

Nanophotonics:

The link between nanotechnology and photonics



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Presenter:
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CSIR
our future through science

Presentation Outline

- **Birth and definition of nanotechnology**
- **Benefits of nanotechnology**
- **What is photonics and importance**
- **The link between nanotechnology and photonics:
Nanophotonics**
- **Importance and future of nanophotonics**
- **Our on-going research on nanophotonics**
- **Conclusions**

MISSION: The **DST/CSIR NATIONAL CENTRE FOR NANOSTRUCTURED MATERIALS** coordinates, facilitates, disseminates new knowledge, and expedites nanoscience and nanoengineering developments to expedite the commercialization of innovation

GOAL: Accelerate the development of high technology and the dissemination of these developments in order to expedite commercialization

Applications

Built Environment

- Housing materials (fire proof)
- Paint (self clean, UV resist.)

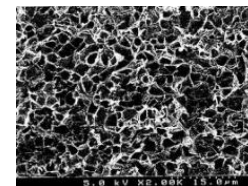


Advanced Manufacturing

- Advanced materials
- Composites

Natural Environment

- Water filtration/purification



NANO-ENGINEERED MEMBRANES

Energy

- Batteries
- Fuel cells



Health

- Gas sensors
- Pathogen detection
- Hygiene
- Drug delivery
- Cosmetics



CSIR
our future through science

Nano-Clays
Nanocomposites
Nanoparticles

Functional Composites

- Anti-bacterial
- Food packaging
- Water filtration



Birth of Nanoscience and Nanotechnology

I want to build a billion tiny factories, models of each other, which are manufacturing simultaneously. The principles of physics, as far as I can see, do not speak against the possibility of maneuvering things atom by atom. It is not an attempt to violate any laws; it is something, in principle, **that can be done; but in practice, it has not been done because we are too big**

— Richard Feynman, 1959

1980's Dr K. Eric Drexler popularized the word “nanotechnology”

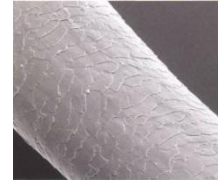
How Small NANO is?

How small?



Ant head

1mm



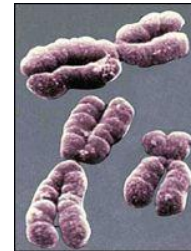
Human hair

100um, 100 000nm



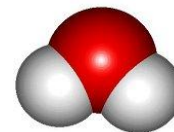
Red blood cell

10um, 10 000nm



DNA

4nm wide



H₂O Molecule

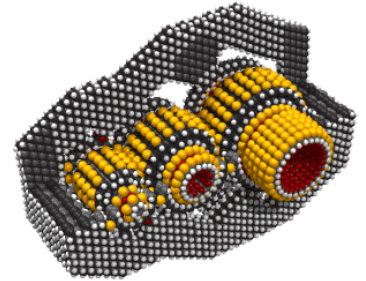
0.2nm

Nanoscience

Nanoscience is the study of phenomena and manipulation of materials at atomic, molecular and macromolecular scales, where properties differ significantly from those at a larger scale

Nanotechnology

Nanotechnology is the engineering of functional systems at the molecular scale



Nanotechnology: Current Definition

.....can refer to measurement or visualization at the scale of 1-100 nanometers

.....become increasingly obvious that "engineering of functional/structural systems at the molecular scale"

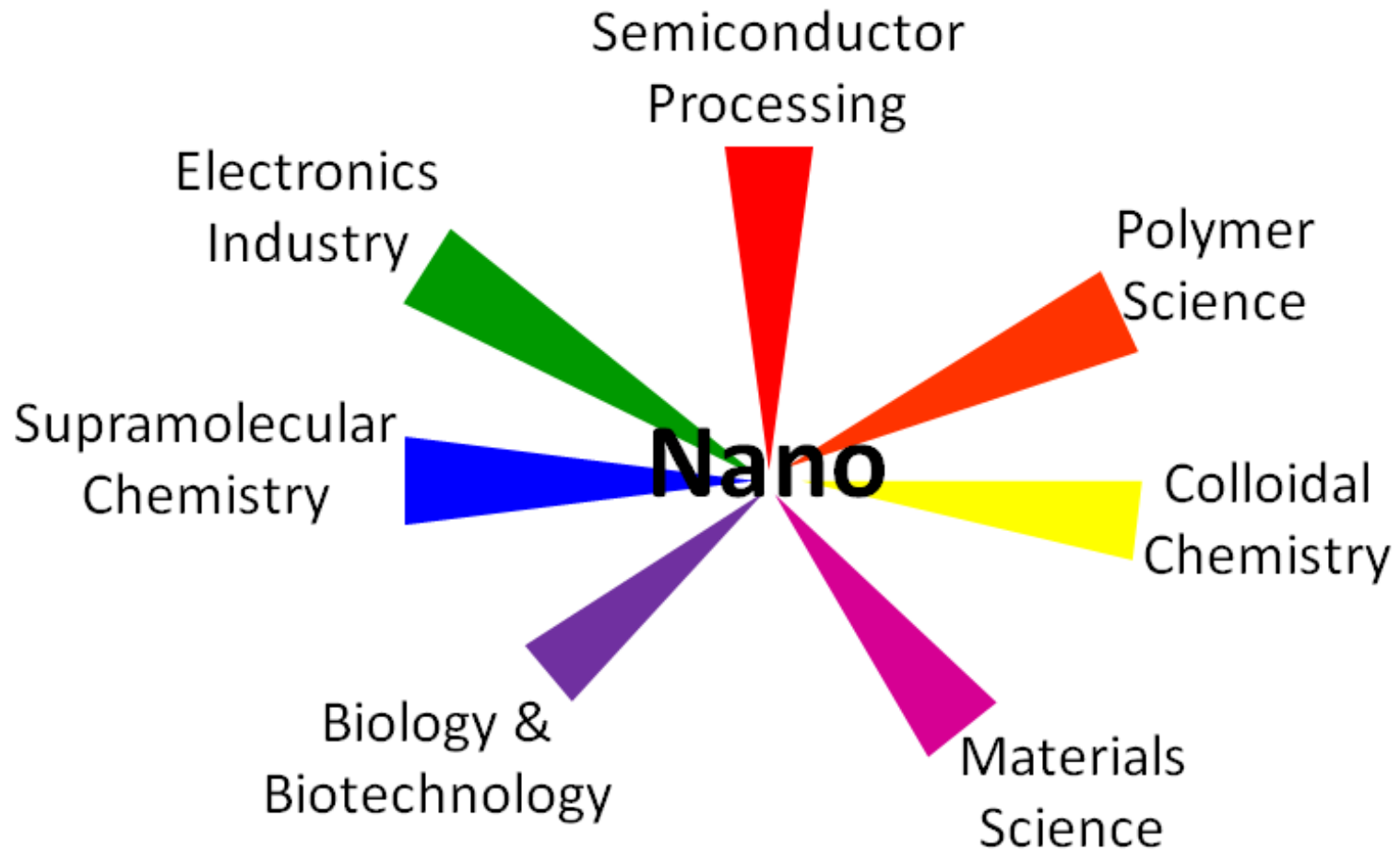
Nano-effect or Nano-phenomena

“means building things from the bottom up, with atomic precision”

Why NANO Rather than Something Else?

- Novel (new) properties (or mixes of properties), and new phenomena
- The confluence of many disciplines (physics, chemistry, bio-sciences, materials science, and engineering)
- A bridge between the living and non-living worlds (“Nature” is the master nanotechnologist)
- A bridge between the quantum world and the “classical” world
- Most efficient length scale for manufacturing

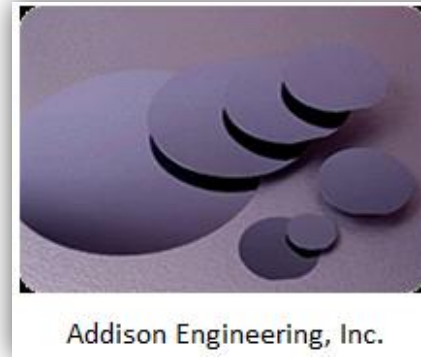
Nanotechnology Active Research Areas



Applications: Electronics/Photonics



Dell, Inc.



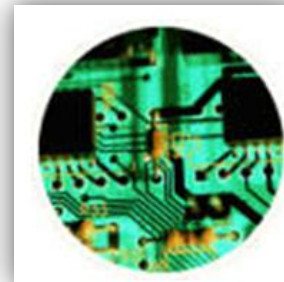
Addison Engineering, Inc.



Sony Corp.



Eastman Kodak Co.



Power Paper Ltd.




...area of study that involves the use of radiant energy (such as light), whose fundamental element is the PHOTON

Photonic applications use the photon in the same way that electronic applications use the ELECTRON

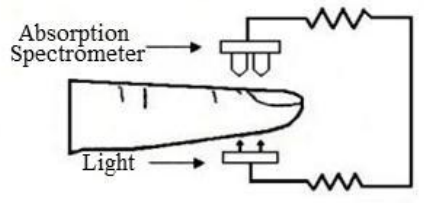
Importance of Photonics

- **Signals travel at the speed of light**
- **Photons, unlike electrons have no weight and create no resistance**
- **Focused light generated by lasers constitutes the highest concentration of energy known on earth**
- **A pulse of photons can be as short as one-millionth of a billionth of a second, the dimension of time in which molecular and atomic reactions take place**
- **Light beams are well-suited not only to help us see, but also to hold and manipulate atoms**
- **As light acts virtually contact-free; it can be used as a tool even under extreme conditions**

Current Technologies in Harnessing Light for Healthcare Diagnostics



Digital Finger Pulse Oximeter



Absorption Spectrometer
Light


Diagram of Operation Principle



Pregnancy Test

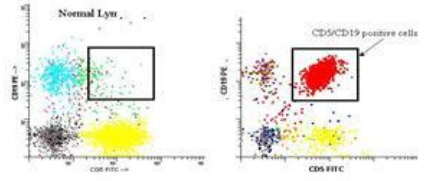
Negative Result 

Positive Result 



Flow Cytometry

CELLS ARE IN CLUSTERS THAT CREATE PATTERNS
Detection of Lymphocytic Cell Surface Markers using antibodies to CD19 and CD5



Normal Lym. CD5 FITC

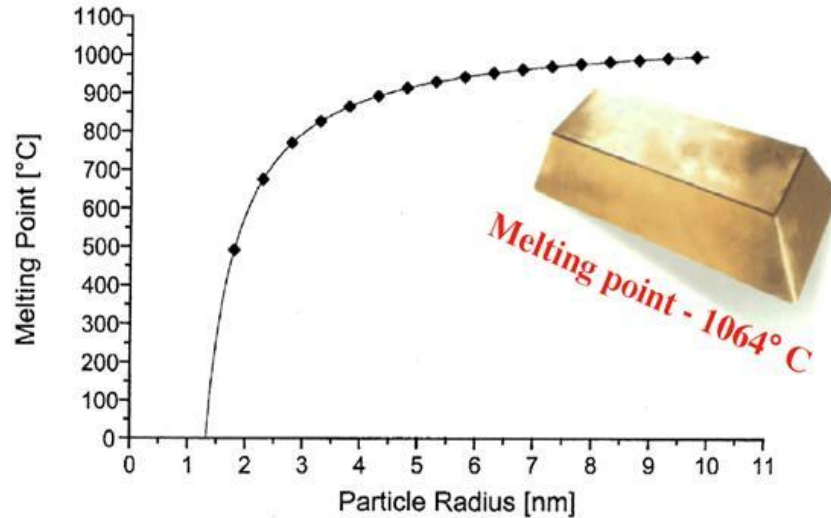
CD5/CD19 positive cells CD5 FITC

Co-expression of C

Copyright © C. Steiner/RPCI

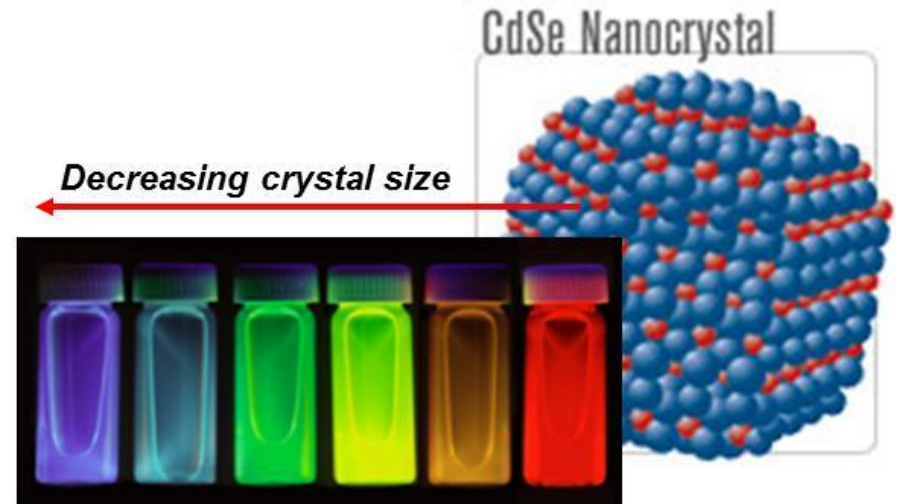
Size Dependent Materials Properties

Melting point of gold particles



K. J. Klabunde, 2001

Fluorescence of semiconductor nanocrystals



*M. Bawendi, MIT: web.mit.edu/chemistry/nanocluster
Evident, Inc.: www.evidenttech.com*

The core concepts of the NANOPHOTONICS were originated in mid 1990s during the phenomena for testing the nanotechnology strength to cater light

Two main concepts are involved in photonics

- **Revealing and exploring the properties of light at the nanometer scale**
- **Enhancing efficient devices power to be used in engineering applications**

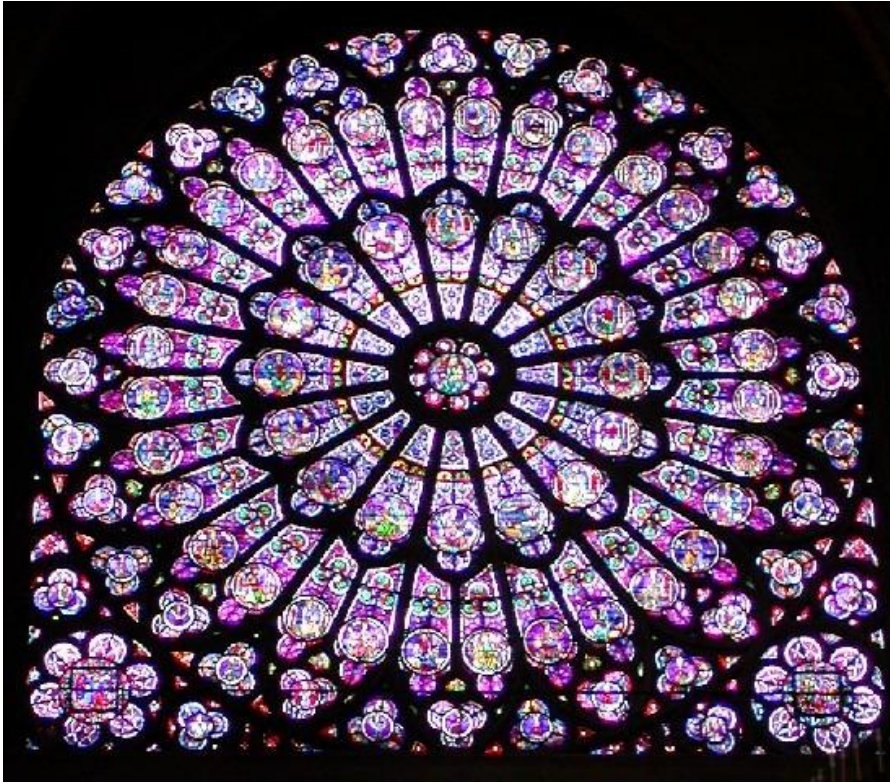
Definition of NANOPHOTONICS?

Nanophotonics is the branch of nanotechnology that deals with the study and behavior of light and optics at nanometer scale

Nanoscale Optical Interactions and Excitation Dynamics: *Manipulation and Manifestations*

- **Size dependent optical transitions**
- **Novel optical resonances**
- **Nano-control of excitations dynamics**
- **Manipulation of light propagation**
- **Nanoscopic field enhancement**

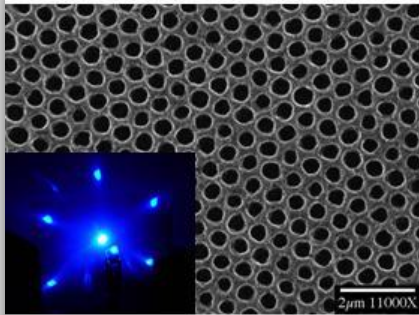
Technologies for Global Priorities



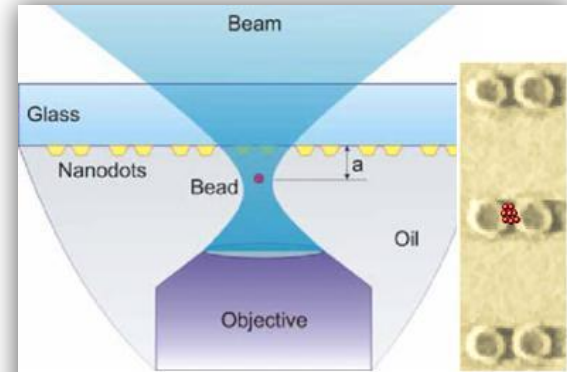
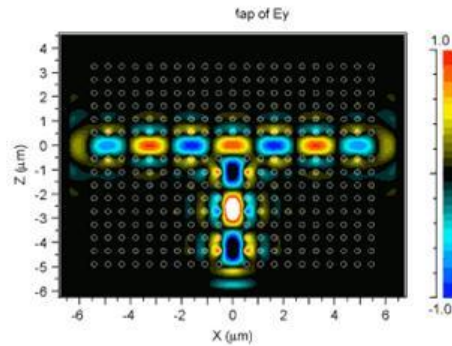
NANOPHOTONICS FROM **MEDIEVAL AGES**
(Stained Glass Window in *Notre Dame de Paris*: Rose Window)

- **Solar energy**
- **Information technology**
- **Environmental monitoring**
- **Healthcare**

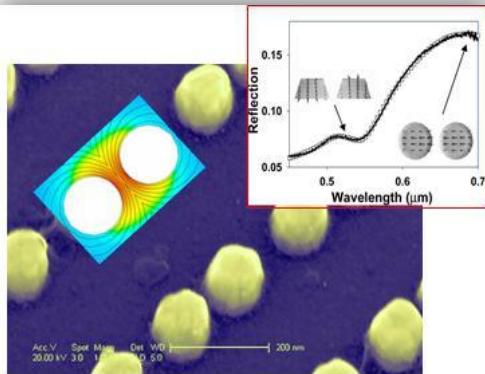
Nanophotonics



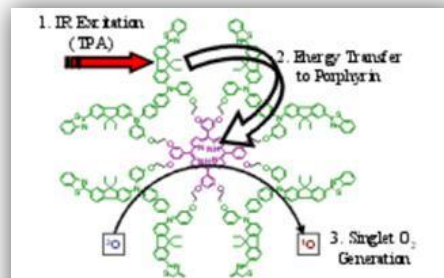
Photonic crystals: Manipulation of light propagation



Nanotrapping: Subwavelength control of field gradients



Plasmonic arrays: Field enhancement, Novel optical resonances

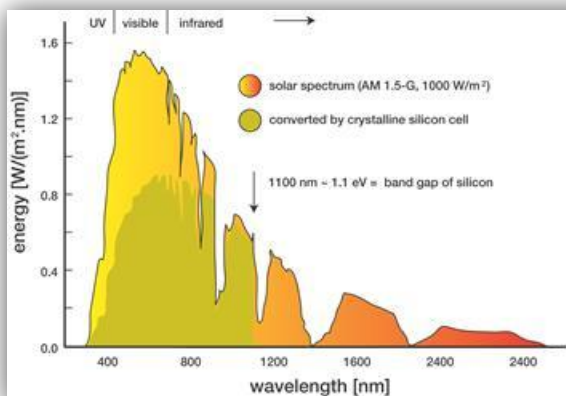


Dendrimers: Control of excitation dynamics



QDs: Size-dependent absorption/emission

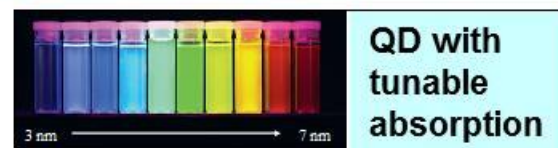
Polymer Nanocomposite Framework (cont.)



Current technologies need improvement in:

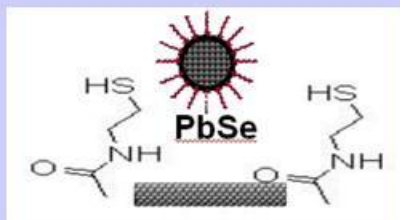
- IR conversion
- UV conversion

Nanophotonics solution:

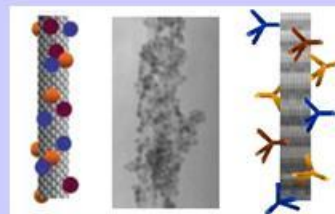


Quantum dots for harvesting IR photons

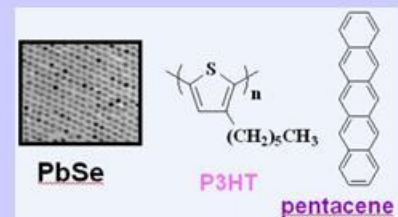
Photon Harvesting by IR absorbing QDs



Facilitated Charge separation By conjugation to SWNT



Enhanced charge collection by high mobility organics



Cho, Prasad et al., *Adv. Mater.* 19, 232 (2007)

Communication:

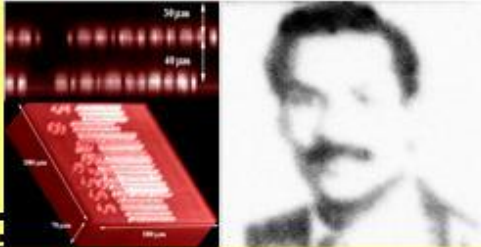
- Reconfigurable Photonic Crystals
- 3D Plasmonic Guiding and Routing Network

Processing:

- Electro-optic Processing Using Supramolecular Structures and Nanocomposites
- Electrically and Optically Switchable Photonic Crystals

Storage:

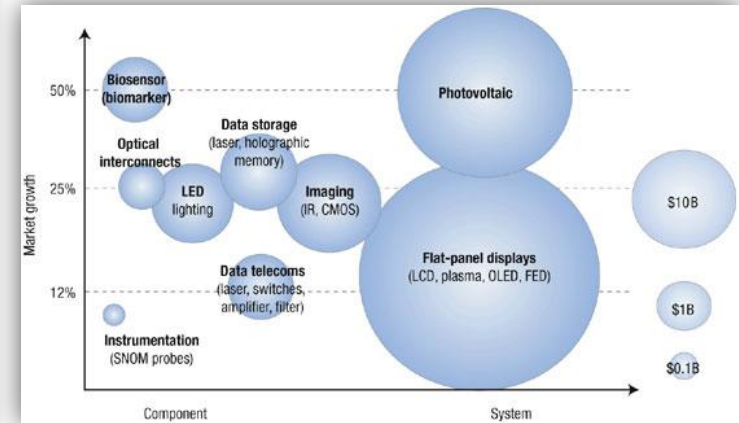
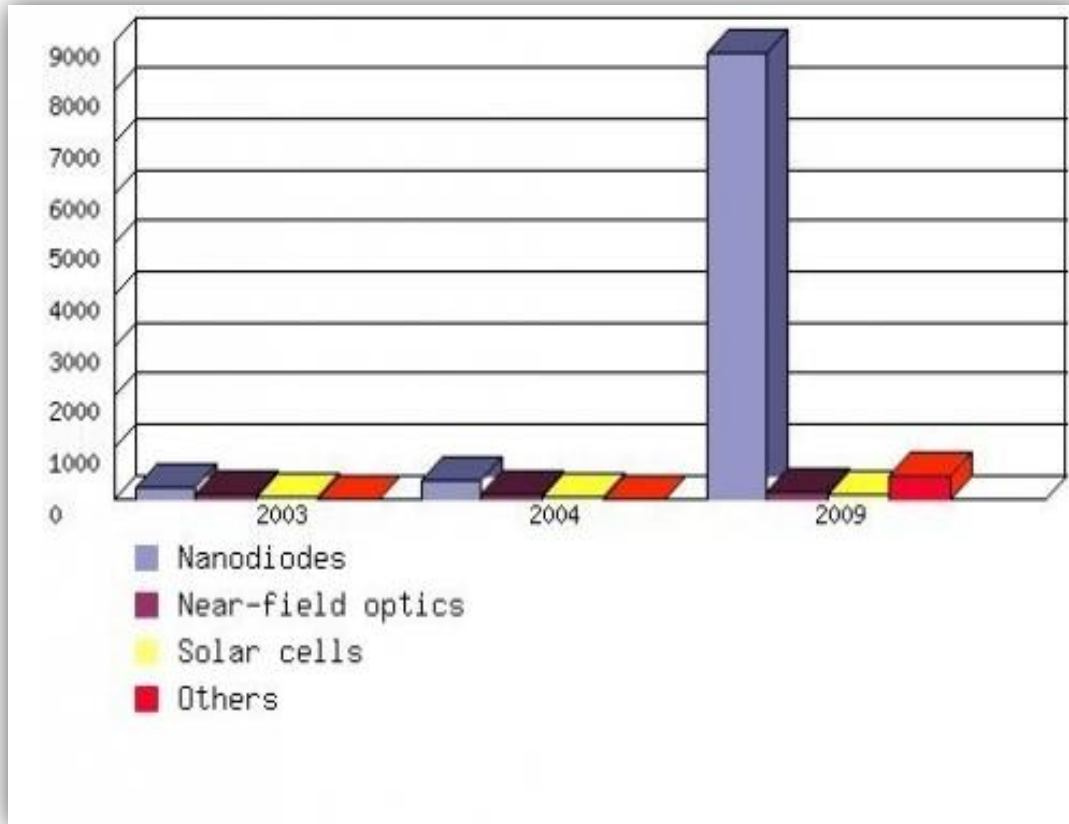
- 3D Two-Photon Storage
- Holographic Storage



Nanophotonics: A Dream or Reality?

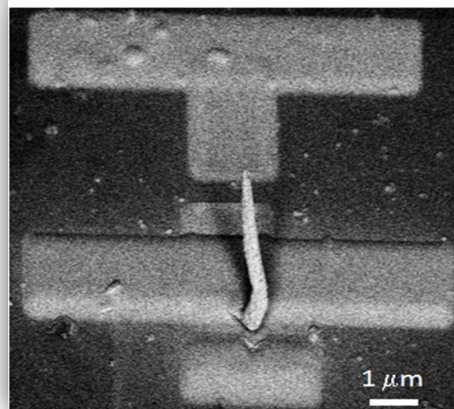
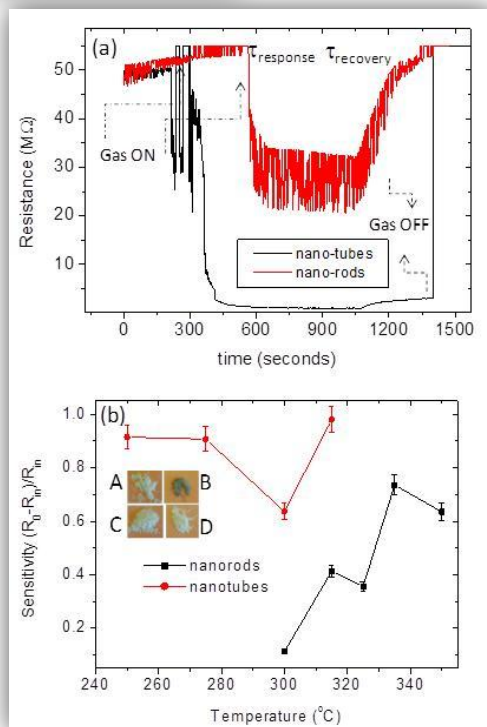
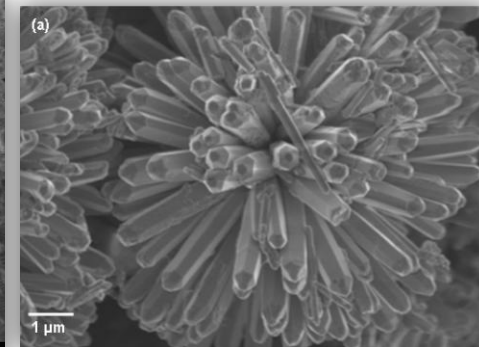
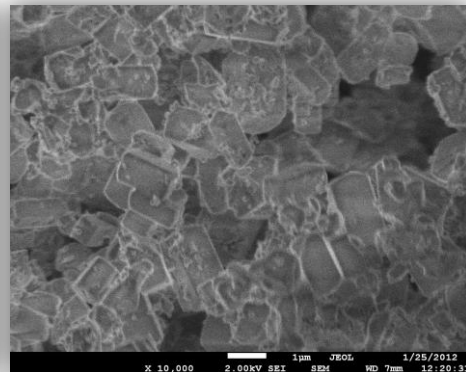
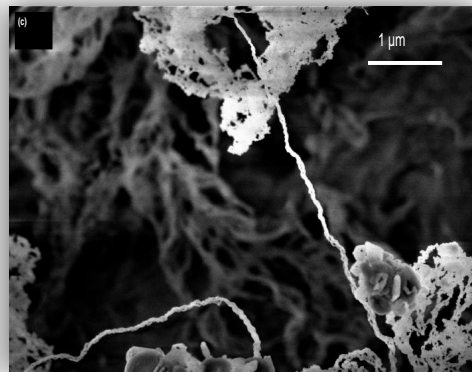
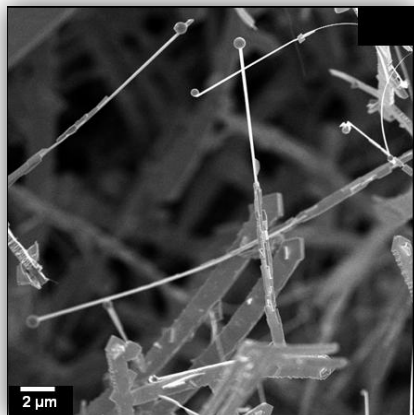
- **Nanoparticle UV absorber in sunscreen lotions:**
 - TiO_2, ZnO
- **Semiconductor Lasers (*Laser pointers, Laser printers, DVD players*)**
 - *Quantum well lasers*
- **Solid State Lasers for chemical sensing**
 - *Quantum cascade lasers*
- **Nanoplasmonic home-pregnancy kit**

Market Growth

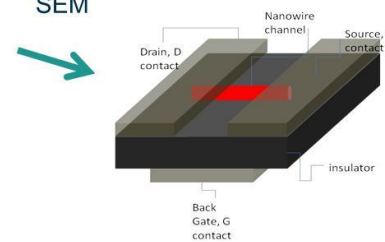


The size of the bubble corresponds to the market size in 2009. Sectors most likely to flourish in Europe include imaging, lighting and data telecoms. B: billion; SNOM: scanning near-field optical microscopy; IR: infrared; OLED: organic LED; FED: field-emission display.

On-going Research at NCNSM

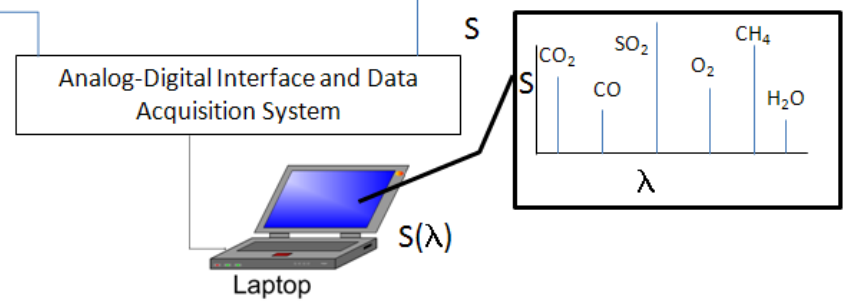
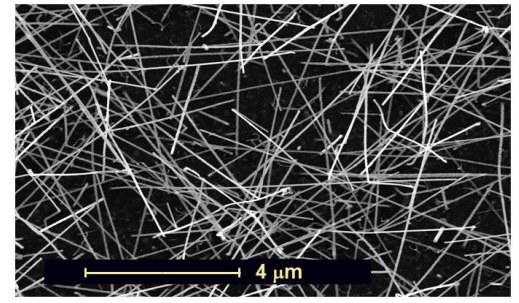
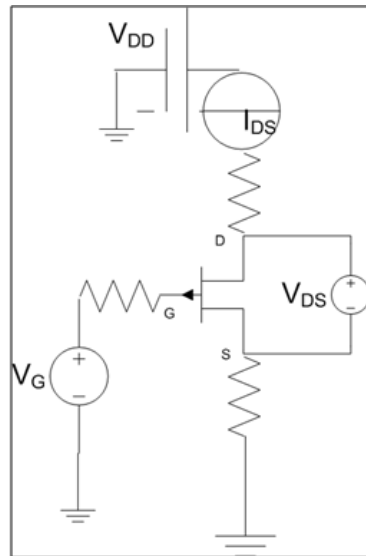
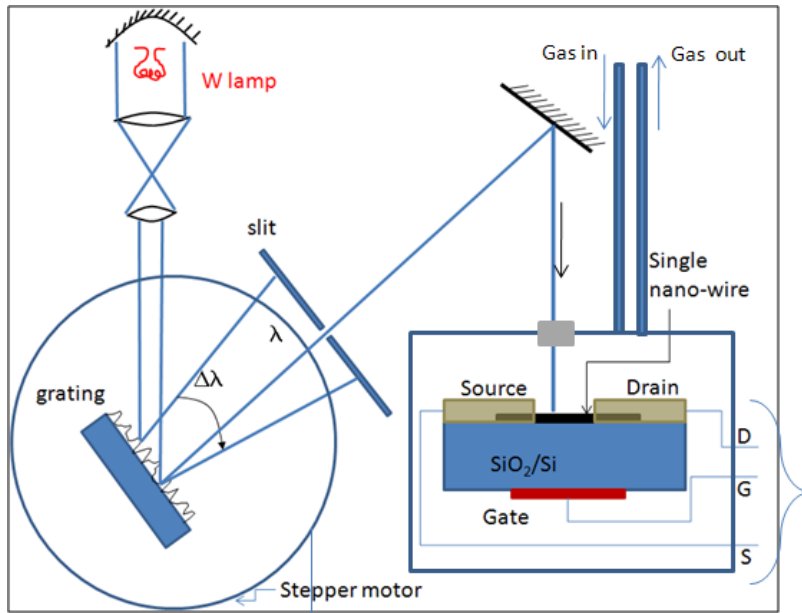


A single WO_3 nanowire between Pt contacts. Contacts evaporated in-situ by FIB while conducting SEM



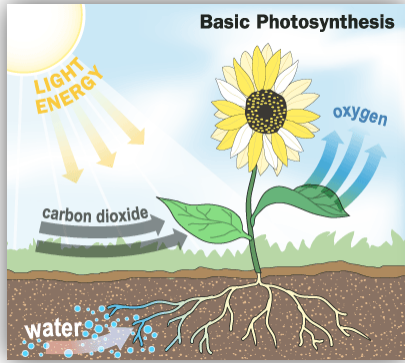
Bonex W Mwakikunga* Thomas Malwela, Kenneth Hillie, Gebhu Ndlovu, Towards an electronic nose based on nano-structured transition metal oxides activated by a tuneable UV light source, IEEE Proc Sensor ISBN 978-1-4244-9288-6, 1109-1112 (2011)

Photonicallly Activated Gas-Selective Sensor



Conclusions

- **One of the major advantage of nanophotonics is its extremely powerful interactive ability with almost every particle that deals with optics**
- **Improved the application diversity and explored the major concepts of light resources that one cannot even imagine**
- **Uses light at its best for treating optics**
- **Nanophotonics applications are not cost effective which is basic drawback of this technology**
- **High scale fabrications and critical light beams are dangerous for the human health because they can penetrate into nervous system and can affect brain and spinal cord**
- **Huge laser consumption encourages skin diseases**



Thank You