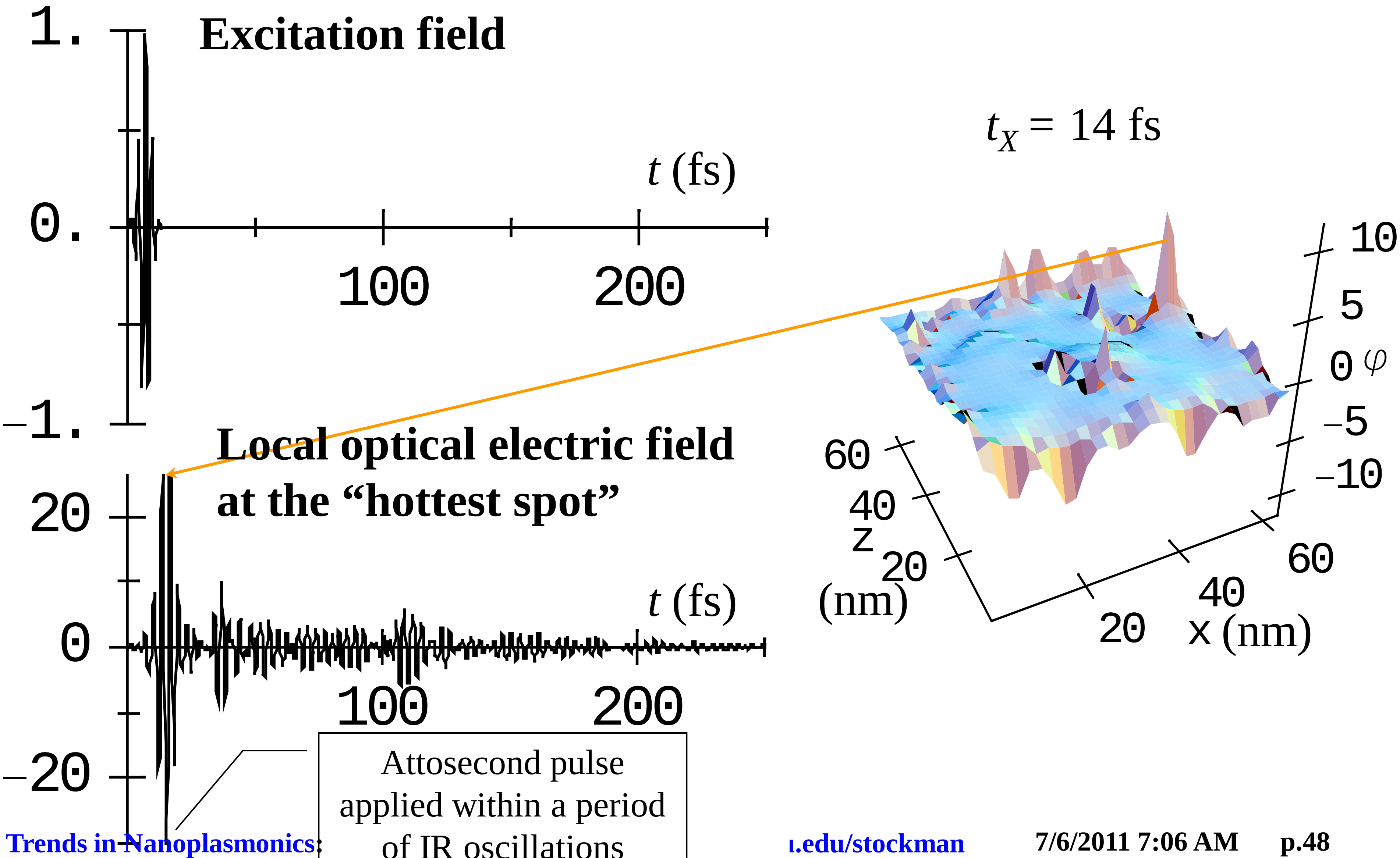
Schematic of Attosecond Nanoplasmonic Field Microscope

PEEM Electron Optics Imaging with Energy Resolution



XUV photoelectrons accelerated by enhanced IR plasmonic local fields



Excitation field

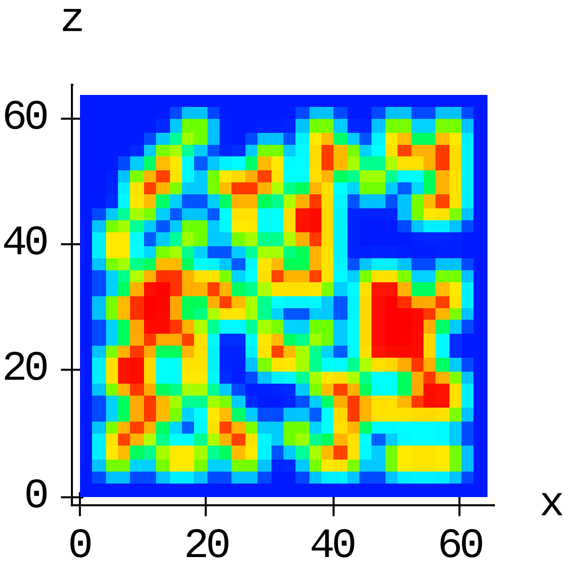
Local optical electric field at the "hottest spot"

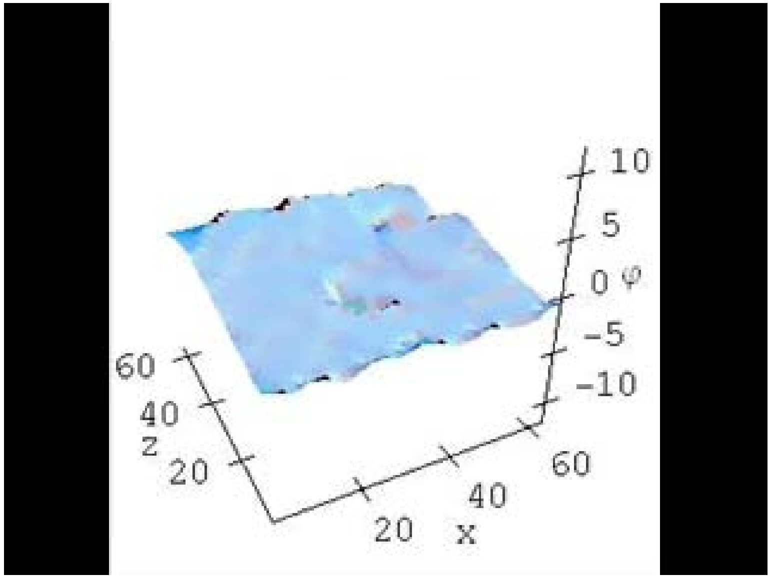
Attosecond pulse applied within a period of IR oscillations

$t_X = 14$ fs

Energy shift (eV) of electrons emitted by a 95 eV XUV attosecond pulse as a function of the as pulse excitation instant with respect to the infrared excitation field (frames are in 200 as) as observed in Photoemission Electron Microscope (PEEM).

Experiment directly measures instantaneous electric potential of nanoplasmonic oscillations with nm spatial and ~200 as temporal resolution





Energy change (eV) of 90 eV XUV photoelectrons from silver nanosystem for 10 GW/cm^2 800 nm IR power; × 10^{15} slowed down

Nanosystem is **60x60 nm** random silver film (50% filling factor)