THAI NGUYEN UNIVERSITY OF EDUCATION

Spectra Chacracterizations of Optical Nanoparticles

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18/2018

THAI NGUYEN UNIVERSITY OF EDUCATION

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Missions

- Training teachers, educational managers at Bachelor, Master and Doctoral degrees;
- Providing training, standardizational and continuous development courses for teachers;
- Doing research, transferring and applying technology in the areas of Education, Natural Sciences, Social Sciences and Humanities in the North mountain of Vietnam

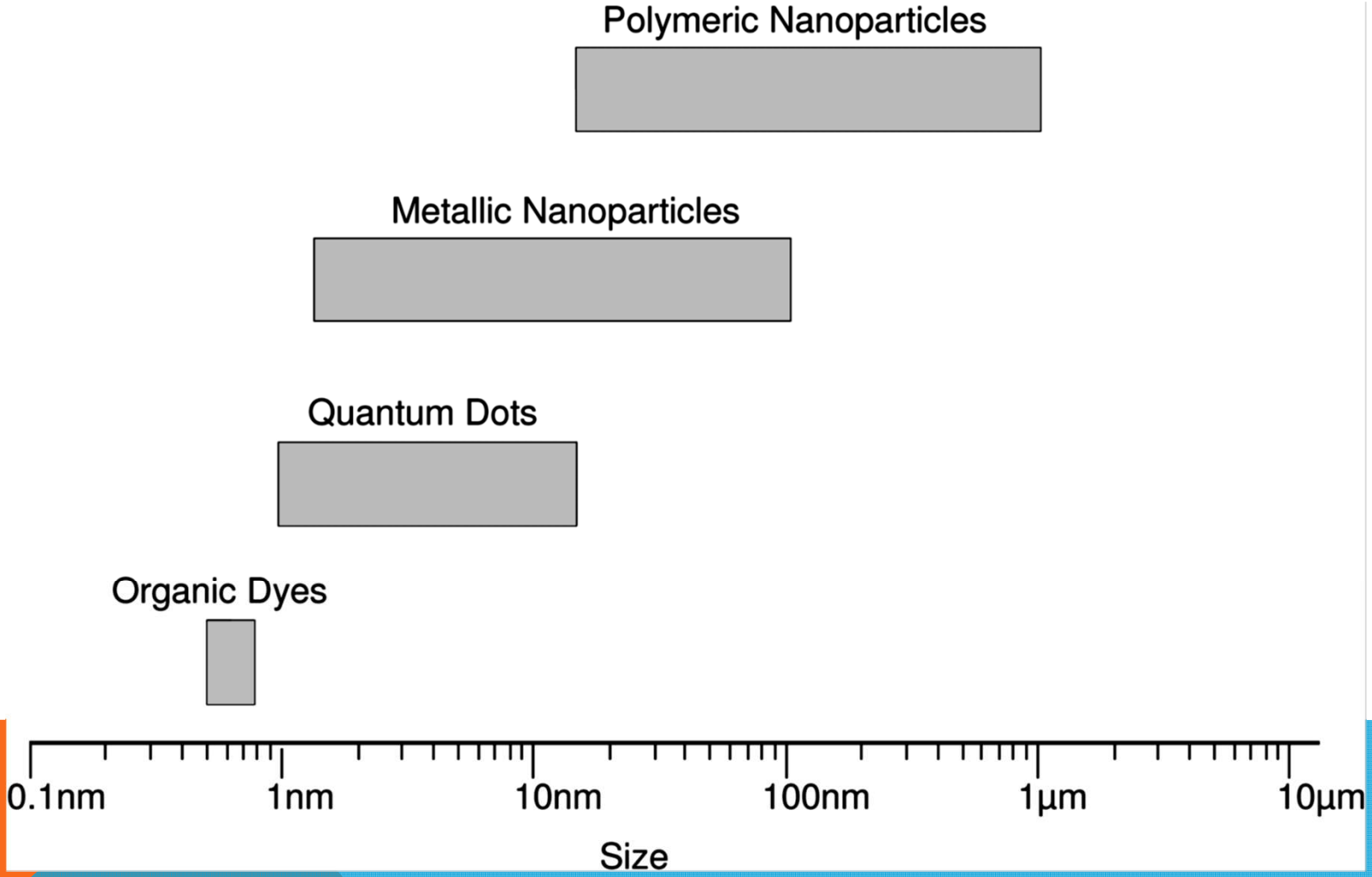
DEPARTMENT OF PHYSICS

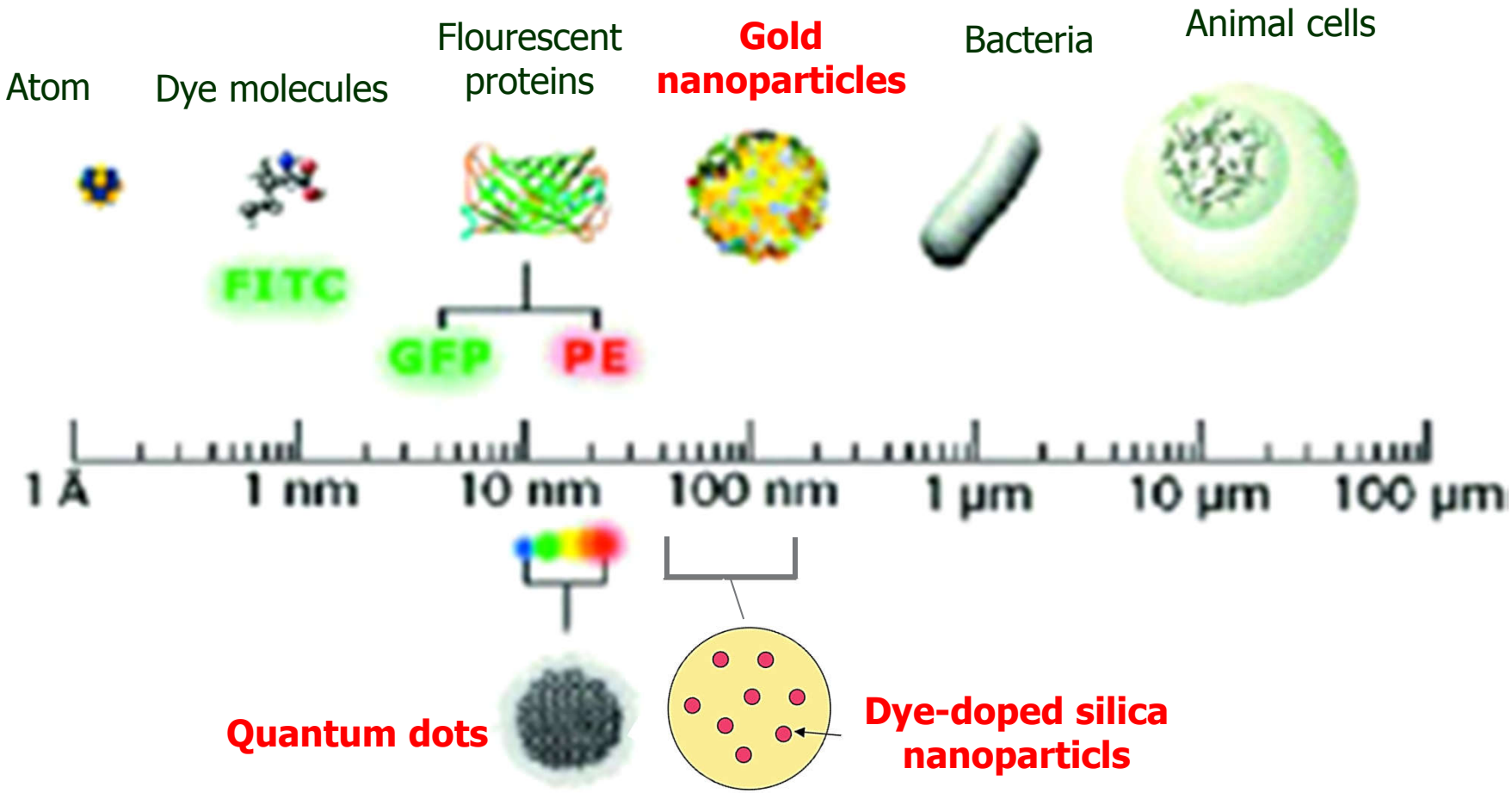
1. Physics Education Research
2. Advanced materials Research: quantum dots, fluorescence silica nanoparticles, gold nanoparticles, multiferroic material
3. Energy transfer between nanoparticles
4. Simulation

Outline

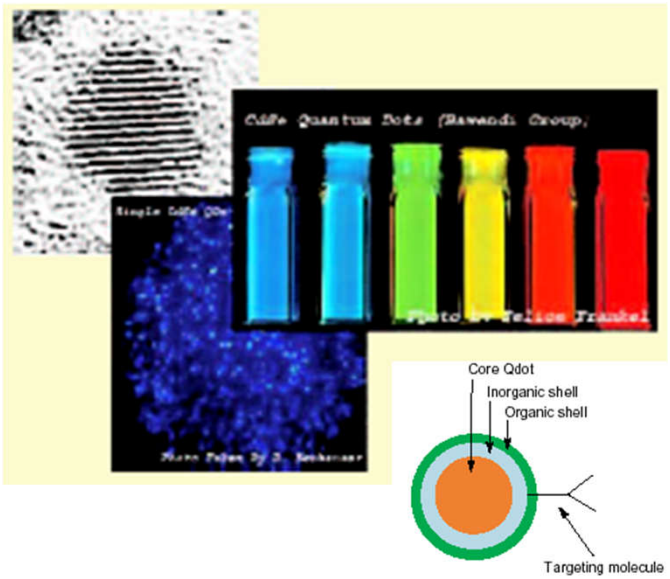
1. Quantum dots
2. Fluorescent silica nanoparticles
3. Metallic nanoparticles

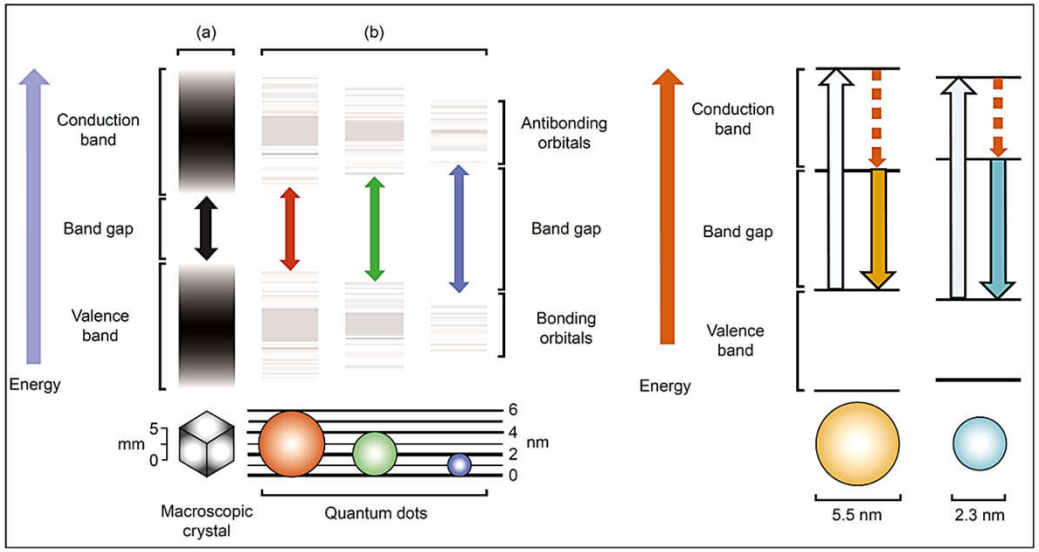
Optical Nanoparticles

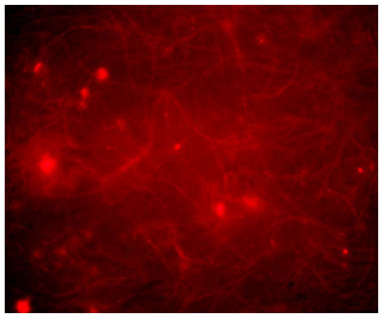



Atom
Dye molecules
Flourescent proteins
Gold nanoparticles
Bacteria
Animal cells
FITC
GFP
PE
1 Å
1 nm
10 nm
100 nm
1 µm
10 µm
100 µm
Quantum dots
Dye-doped silica nanoparticls

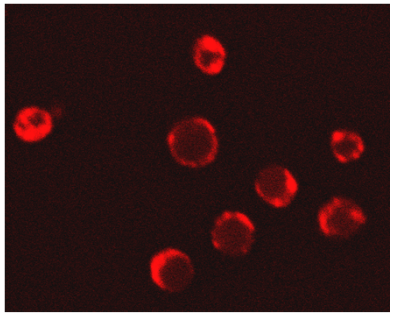
QUANTUM DOTS







Fluorescence images of phage-HER2 labeled by Qdot 655 QDs (+)



Fluorescence image of two photon excitation by Ti:Sa laser 300fs at 890 nm of Lipomyces Starkeyi yeast cells labeled with Qtracker 605 visualized by microscope Leica TCS LS (++)

Characters of Quantum dots Nanocrystals:

- Size-tunable light emission
- Superior signal brightness
- Resistance to photobleaching
- Simultaneous excitation of multiple fluorescence color

Applications:

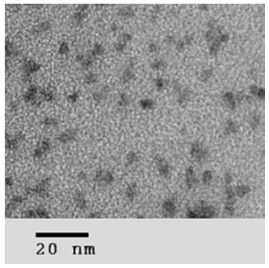
- Biomarkers
- Multiplexed cellular imaging,
- Long-term *in vitro* and *in vivo* labeling
- Deep tissue structure mapping
- Single particle investigation of dynamic cellular processes

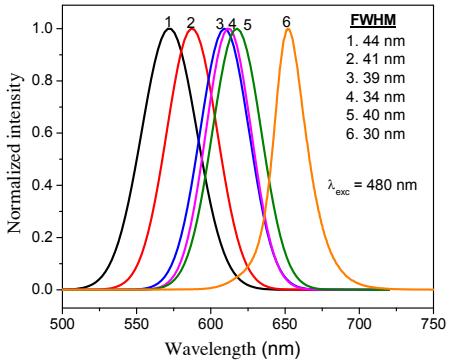
(+) V. H. Chu et al, *Journal of Advances in Natural Sciences: Nanoscience and Nanotechnology*, IOP Publishing, 2 (2010) 025005
(++) T. H. Nhung et al, *Communications in Physics*, Vol.18, 2008, 185 - 192

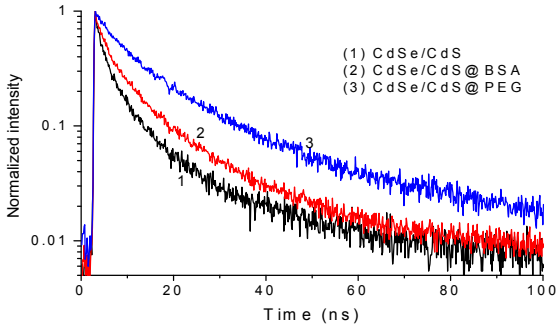
Optical properties of CdSe/CdS quantum dots

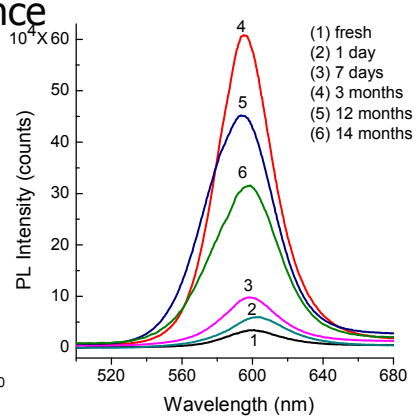
The quantum dots prepared at the laboratory of solid state physics, optics, and photonics in TNUE:

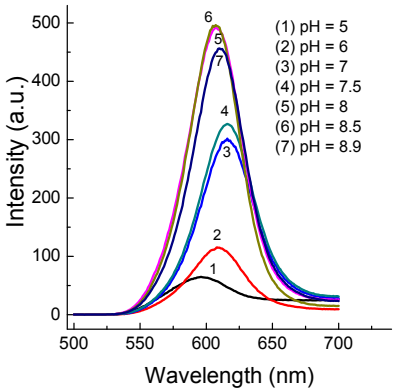
- Based on CdSe and CdS semiconductors
- Synthesized via wet chemical method, directly in aqueous solution for biological labeling applications
- Mono-dispersed in solution, have strong luminescent emission intensity under excitation of ultra violet lamp
- The emission color of the nanoparticles can be tuned in a wider range from blue to red by changing synthesis conditions.
- The photoluminescence intensity enhances up many times after preparation.
- High-quality with the quite high fluorescence quantum yield and high photostability.











Advances in Natural Sciences: Nanoscience and Nanotechnology, IOP Publishing, 2 (3), 025017 (7pp), 2012
Advances in Optics, Photonics, Spectroscopy & Applications VI, 526-531, 2010
Advances in Optics Photonics Spectroscopy& Applications VIII, 272-278, 2014
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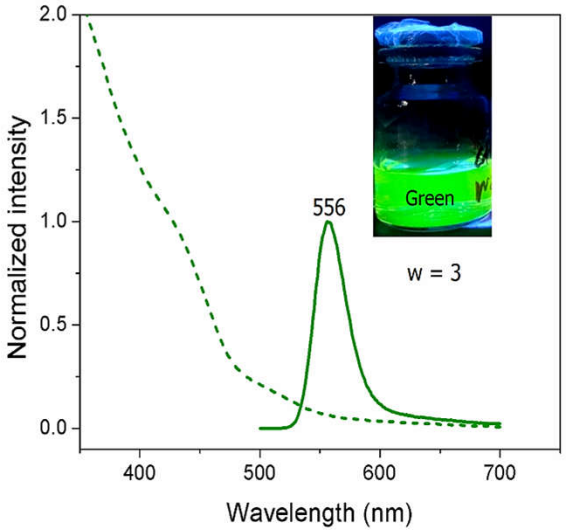
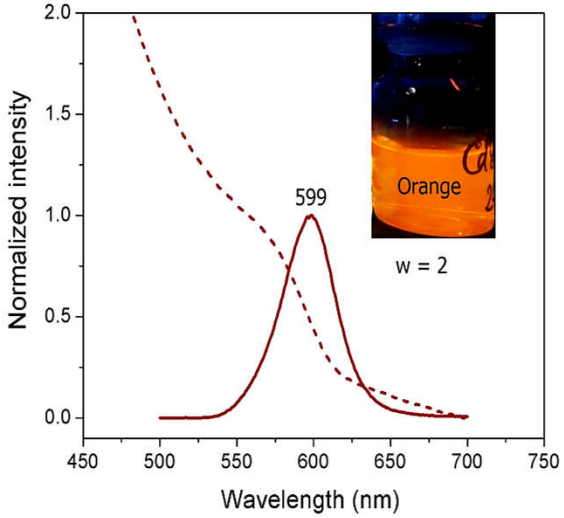
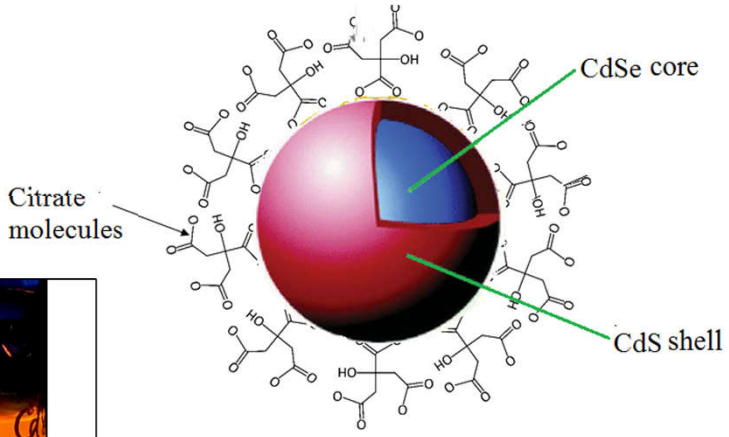
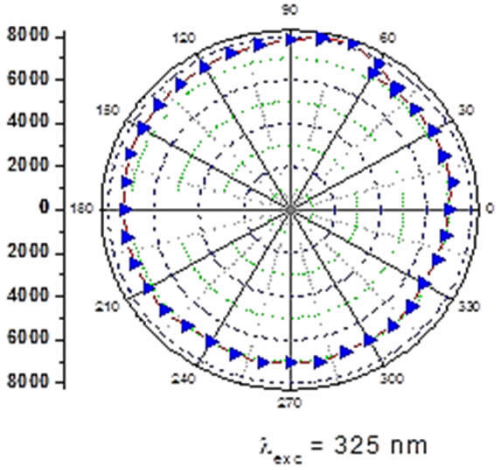
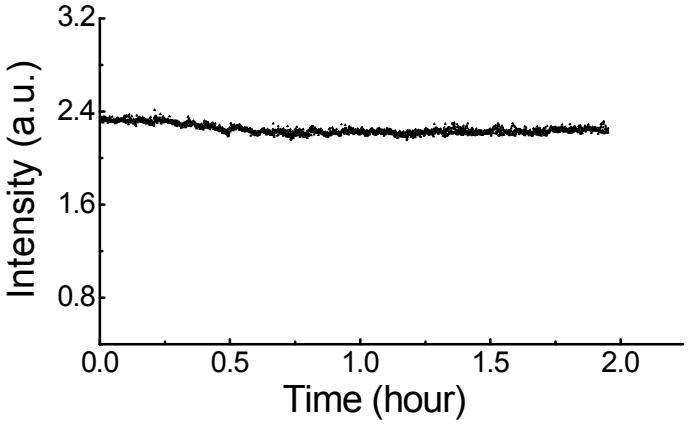
Spectra Chacracterizations of CdSe/CdS QDs



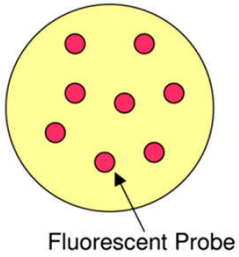








Synthesis and optical properties of fluorescent silica nanoparticles based on dyes or quantum dots



Silica matrix

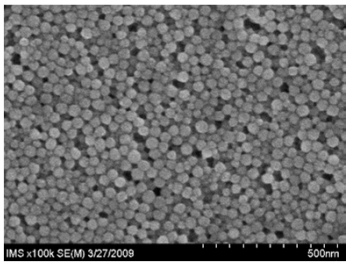
⇒ Inert in many environments
⇒ Biocompatible
⇒ Prevents agglomeration
⇒ Readily bioconjugated Functionality

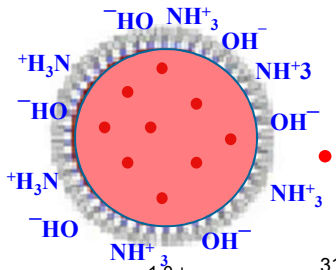
Size of silica nanoparticles

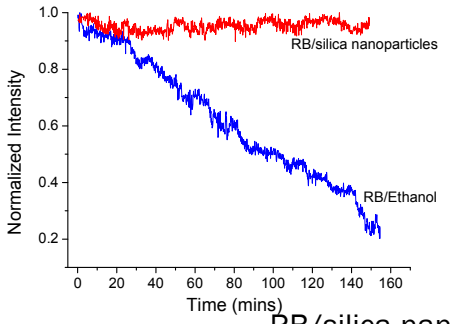
⇒ Readily controlled
⇒ Preferably 2-200 nm ± 10%

Silica nanoparticles doped with organic dyes or quantum dots have:

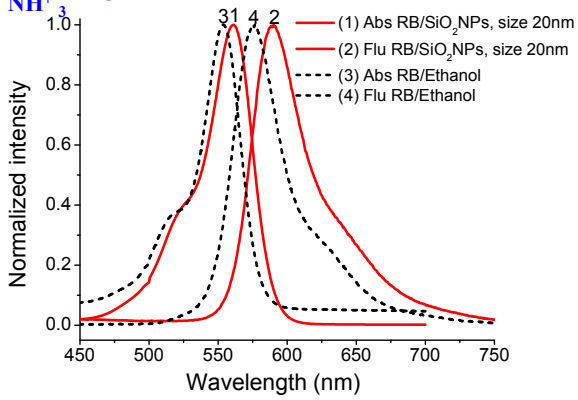
- High photostability
- Excellent brightness
- Bioenvironmental stableness
- No blinking

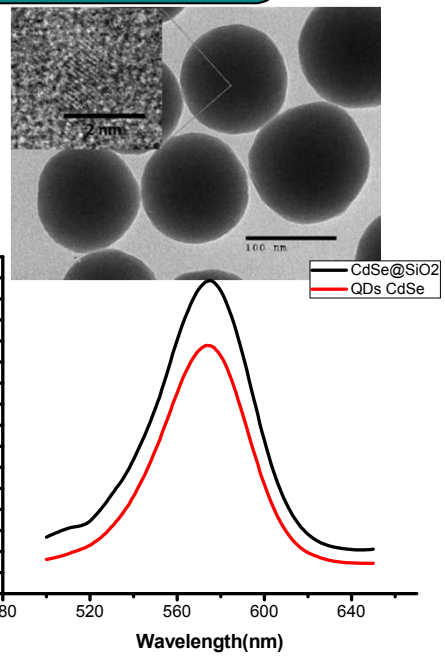






RB/silica nanoparticles





CdSe/CdS@SiO_2 nanoparticles

Advances in Natural Sciences: Nanoscience and Nanotechnology, IOP Publishing, 4 (4), 043001 (13pp), 2013
Advances in Natural Sciences: Nanoscience and Nanotechnology, IOP Publishing, Review article, 4 (4), 023002 (14pp), 2015
Advances in Natural Sciences: Nanoscience and Nanotechnology, IOP Publishing, 43(4), 043001 (13pp), 2012

Some results on using fluorescent nanoparticles for biological applications

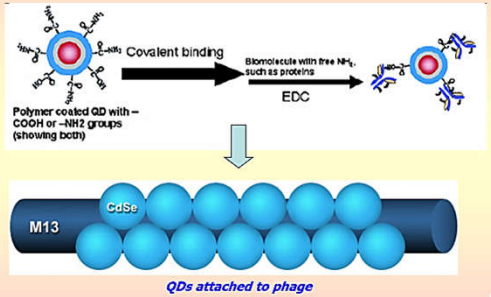
3.1. Attaching QDs to HER2 specific phage antibodies

The direct conjugation of QDs to antibodies through amine–carboxylic acid coupling using EDC (N-(3-dimethylaminopropyl)-N′-ethylcarbodiimide hydrochloride) as catalyzer, to create amide bond:

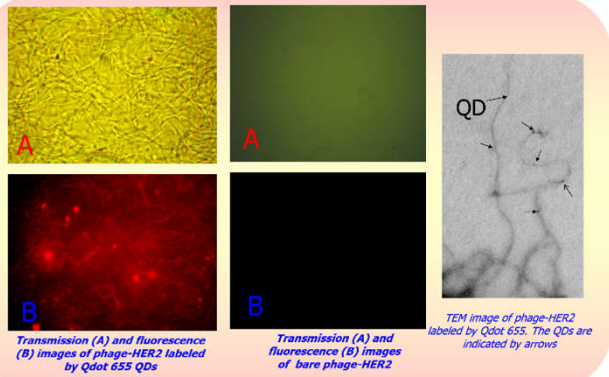
$$-H_3N^+ + -COO^- \rightarrow -\overset{\overset{O}{\|}}{C}-N- + H_2O$$

The protein coat of phage has both of amine and carboxyl groups so that QDs can be attached to the antibodies by the covalent amide bond.

Phage-Abs + QDs $\xrightarrow{\text{EDC}}$ **Complex QDs-Abs**



QDs attached to phage

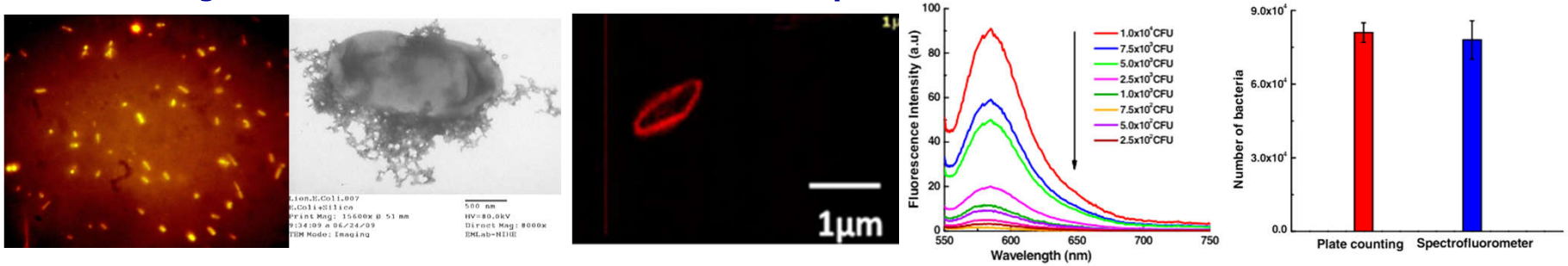


Transmission (A) and fluorescence (B) images of phage-HER2 labeled by Qdot 655 QDs

Transmission (A) and fluorescence (B) images of bare phage-HER2

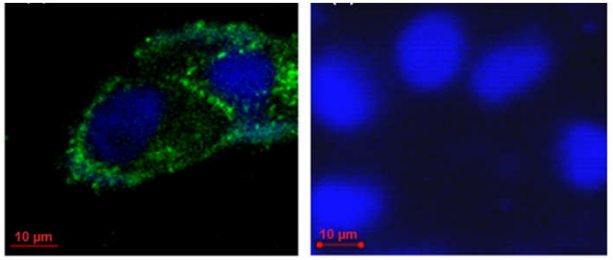
TEM image of phage-HER2 labeled by Qdot 655. The QDs are indicated by arrows

3.2. Labeling *E.Coli O157:H7* bacteria with RB/silica nanoparticles



A litlle number of E.coli bacteria can be detected => a rapid method of detection of E.coli – food poisoning bacteria

3.3. Fluorescence microscope image of cells incubated with HER2aptamer-DDNP conjugates to BT-474 cells and Hela cells



→ Good biomarkers

Advances in Natural Sciences: Nanoscience and Nanotechnology, IOP Publishing, 1(2), 025005 (4pp), 2010
Advances in Natural Sciences: Nanoscience and Nanotechnology, IOP Publishing, 43(4), 043001 (13pp), 2012
Advances in Natural Sciences: Nanoscience and Nanotechnology, IOP Publishing, Review article, 4 (4), 023002 (14pp), 2015

Spectral characrizations of metallic nanoparticle: Surface plasmon effect

Plasmon effect of metallic nanostructures

Plasmons:

- collective oscillations of the "free electron gas" density, often at optical frequencies.

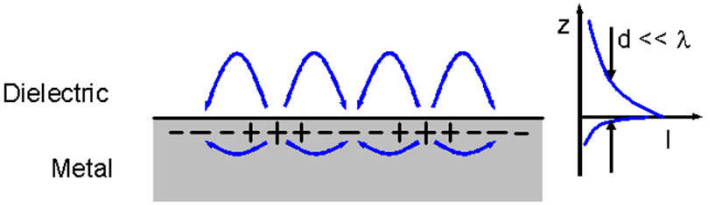
Surface Plasmons:

- plasmons confined to surface (interface) and interact with light resulting in polaritons.
- propagating electron density waves occurring at the interface between metal and dielectric.

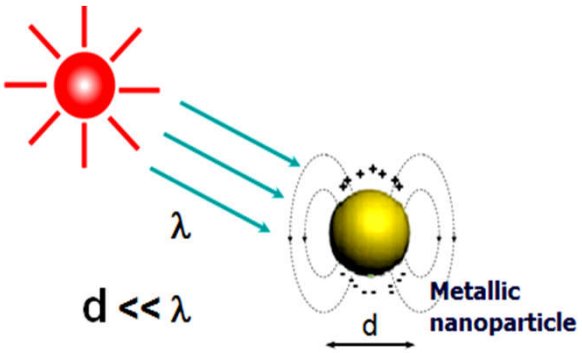
Surface Plasmon Resonance:

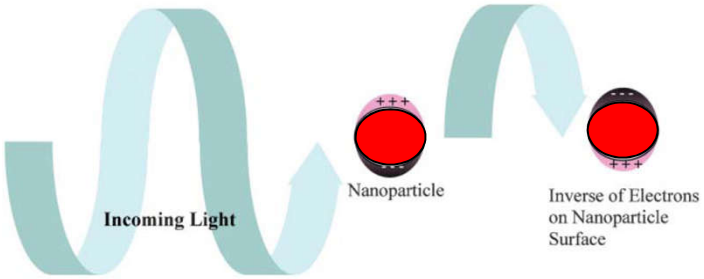
- light (λ) in resonance with surface plasmon oscillatio

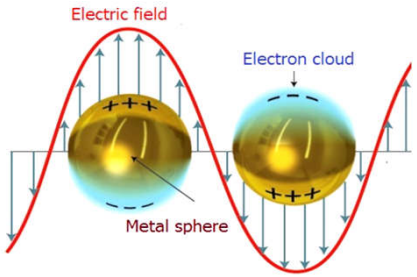
Surface plasmons are coupled modes of electromagnetic field and free electrons in metal.



Nanoparticle Surface Plasmon: Light resonance with the surface plasmon oscillation causes the free electrons in the metal to oscillate

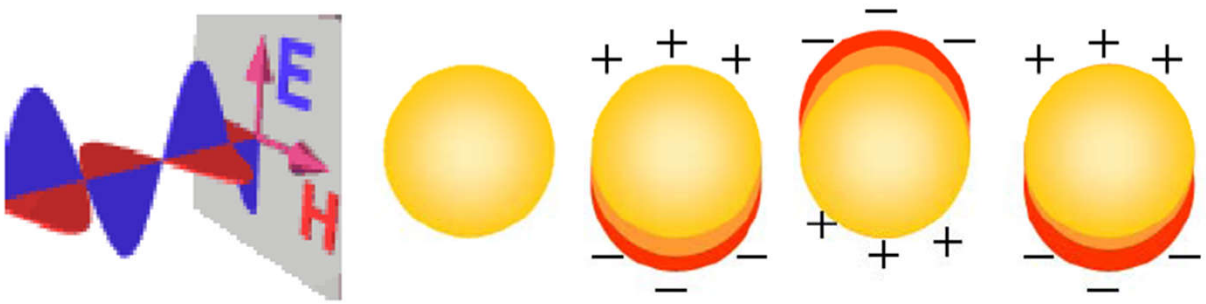




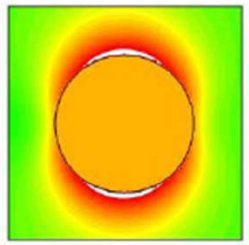


Localized plasmon

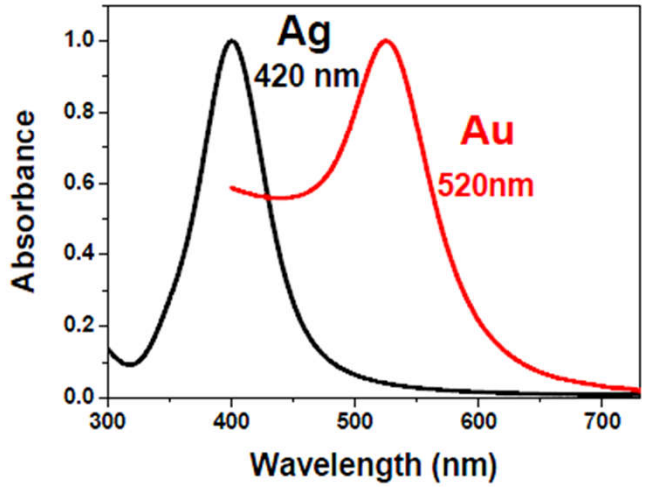
(Localized) Surface plasmons in (nano)metals

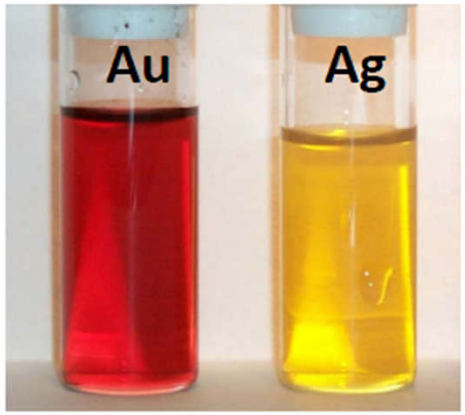


Surface plasmons: charge fluctuations at a metal-dielectric interface



Near-electric field on the particle surface

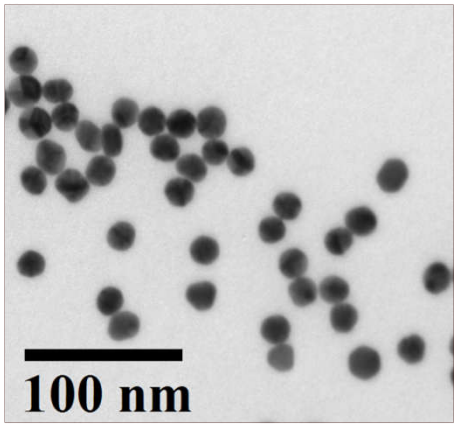


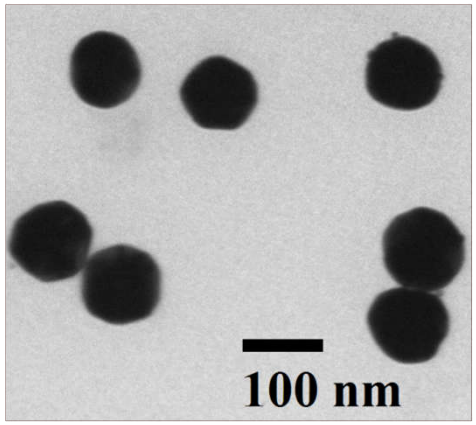


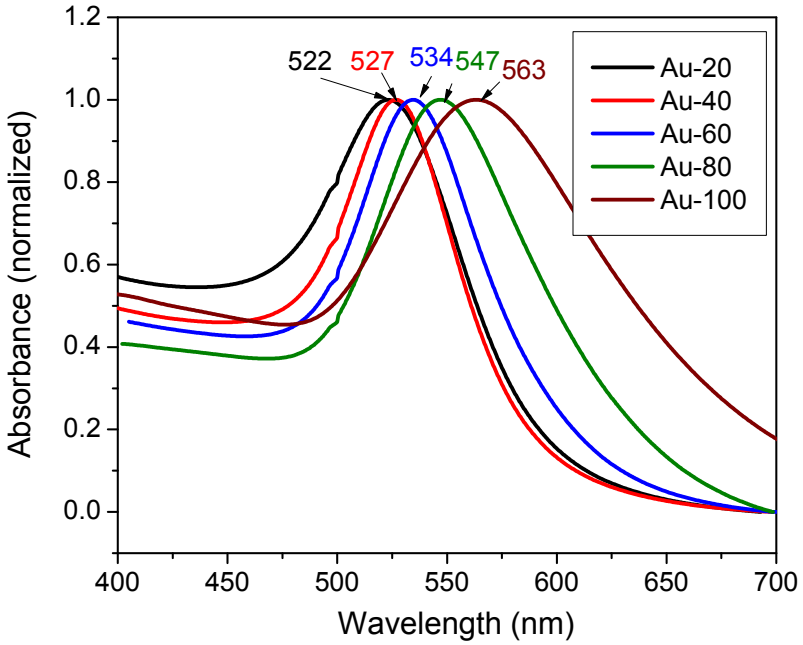
The oscillation frequency depends on several parameters, including particle shape and size, surface charge and the nature of the environment.

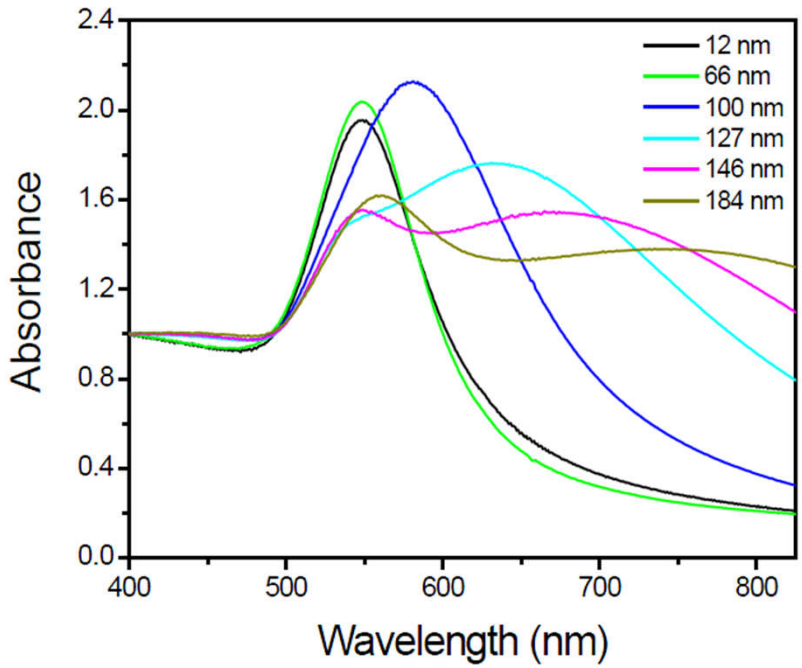
L.M. Liz-Marzán, *Materials Today* **2004**, *7(2)*, 26

Spectra chacracterizations of gold nanoparticles: Plasmon resonance absorption spectra depend on particle size.

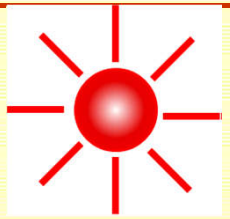




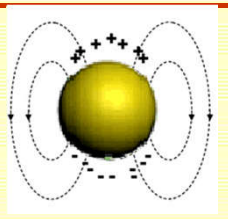




Interaction between fluorophores and gold nanoparticles: Influence of surface plasmon resonance on the emission of fluorescence nanoparticles



Depends on distance



The increase of radiative recombination rate

enhanced

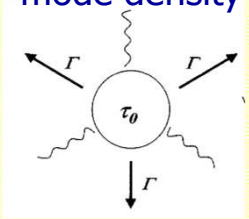
quenched

The decrease of radiative recombination rates

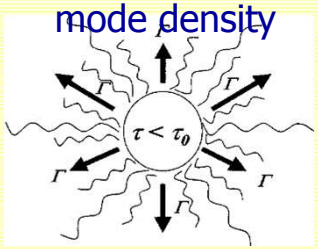
The radiating surface plasmon coupling emission process dominates

The Förster energy transfer from fluorescent particles to gold particles exciting absorbing plasmon dominates

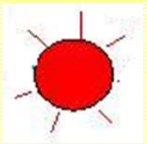
No Metal: Low photonic mode density



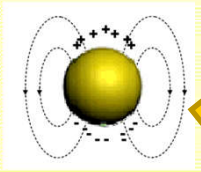
With Metal: High photonic mode density



Donor (fluorophore) **Acceptor** (Au nanoparticles)



energy transfer



Localized plasmons

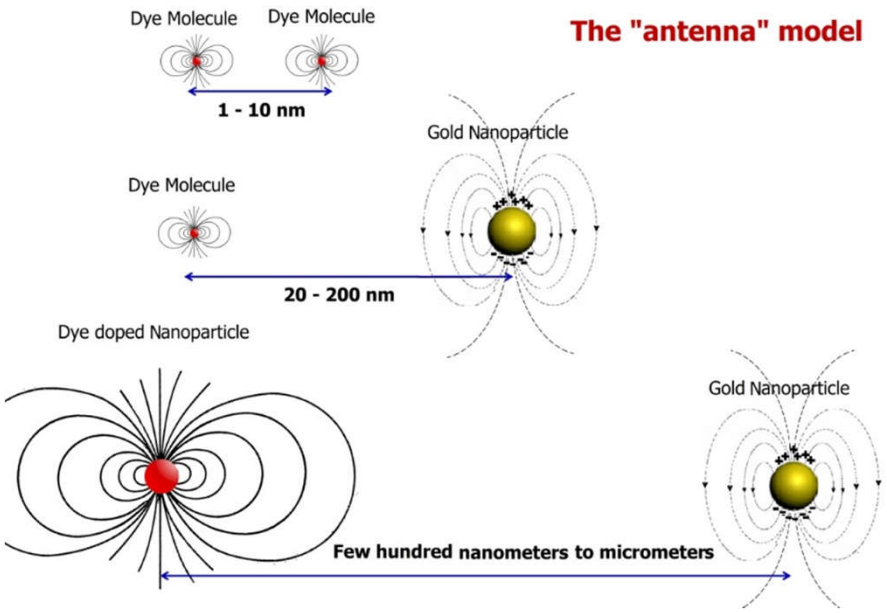
Surface energy transfer mechanism SET

Interaction between fluorophores and gold nanoparticles: Influence of surface plasmon resonance on the emission of fluorescence nanoparticles

	Donor		Acceptor		Critical transfer distance R_0
	Type	Size	Type	Size	
	Dye molecules	A°	Dye molecules	A°	2 – 10 nm
	Dye molecules	A°	Nanogolds	few tens nanometers	20 – 200 nm
	Fluorescence nanoparticles	From tens to few hundred nanometers	Nanogolds	few tens nanometers	~ μm

The local field dependence of the critical distance of energy transfer between nanoparticles also described as the working distance of a "**wave emitter station and antenna**" or "the antenna" model.

In this model, the local field of dye molecules, gold and dye doped nanoparticles is considered as the power of a wave emitter station. The more powerful station, the longer distance it can emit its wave. The bigger is the antenna, at the longer distance it can detect the emitter signals.



Optics Communications, Vol 353, No 15, 49-55, 2015.
Communications in Physics, Vol 24, No 3S2, 121-129, 2014
Advances in Natural Sciences: Nanoscience and Nanotechnology, IOP Publishing, 2(4), 045010 (4pp), 2011


Thank you so much for your attention!