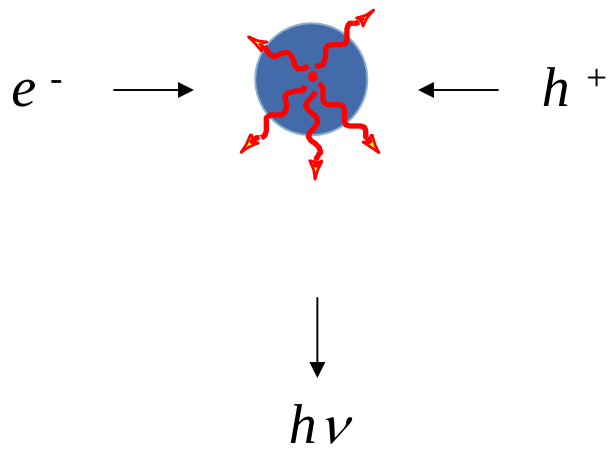
OPTICAL ANTENNAS FOR ENHANCED LIGHT-MATTER INTERACTIONS



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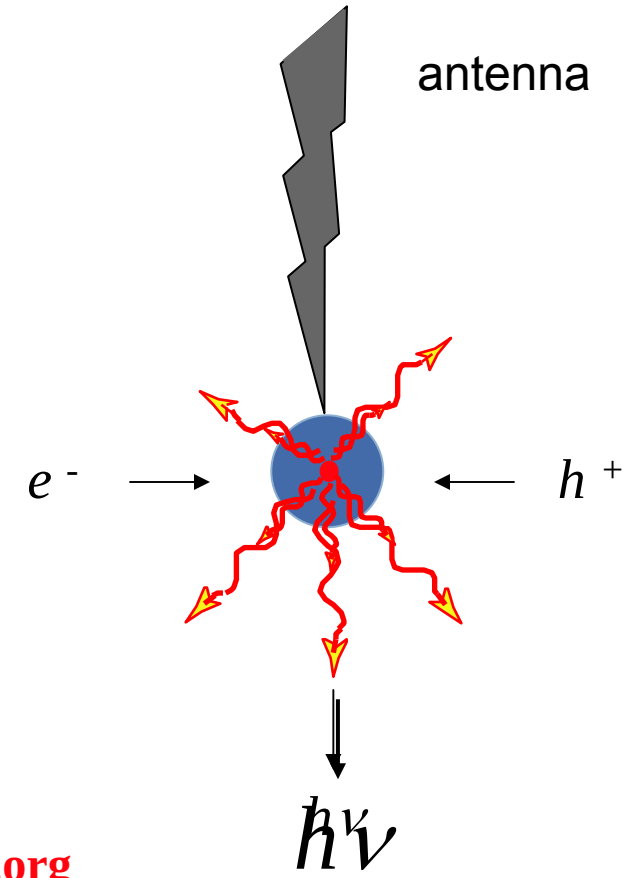
AFOSR, DOE, NSF

OPTICAL ANTENNAS FOR ENHANCED LIGHT-MATTER INTERACTIONS



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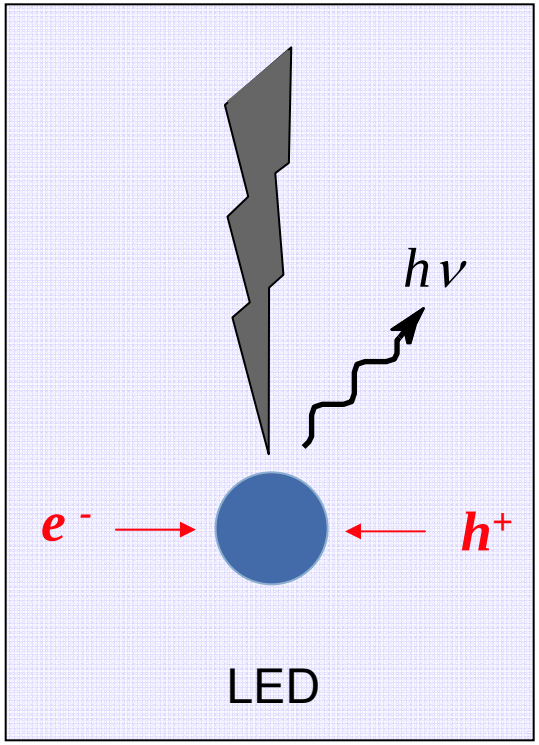
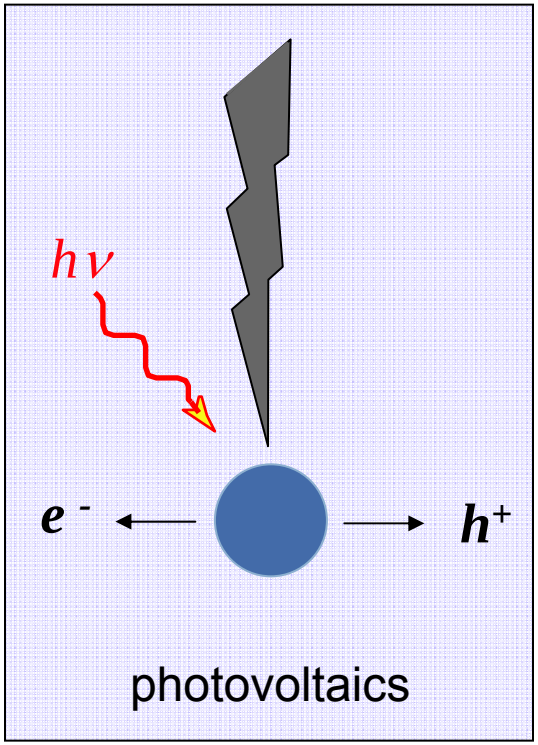
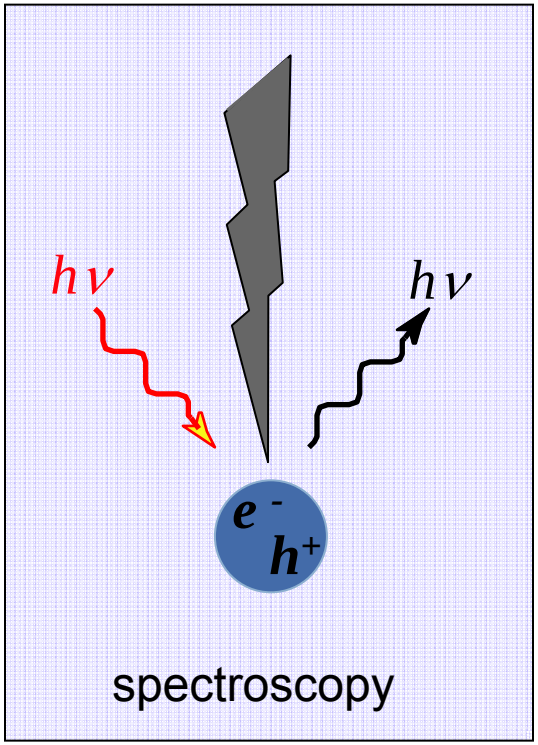
AFOSR, DOE, NSF

ANTENNA-BASED INTERACTIONS







Adv. Opt. Photon. **1**, 438 (2009)
Nature **455**, 887 (2008)

ETYMOLOGY

AN-TENN-A

‘up’

Indo-European: ‘to stretch’

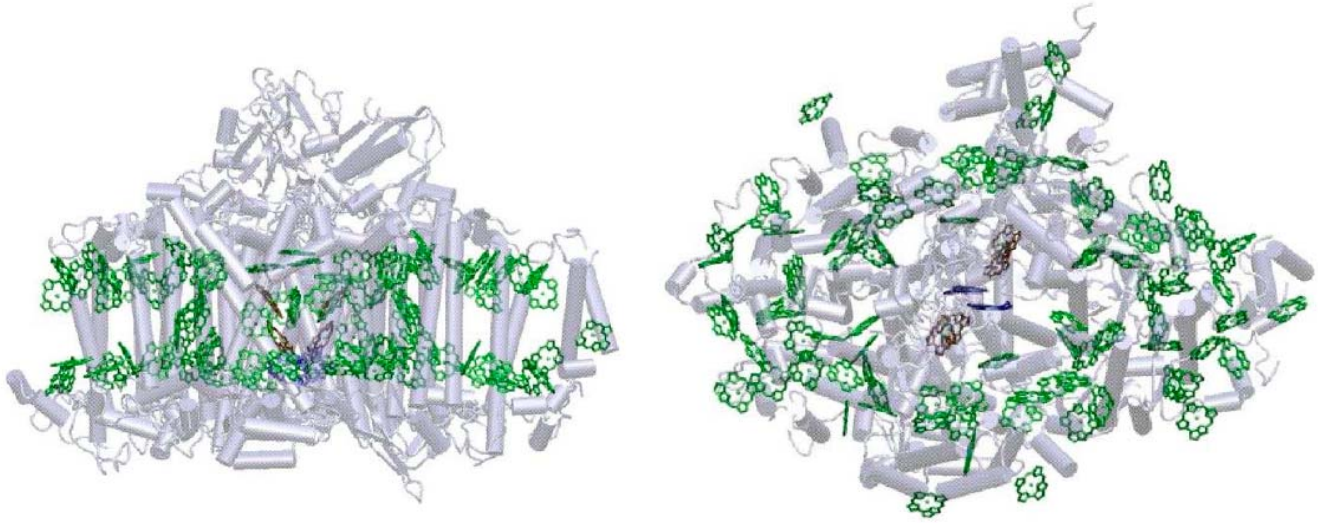
e.g. tension, pretend, tenacious, ..
tan (Sanskrit)
tendere (Latin)
teinei (Greek)
dehnen (German)
tyanut (Russian)
taanna (Hindi)

ANTENNA = THE ‘THING’ STRETCHING UP

ANTENNA

A DEVICE TO CATCH THE WIND (GREEK,LATIN)

OPTICAL ANTENNAS IN NATURE

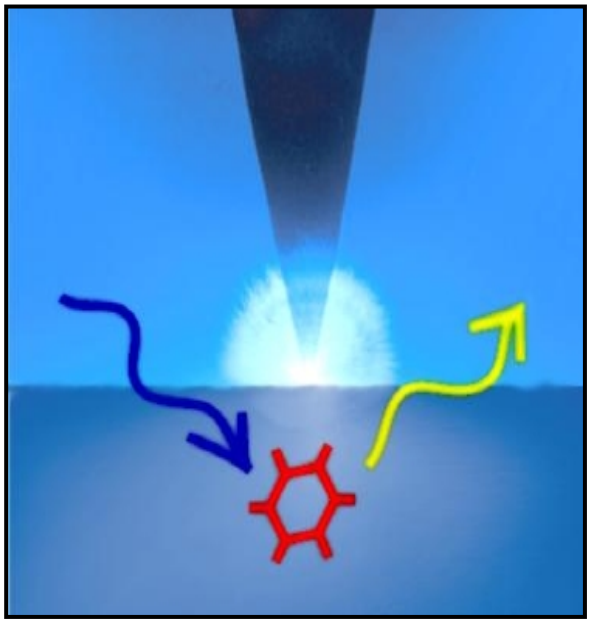


PHOTOSYNTHESIS: COLLECTIVE RESPONSE OF CHLOROPHYLL MOLECULES

ANTENNA

A DEVICE TO CATCH ELECTROMAGNETIC WAVES

OPTICAL ANTENNA

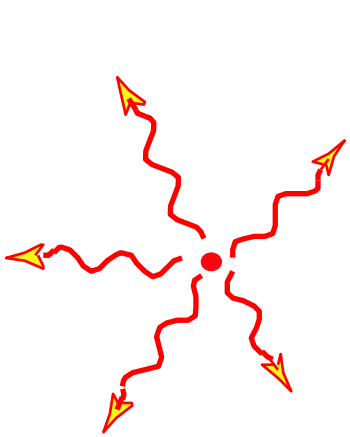


A DEVICE TO CONVERT OPTICAL RADIATION
TO LOCALIZED ENERGY, AND *VICE VERSA.*

Adv. Opt. Photon. **1**, 438 (2009)

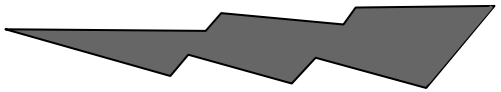
PROBLEM STATEMENT

-> coupled system of 3 entities

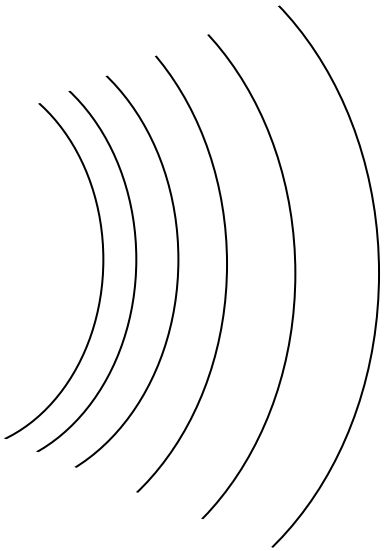


receiver/transmitter

(molecule, ion, quantum dot, ..)



antenna



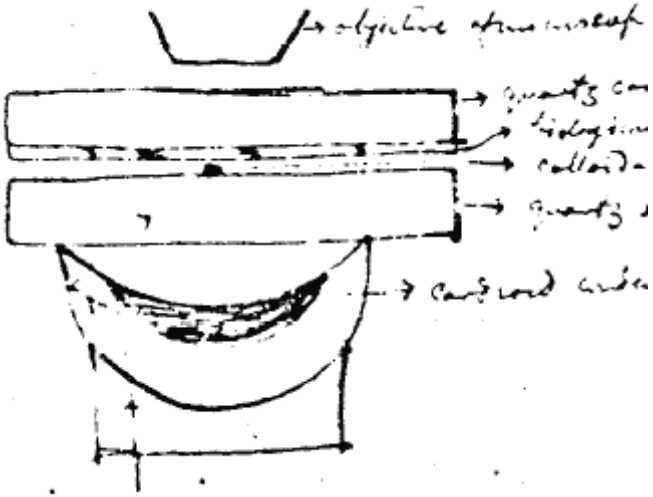
radiation

E. H. Synge

Knockree
Dundrum
22.4.28. Co Dublin
Ireland.

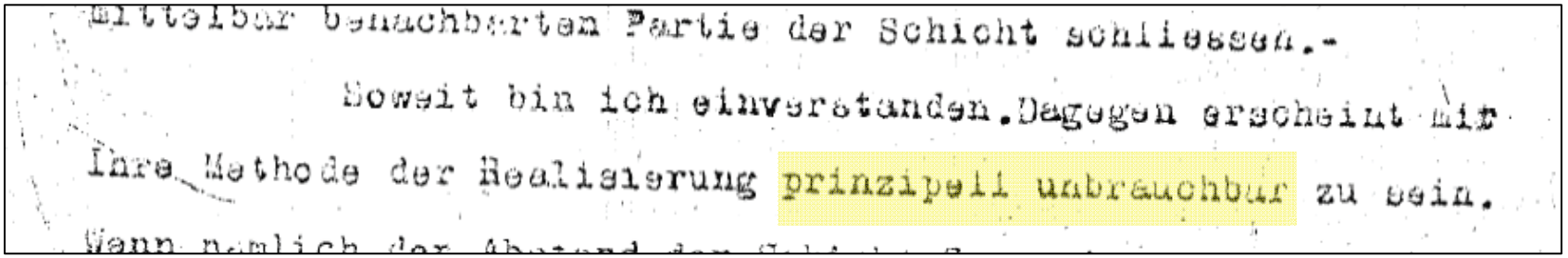
Dear Professor Einstein

You will, I think, be interested to hear that, after many delays, the collected Edition of Hamiltons works has at length been definitely undertaken by the Royal Irish Academy. My brother and another are at present engaged



Rep. Prog. Opt. ***50***, 137 (2007).

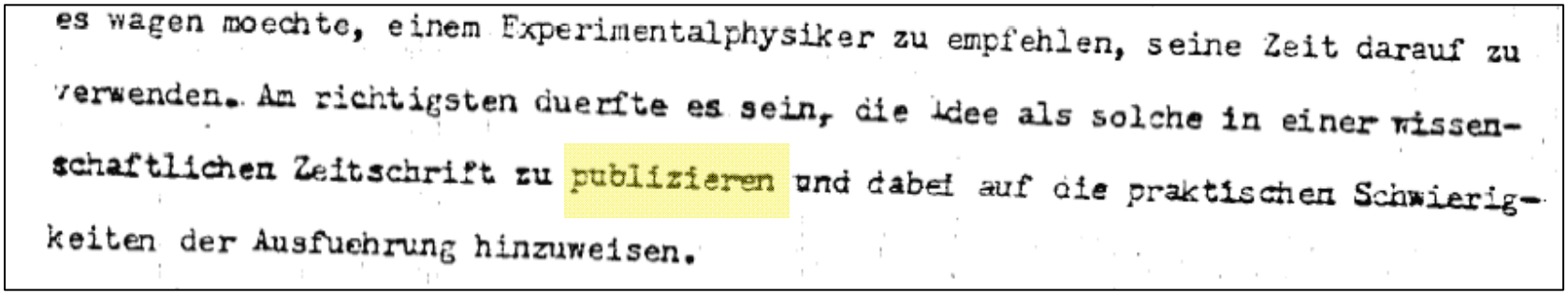
A. EINSTEIN (1928)



mittelbar benachbarten Partie der Schicht schliessen.-

Soweit bin ich einverstanden. Dagegen erscheint mir Ihre Methode der Realisierung prinzipell unbrauchbar zu sein. Wenn nämlich der Abstand der

→ **SYNGE DEVELOPS REVISED CONCEPT (APERTURE) !**

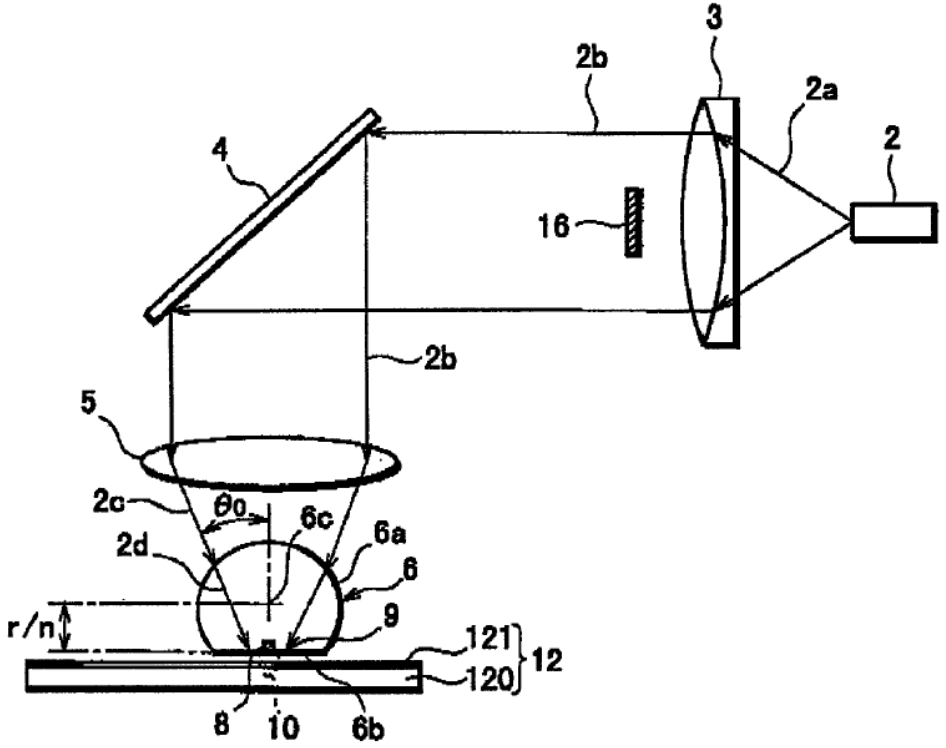


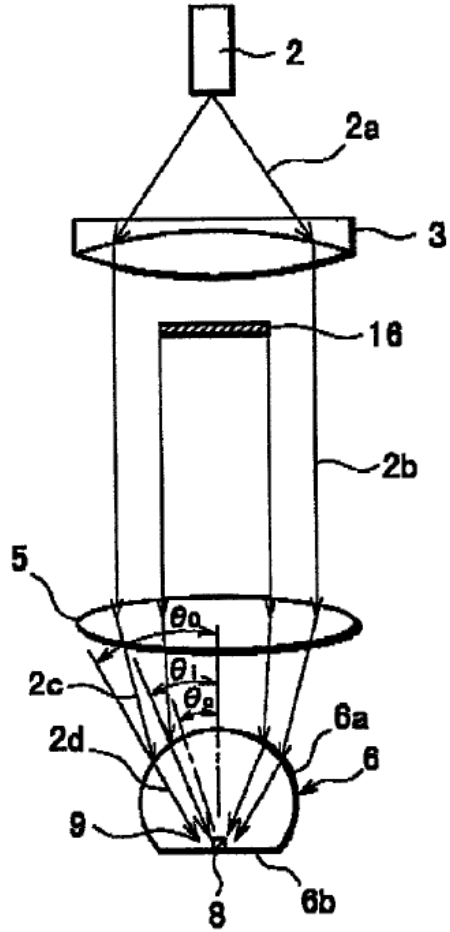
es wagen moechte, einem Experimentalphysiker zu empfehlen, seine Zeit darauf zu verwenden. Am richtigsten duerfte es sein, die Idee als solche in einer wissenschaftlichen Zeitschrift zu publizieren und dabei auf die praktischen Schwierigkeiten der Ausfuehrung hinzuweisen.

→ **SYNGE's PUBLICATION !**

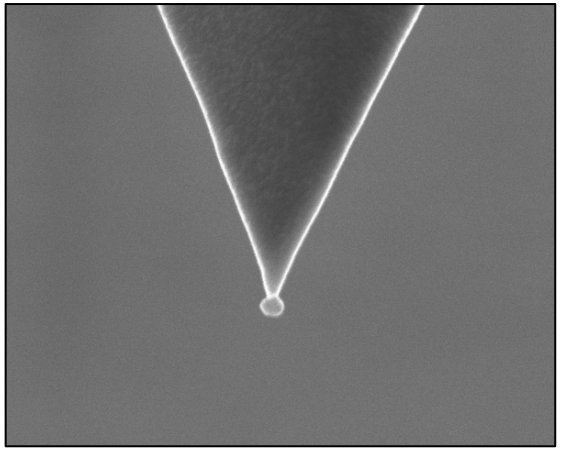
E.H. Synge, *Phil.Mag.* **6**, 356 (1928)

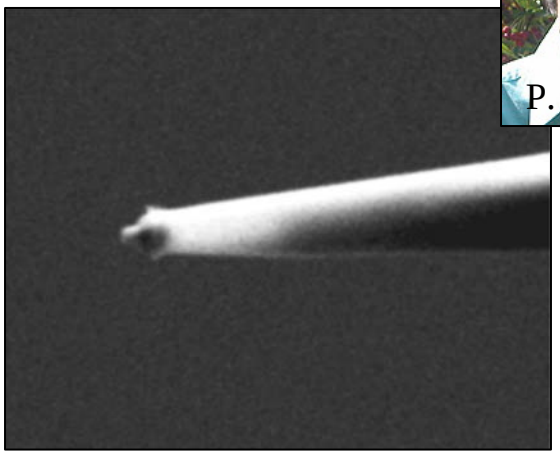
2001 FUJI-XEROX PATENT

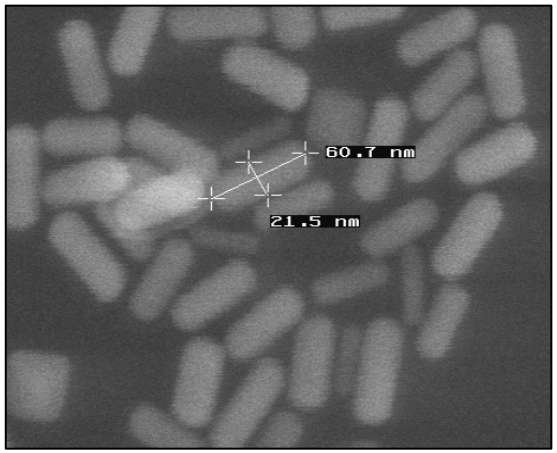




BOTTOM-UP SYNTHESIS OF OPTICAL ANTENNAS







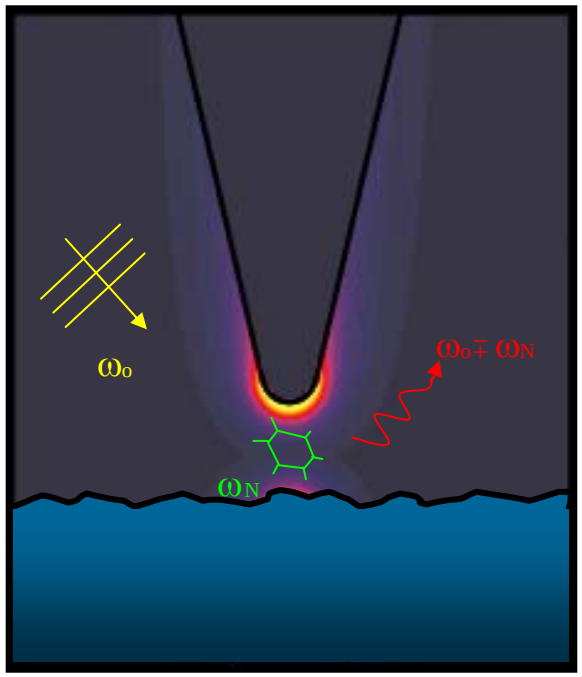
RAMAN SCATTERING

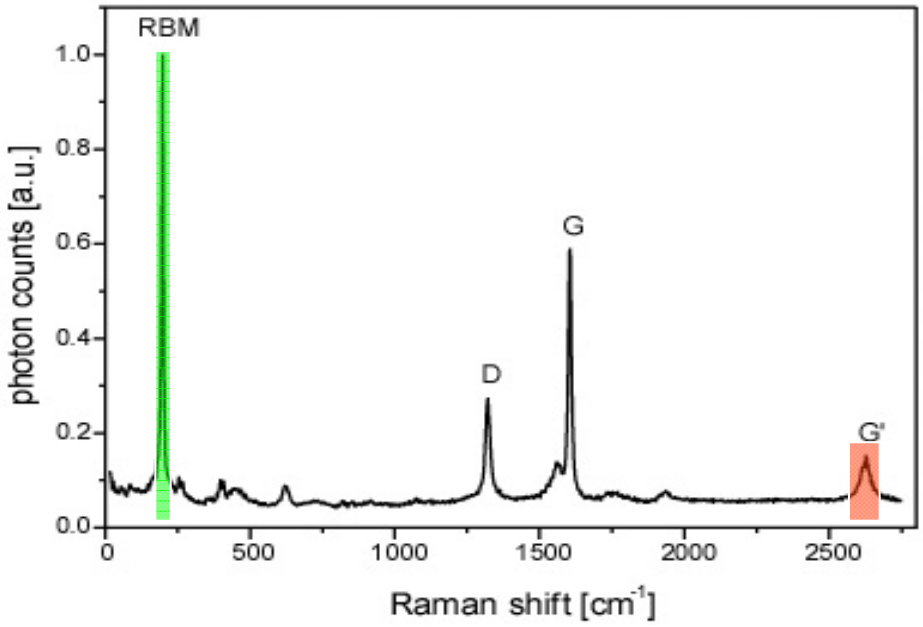
NEAR-FIELD RAMAN SCATTERING


A. Hartschuh


N. Anderson

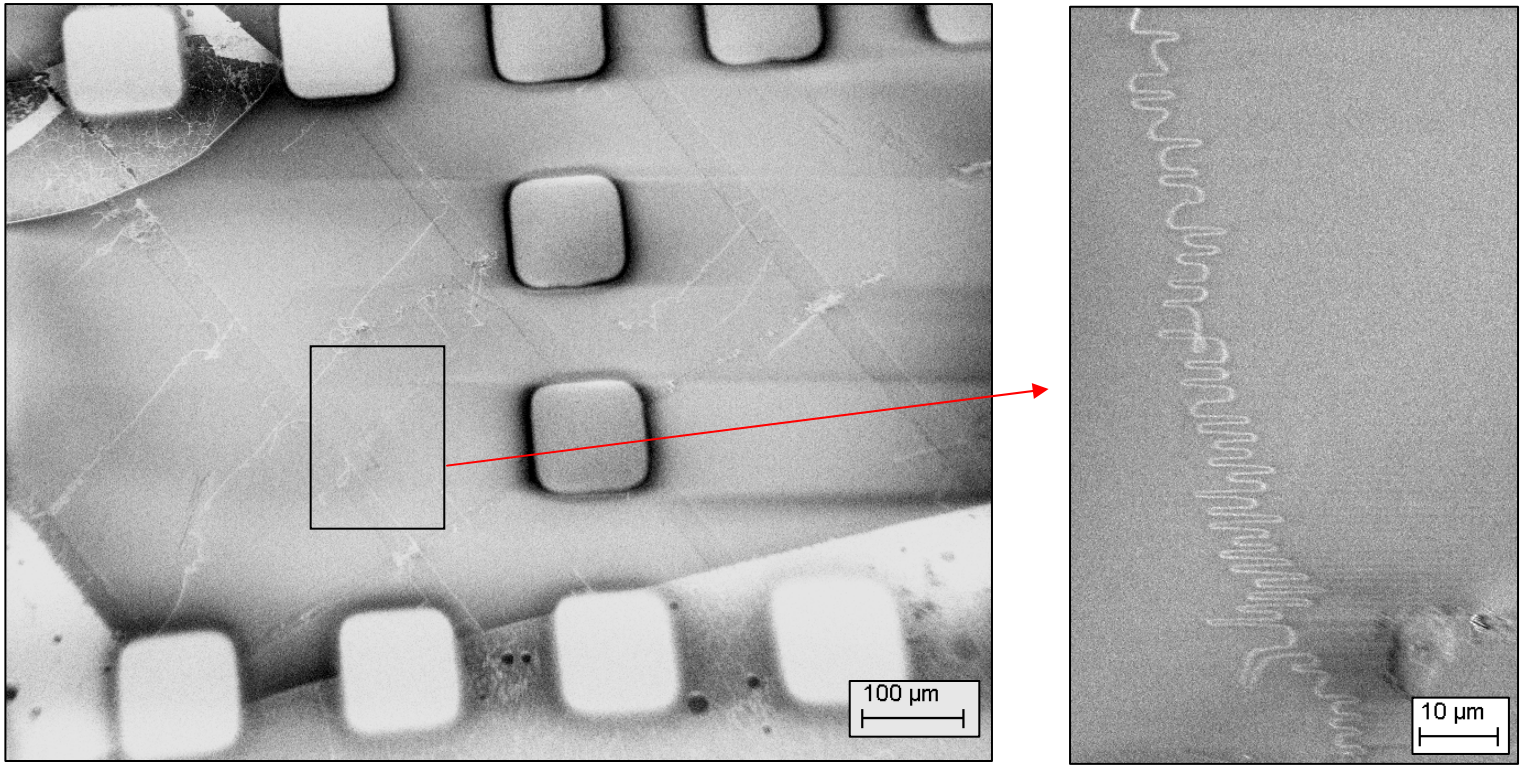

G. Cancado

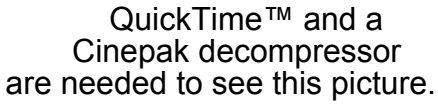




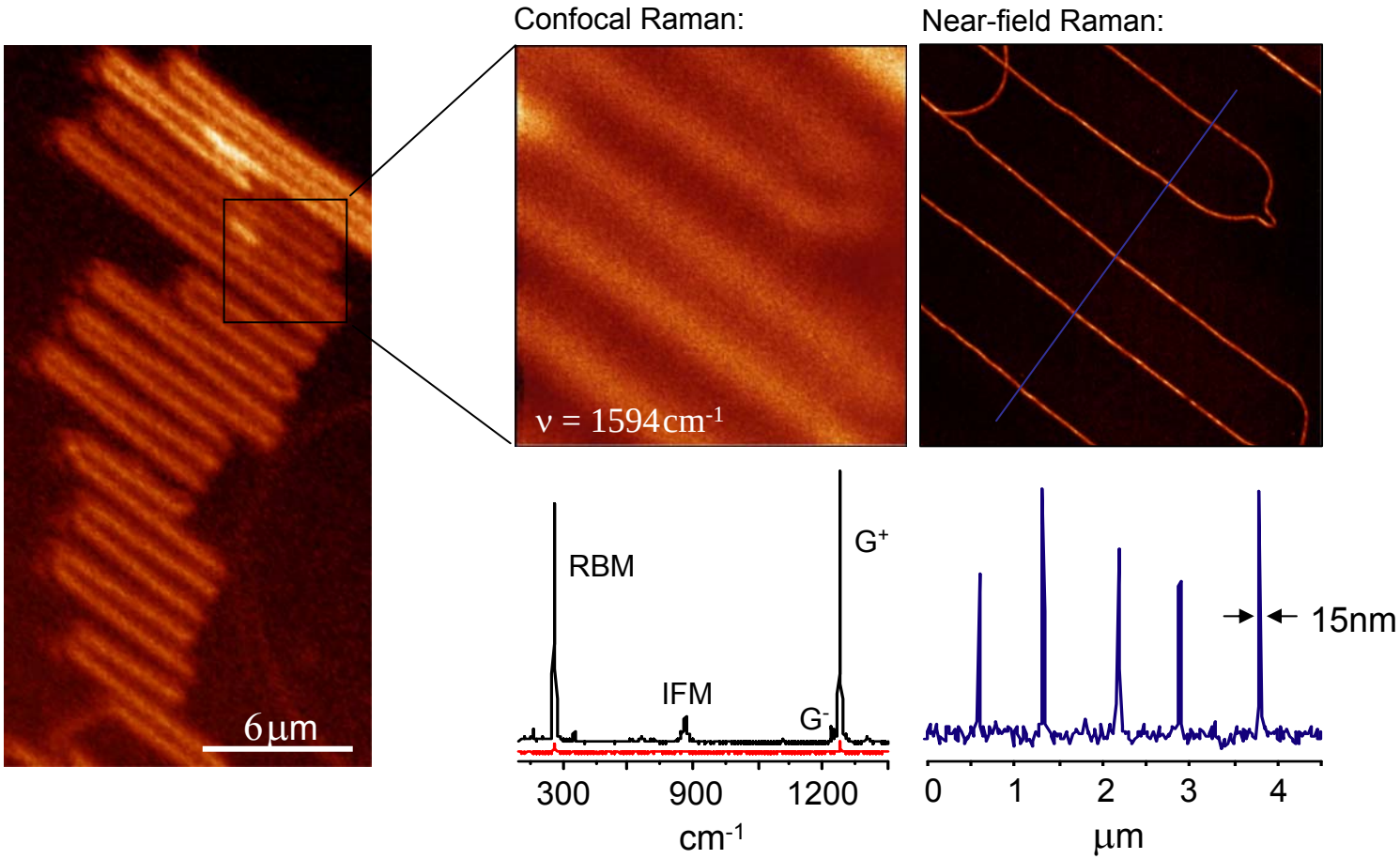
SERPENTINE NANOTUBES

(E. Joselevich)

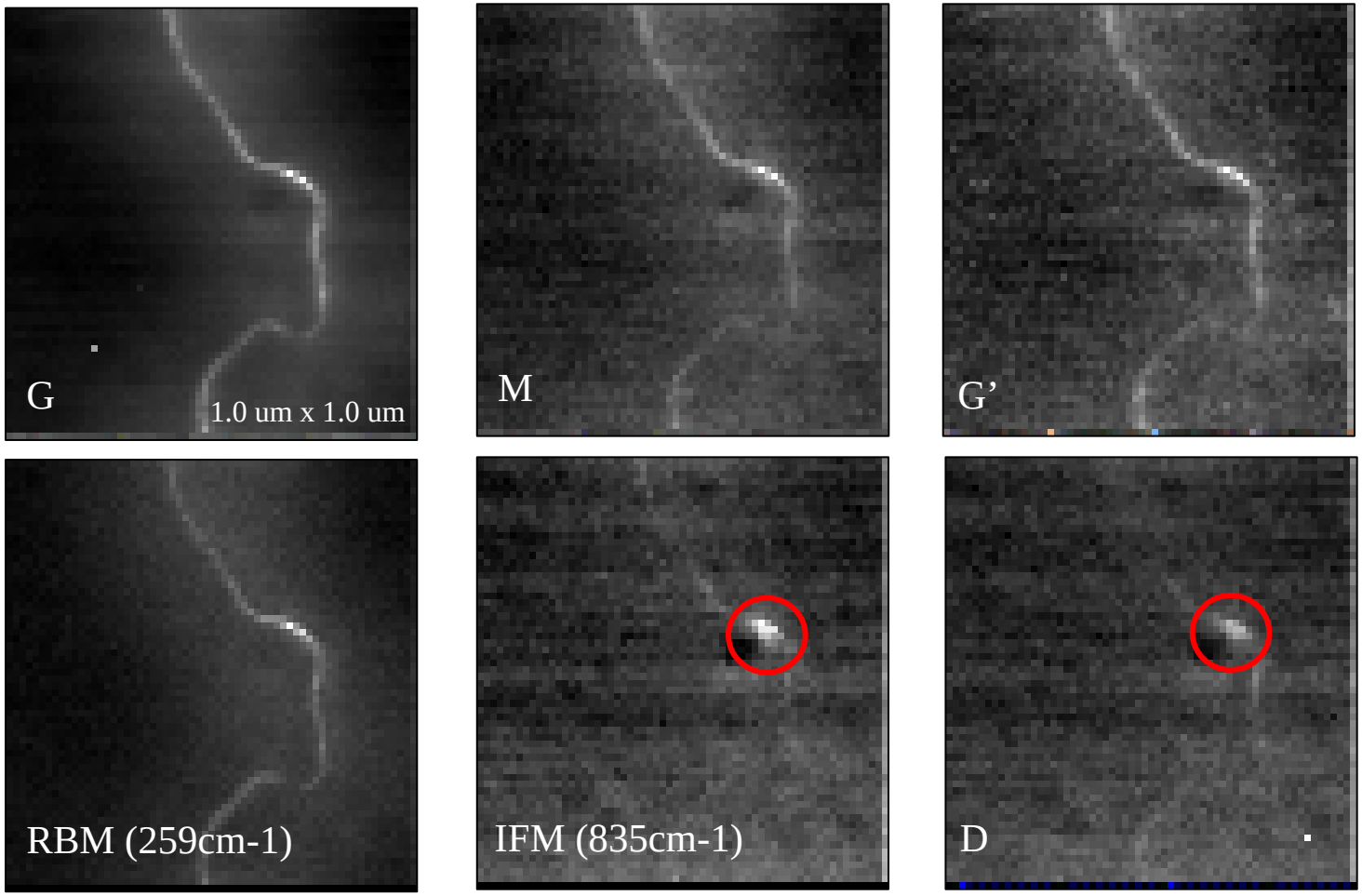



QuickTime™ and a
Cinepak decompressor
are needed to see this picture.

NEAR-FIELD RAMAN IMAGING OF SERPENTINE NANOTUBES



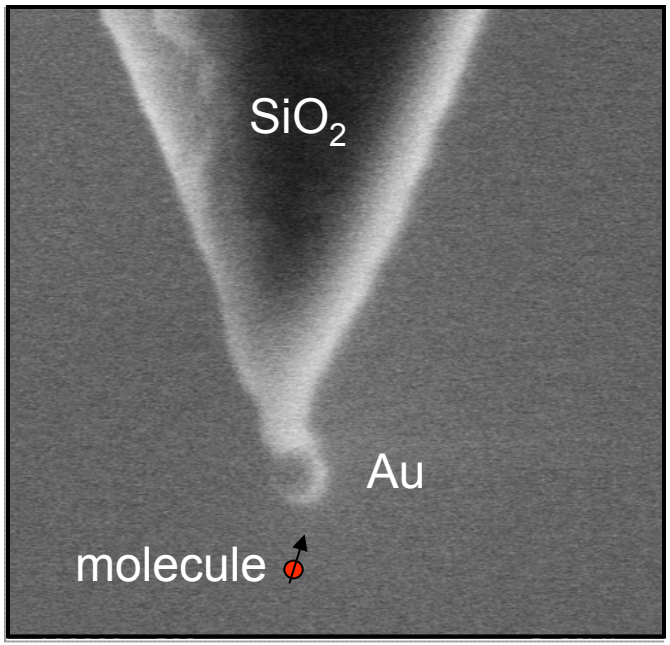
LOCALIZATION OF DEFECTS

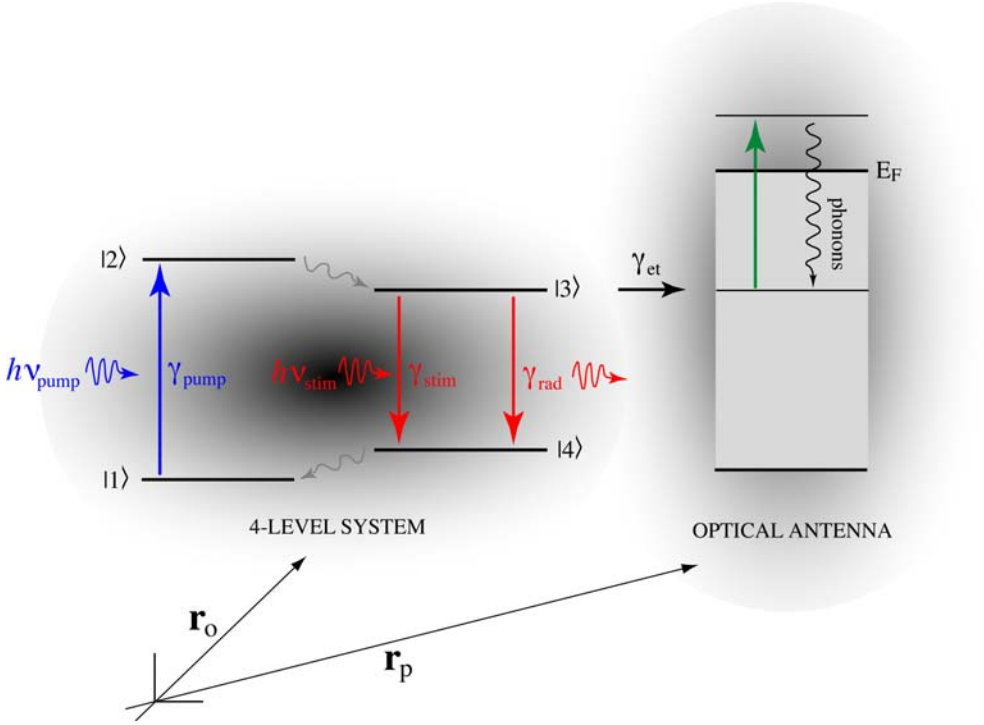


(n,m) = (8,5) : d_t ~ 0.9nm

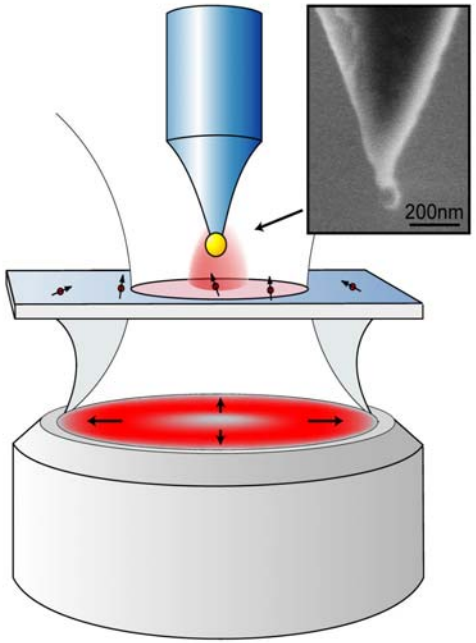
ENHANCING LIGHT EMISSION

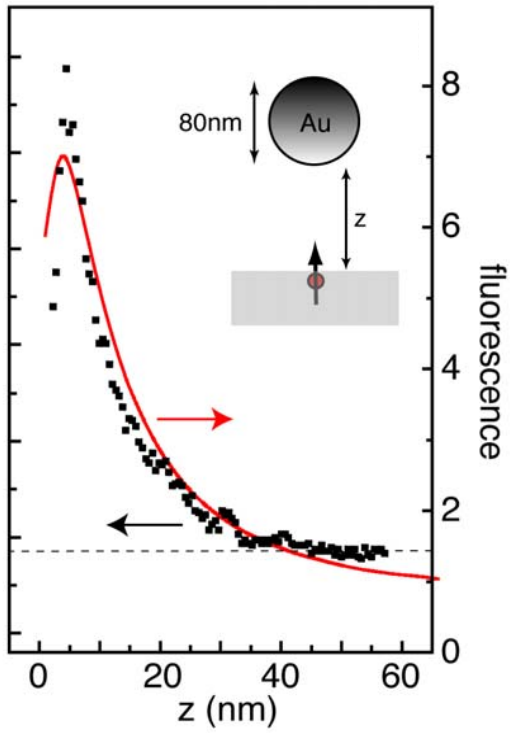
ANTENNA-COUPLED PHOTOEMISSION





ENHANCEMENT AND QUENCHING OF SINGLE MOLECULE FLUORESCENCE

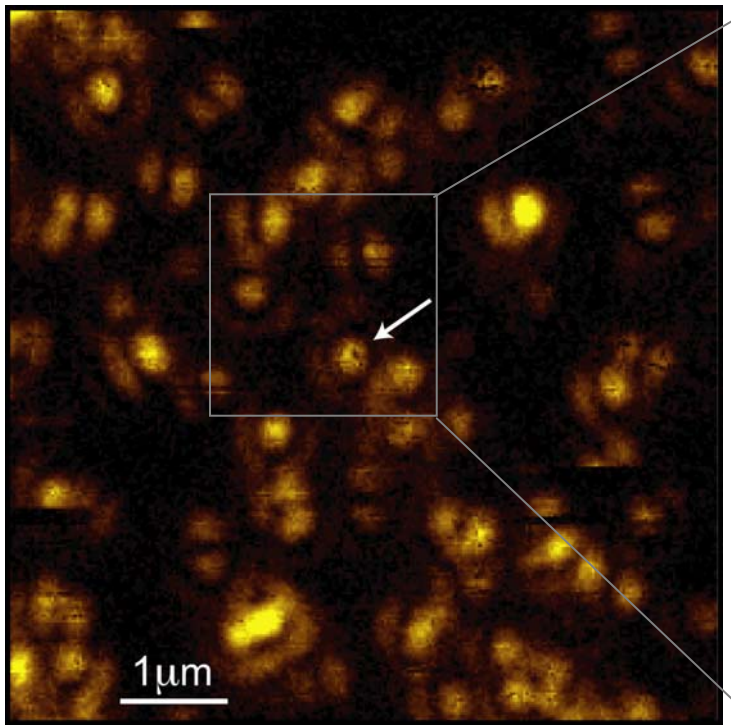




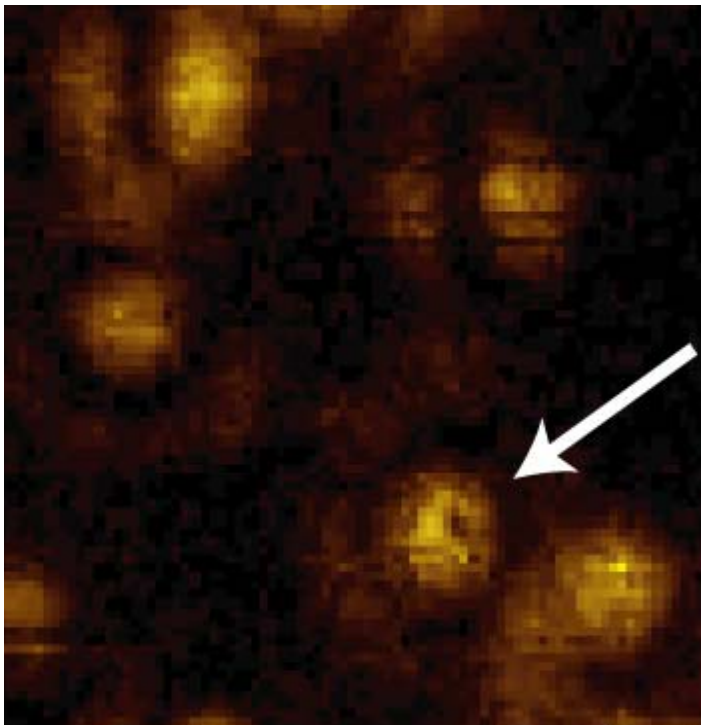
PRL **96**, 113002 (2006)

ANTENNA-ENHANCED FLUORESCENCE

without Au particle :



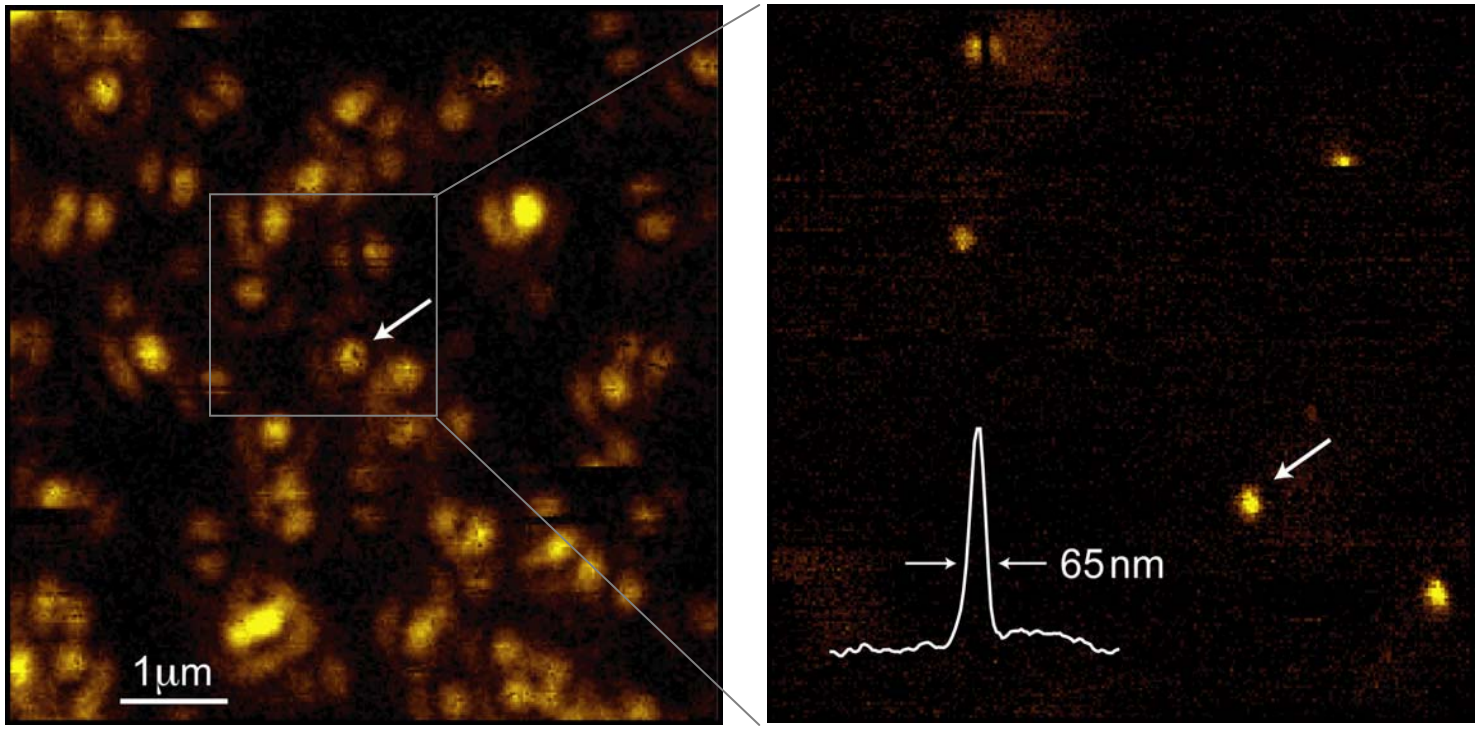
without Au particle:



ANTENNA-ENHANCED FLUORESCENCE

without Au particle :

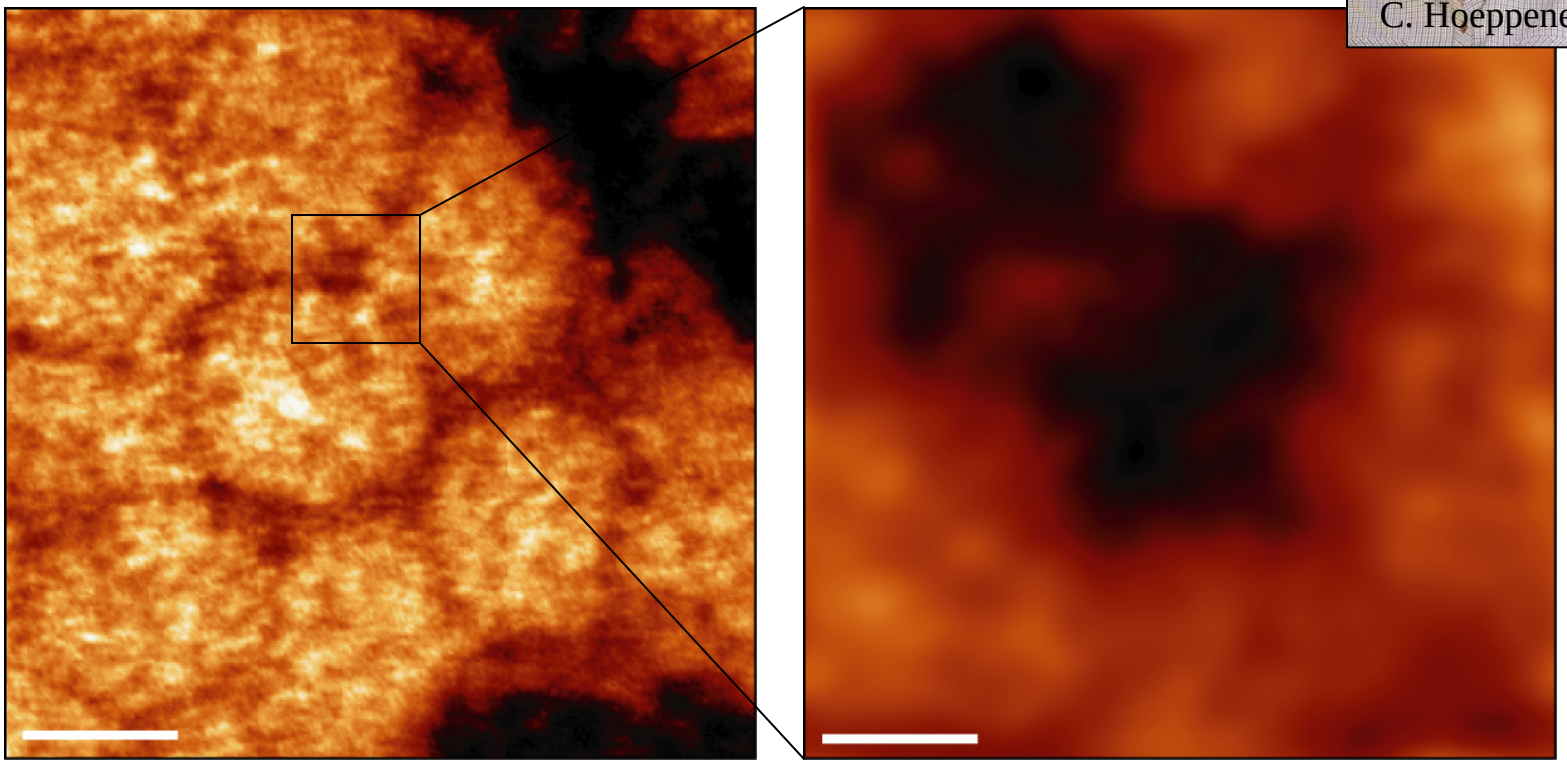
with Au particle antenna:



PRL **96**, 113002 (2006)

IMAGING OF SINGLE Ca^{+} ION CHANNEL PROTEINS IN ERYTHROCYTE MEMBRANES


C. Hoeppener



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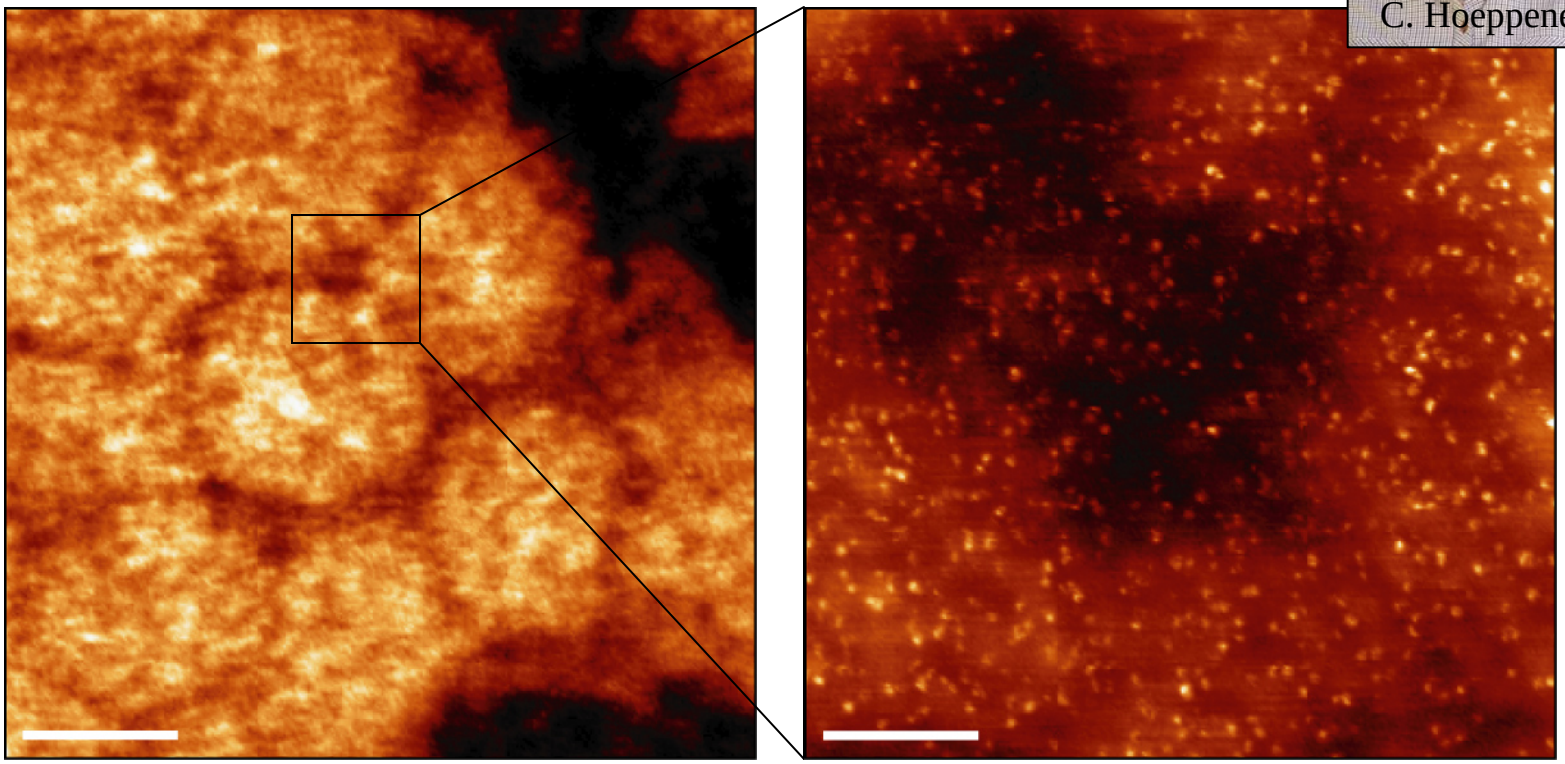
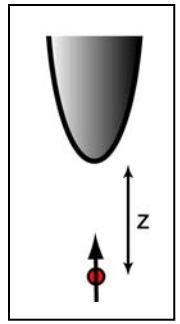


Nano Lett. **8**, 642 (2008)

QUANTUM YIELD

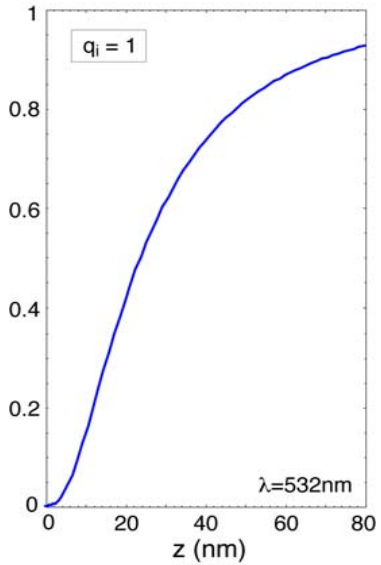


$$q(z) = \frac{\gamma_r(z)}{\gamma_r(z) + \gamma_{nr}(z)}$$

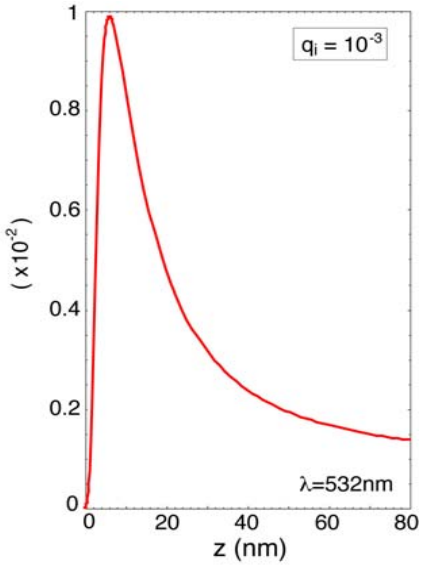
energy transfer + intrinsic

$\gamma_{et}(z)$ $\qquad$ $\gamma_i = [1/q_i - 1]\,\gamma_r(z \to \infty)$

Fluorophore



Nanotube

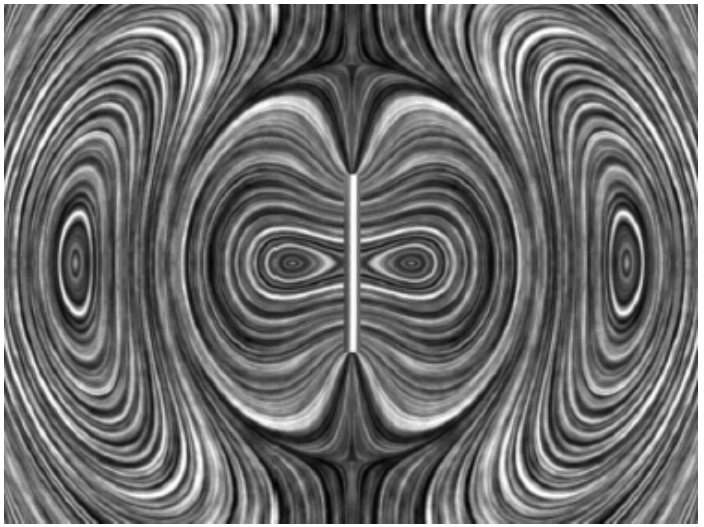


Nano Lett. **5**, 2310 (2006)

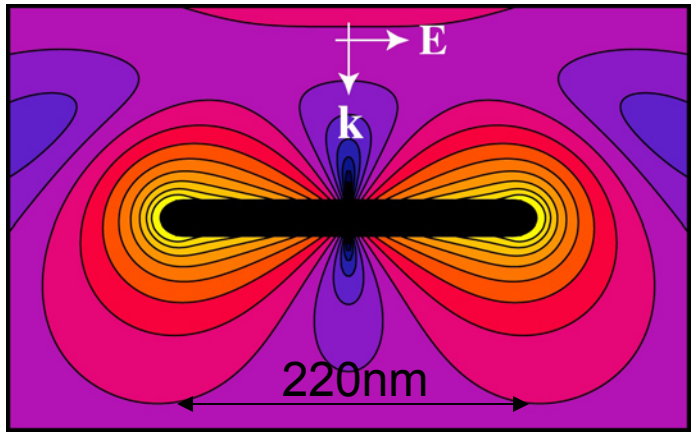
SCALING OF ANTENNA PARAMETERS

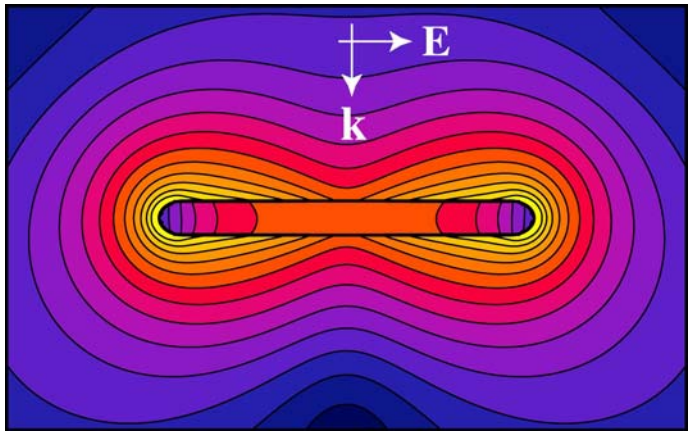
HALF WAVE ANTENNAS

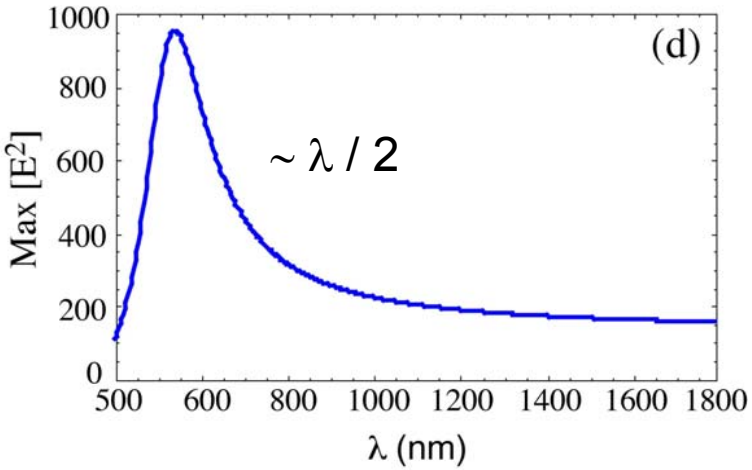
QuickTime™ and a
TIFF (Uncompressed) decompressor
are needed to see this picture.

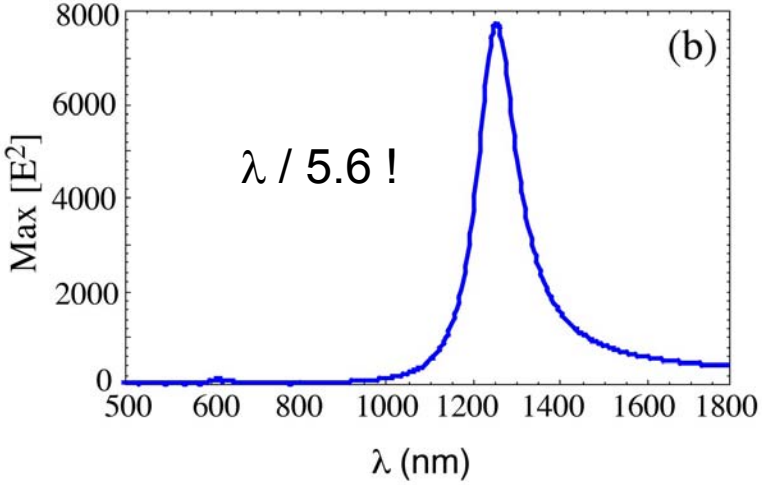


OPTICAL HALF-WAVE ANTENNA

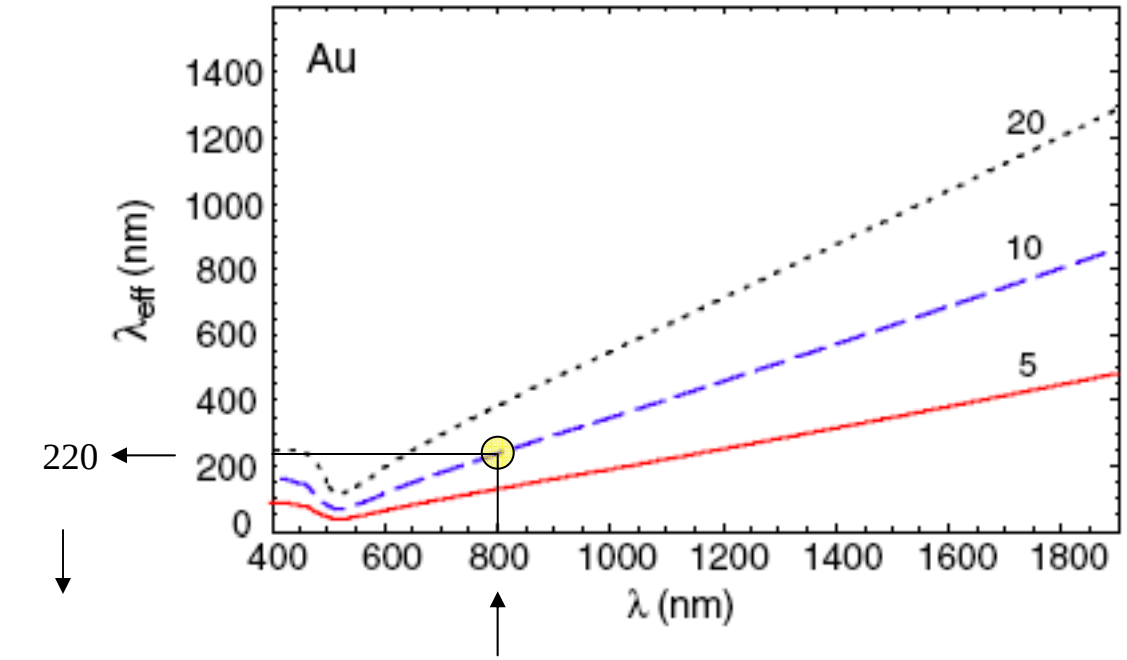








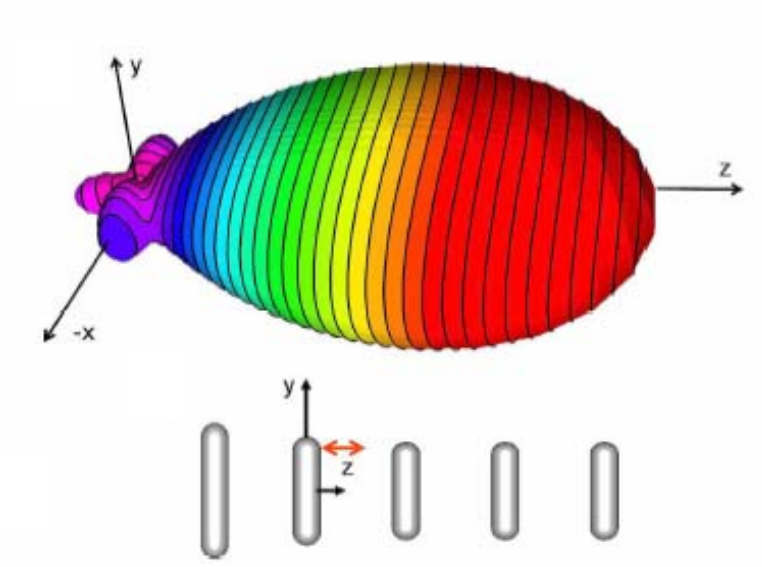
EFFECTIVE WAVELENGTH SCALING

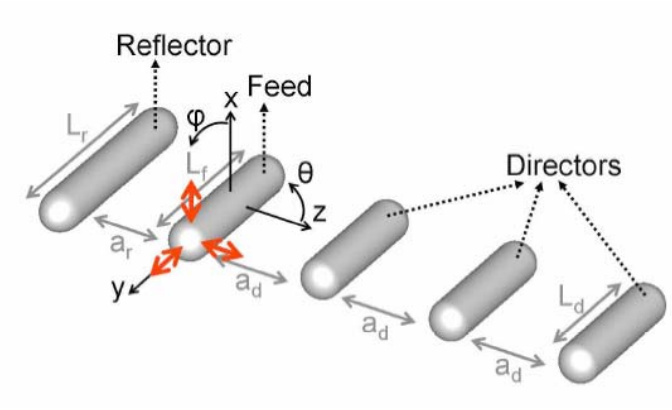


PRL **98**, 266802 (2007)

OPTICAL YAGI-UDA ANTENNA

QuickTime™ and a
TIFF (Uncompressed) decompressor
are needed to see this picture.



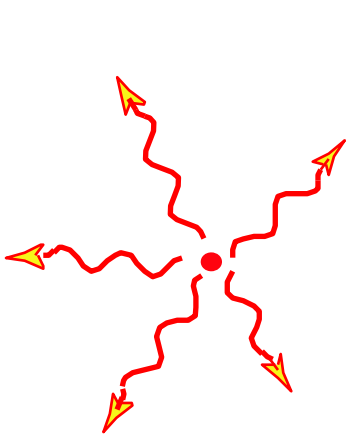


$$K_{exc}(\varphi,\theta) = \frac{D(\varphi,\theta)}{D_0} K_{rad}$$

T. Taminiau et al., Opt. Exp. **16**, 10858 (2008)

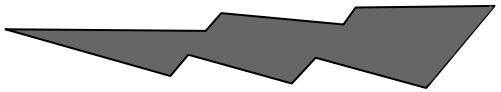
PROBLEM STATEMENT

-> coupled system of 3 entities

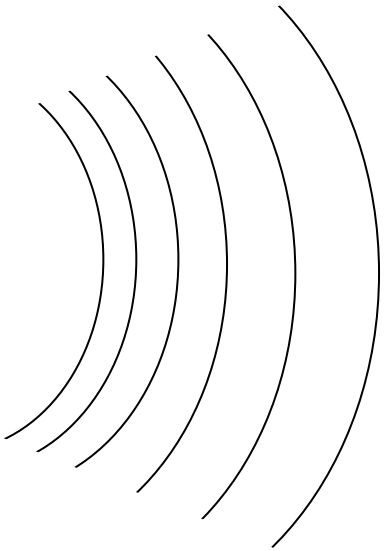


receiver/transmitter

(molecule, ion, quantum dot, ..)

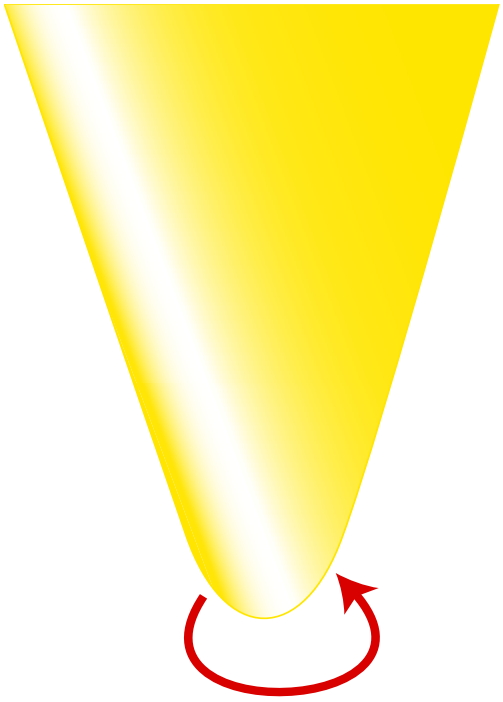


antenna



radiation

NEAR-FIELD TRANSITIONS



d~ 5-20 nm

Farfield : $k = 2\pi/\lambda \sim 10^5\ cm^{-1}$

Near-field : $k_{nf} \sim \pi/d \sim 10^7\ cm^{-1}$

Direct intraband transitions are possible in the NEAR-FIELD !!

$\langle f | \hat{\mathbf{p}} \cdot \hat{\mathbf{A}} | i \rangle \longrightarrow \hat{\mathbf{A}} \neq const.$!

Standard selection rules do not apply in the NEAR-FIELD !!

CONCLUSIONS

Antenna-coupled light-matter interactions

- Spectroscopy with spatial resolution ~10 nm

- Opportunities for LEDs, photovoltaics

- Nonlinear plasmonics

Thanks: Ado Jorio, Ernesto Joselevich, Stephen Stranick, Bradley Deutsch, Shanlin Pan, Barbara Schirmer, Rainer Hillenbrand, Brian McIntyre,

---

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