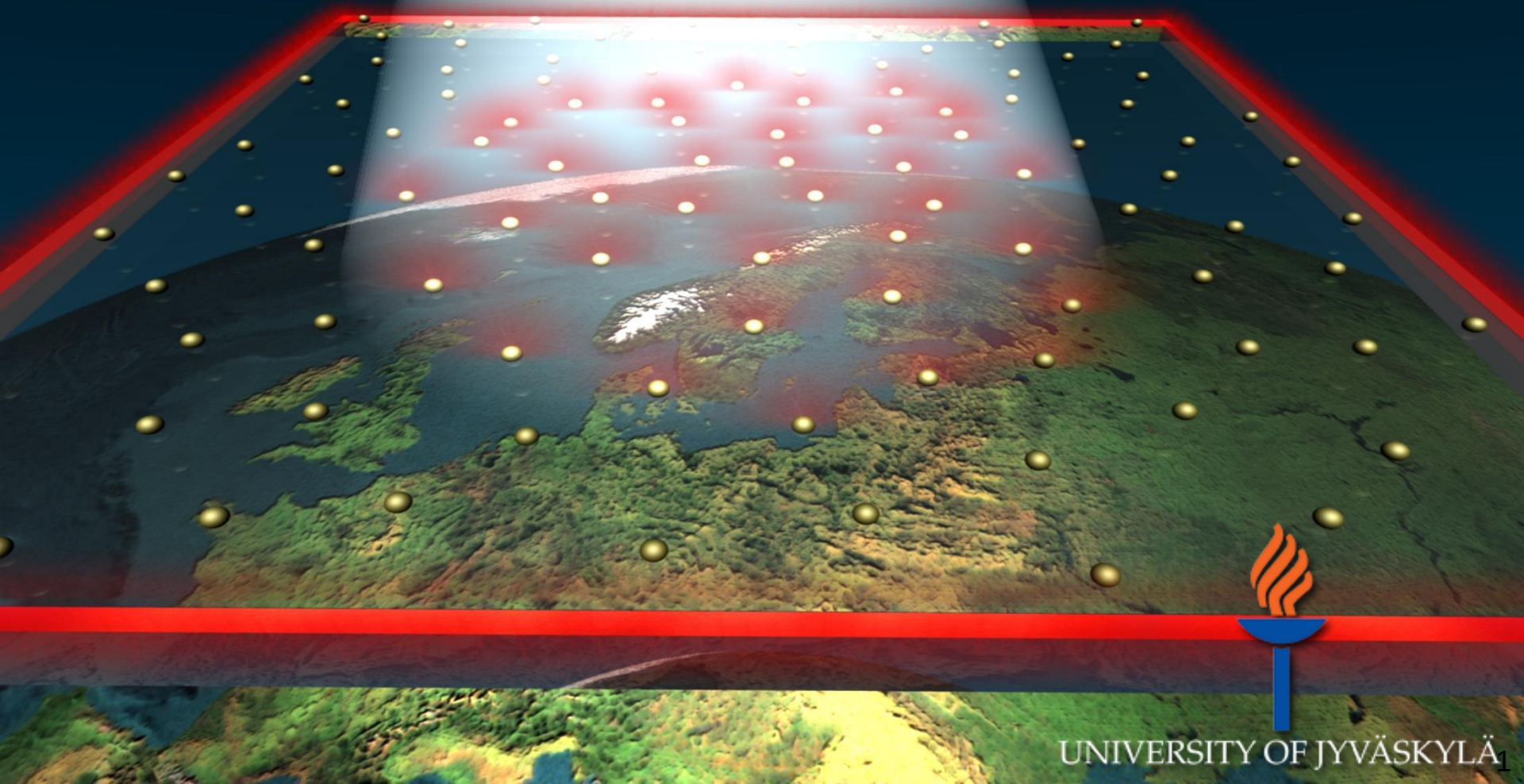
WISC
Window Integrated Solar Collector

Jussi Toppari | *Department of Physics* | *Nanoscience Center* | *University of Jyväskylä*



WISC project

Funding: EU INNO INDIGO / Academy of Finland

Partners:

- Jussi Toppari & Janne Simonen
  NSC, Jyväskylä, Finland
- Wolfgang Fritzsche & Frank Garwe
  IPHT, Jena, Germany
- Vamsi Komarala & Eshwar Thouti
  CES, IIT, Delhi, India
- Johannes Skaar & Christopher Dirdal
  NTNU, Trondheim, Norway

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Connecting India and EU – Mobility

- **Nov 2014** - Pre-Kick-meeting at JYU, Nanoscience Days 2014
- **May 2015** - Kick-Off-meeting at IPHT Germany, Molecular Plasmonics 2015
- **End of 2016** - Final Workshop at CES India, Plasmonics for Solar Energy Applications
- **May 2017** - Wrap-up meeting, Molecular Plasmonics 2017

In addition, research visits as needed.

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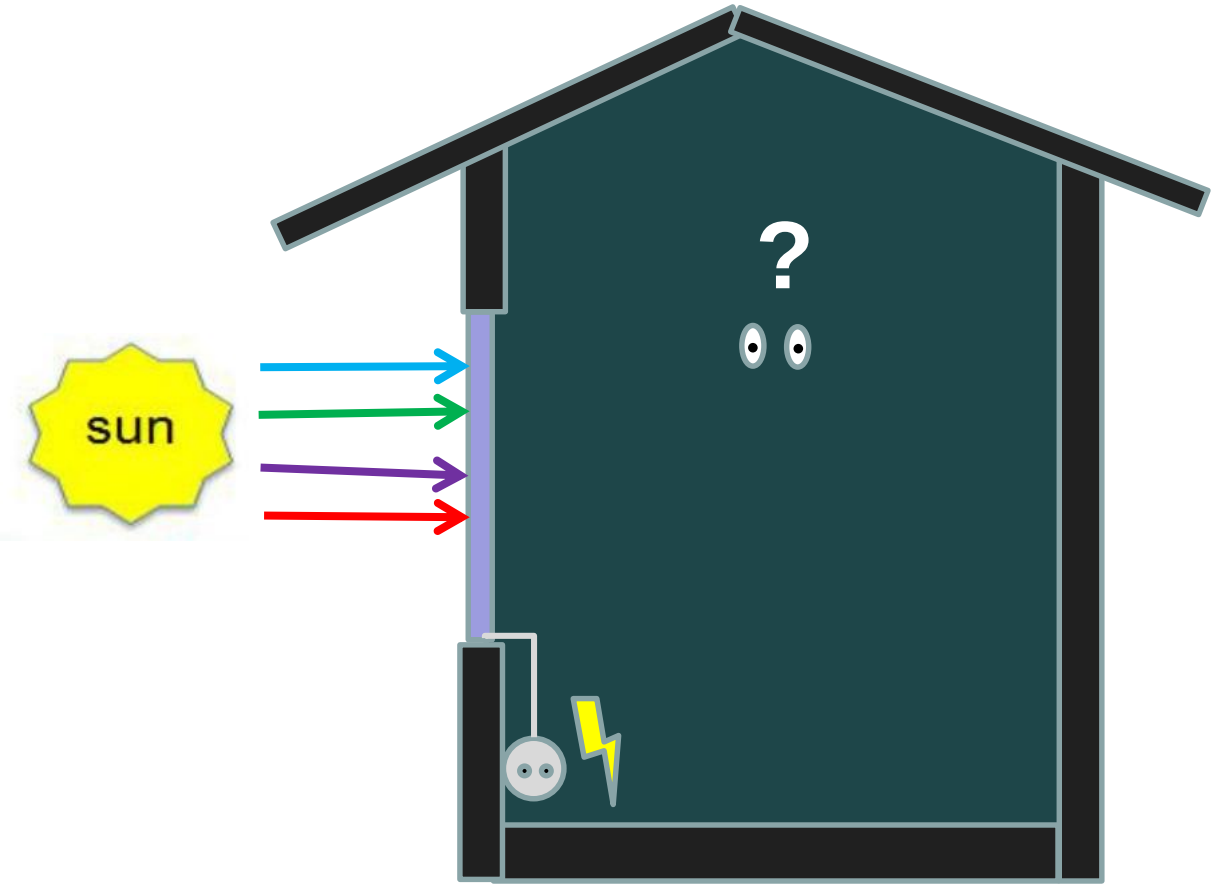
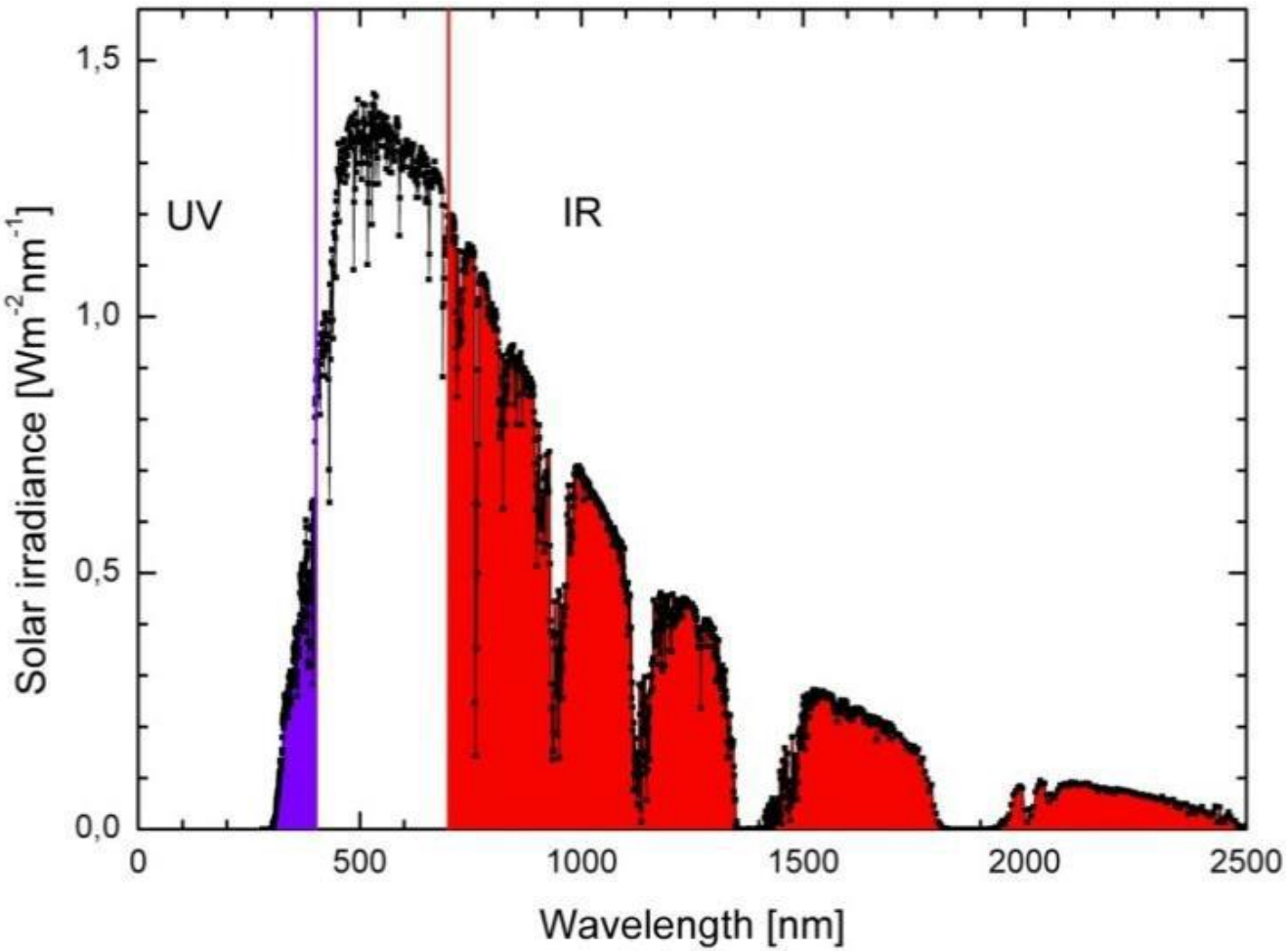


Solar spectrum



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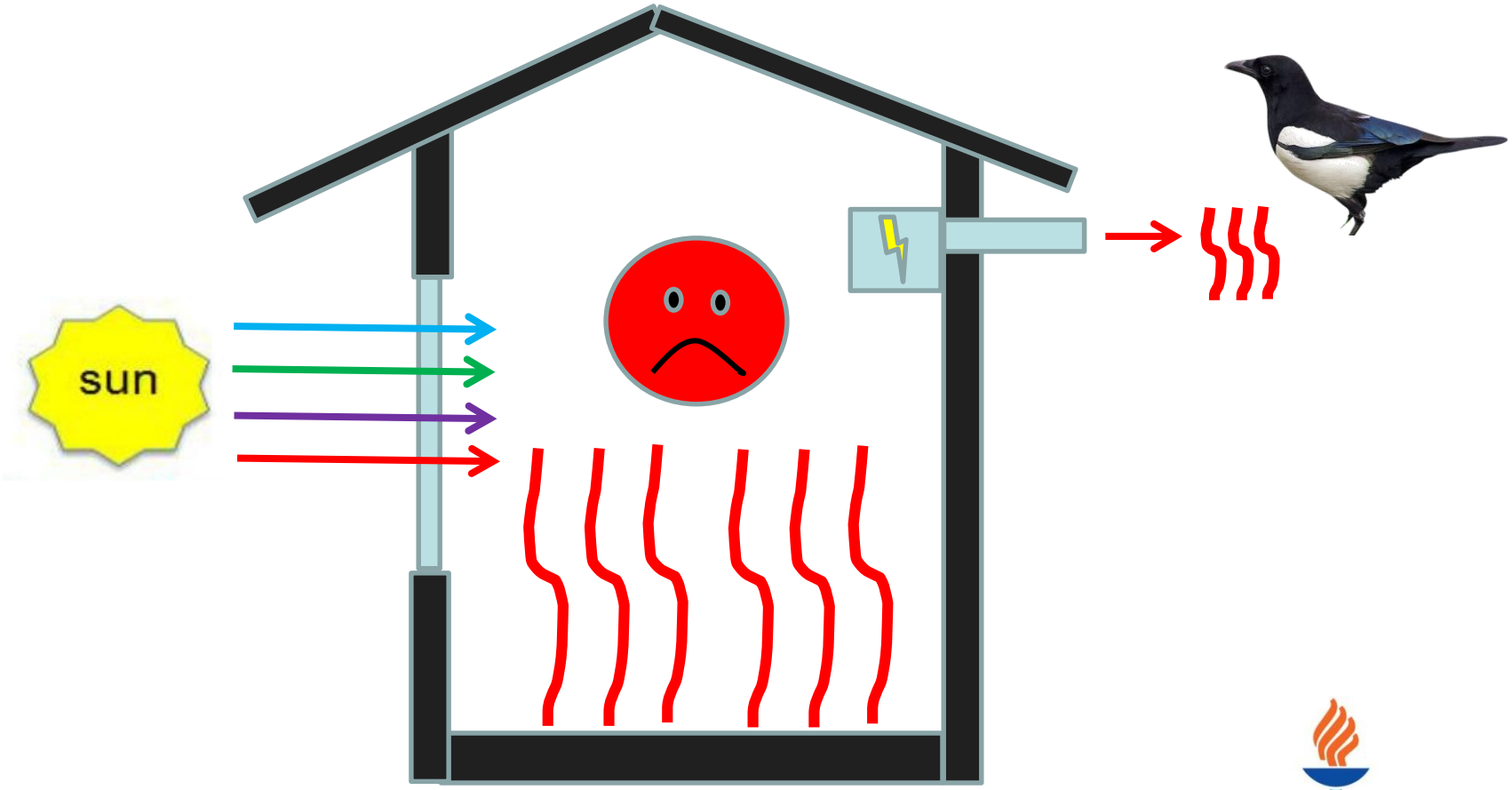
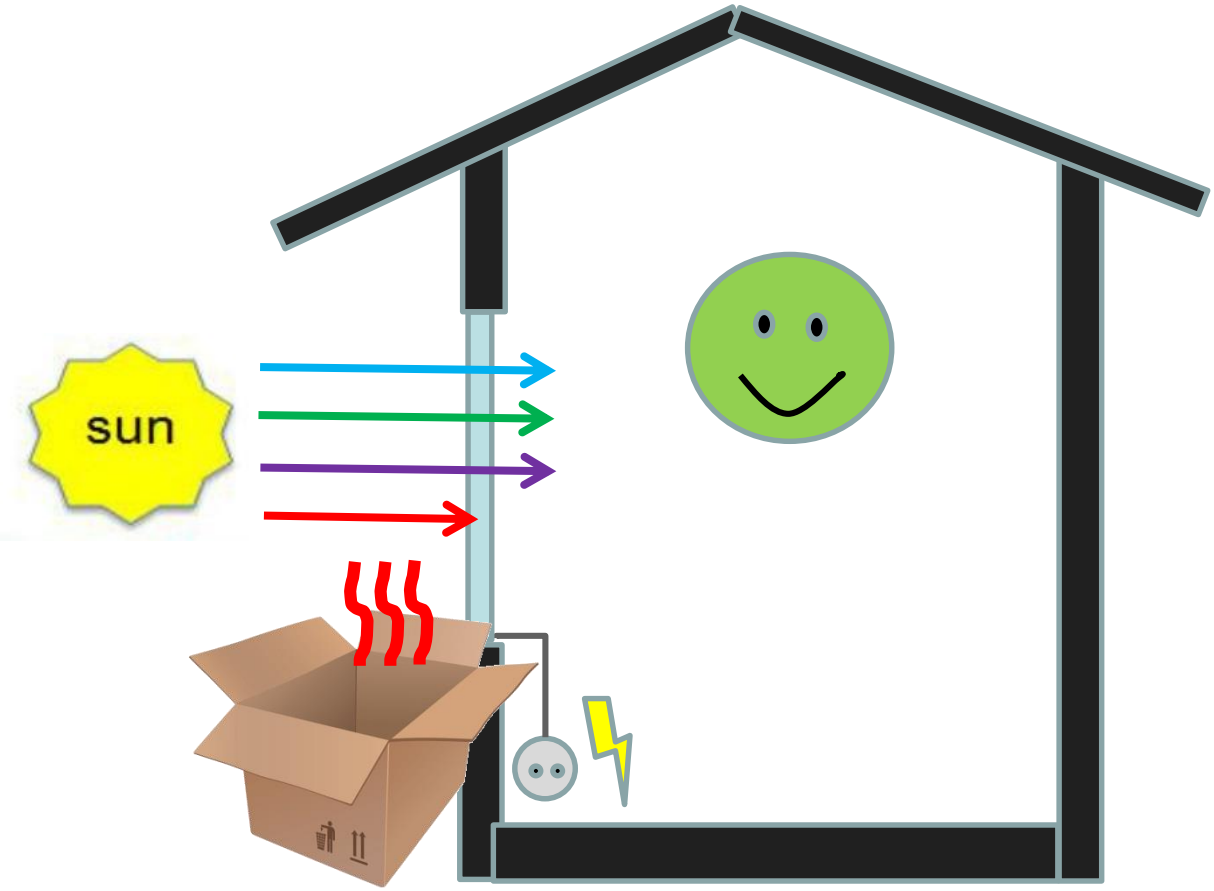
The problem – infrared heating



Partial solution – prevent the IR

The solution – collect the IR



Windows that produce solar energy

- Globally increased green energy production
- Less need to cool buildings

  → **In theory 200% efficiency possible!**

- No extra surface area needed for solar panels

Huge global impact in reducing greenhouse emissions!

Window Integrated Solar Collector

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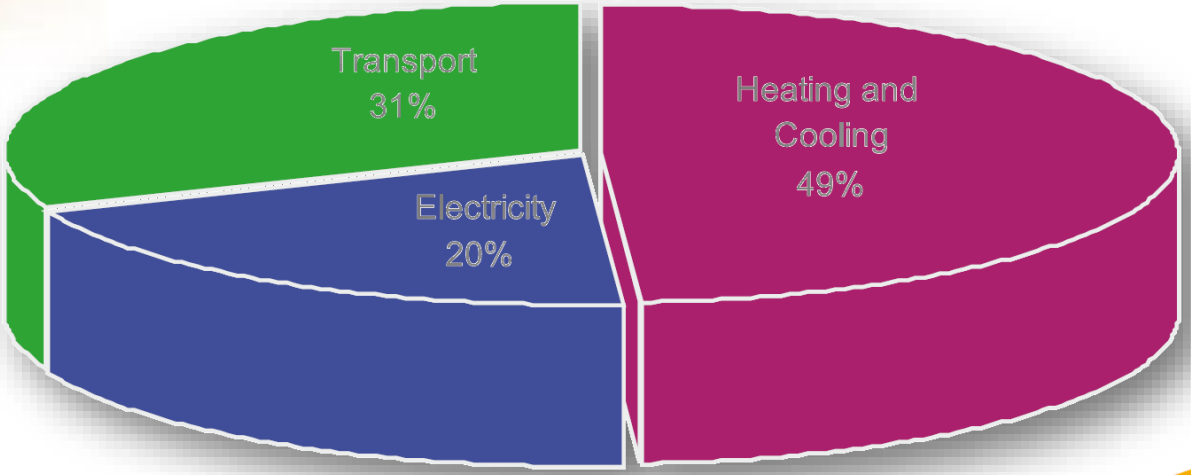
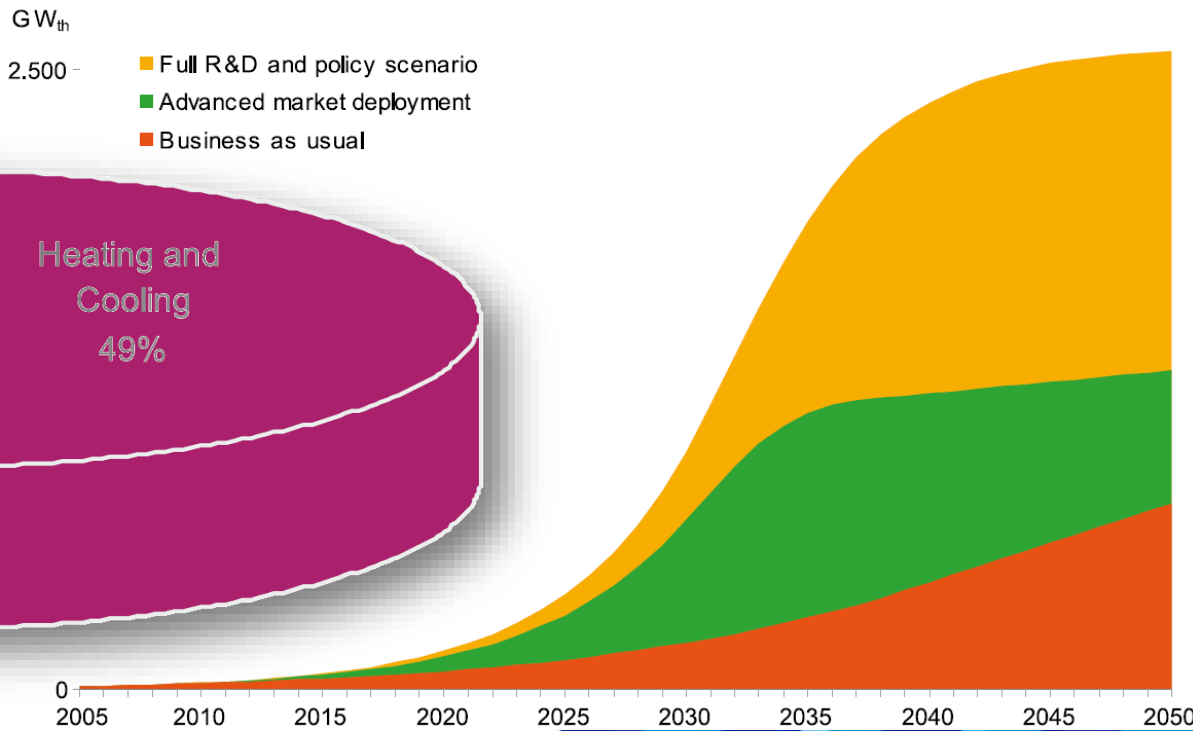
Solar power globally

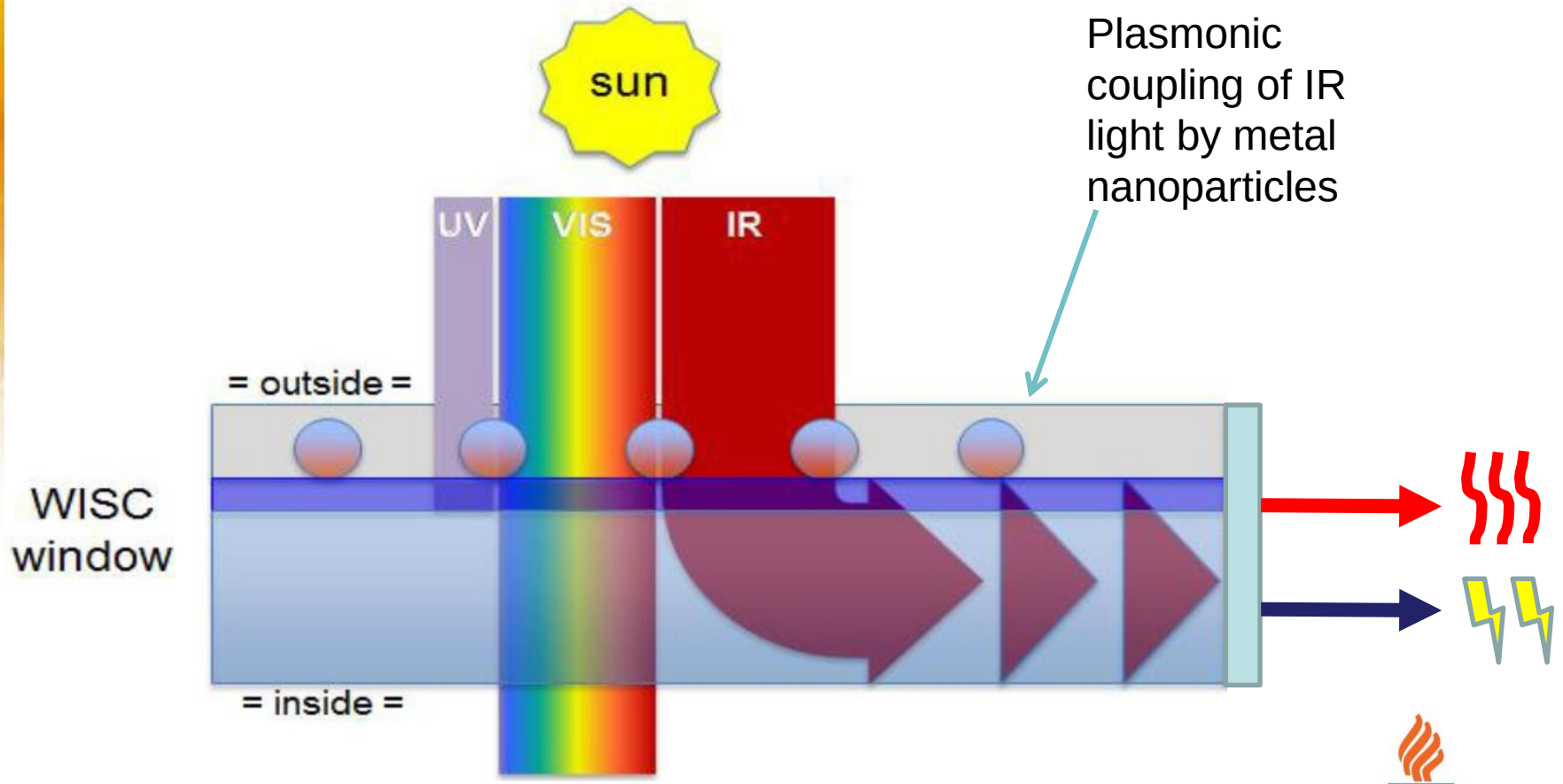
- Global cumulative installations 139 GW in 2013 (EPIA)
- 136 mrd $ during 2011
- Eurobarometer: 94% of people support increasing of the solar power

→ Integration of the solar collectors to buildings saves space and could dramatically increase the usability.





WISC: Basic Idea



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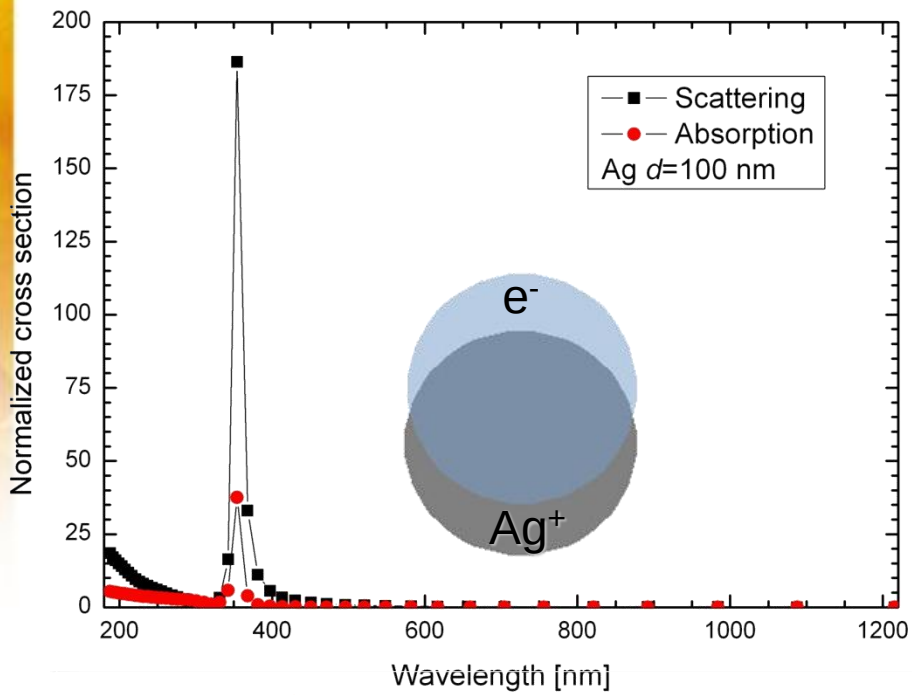
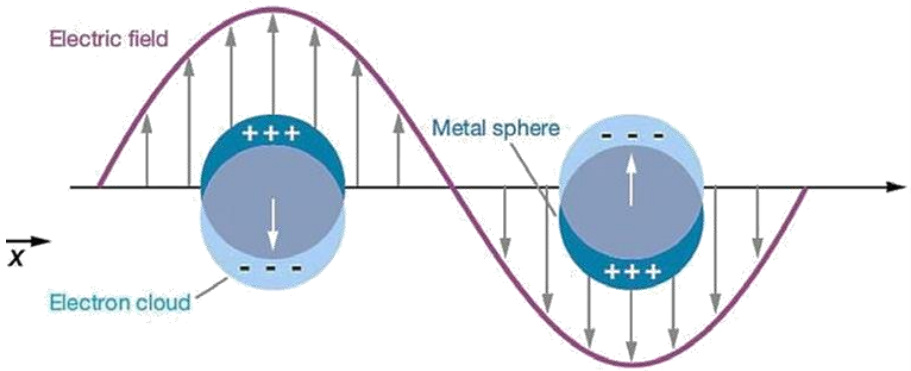
Localized Surface Plasmon Resonance





- Property of subwavelength metallic particles
  - Strong absorption and scattering at the resonance
  - Resonance comens from the resonence of 'mechanical' oscillation of the electron cloud

→ **Localized Surface Plasmon Resonance LSPR**

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Two ways of enhancement

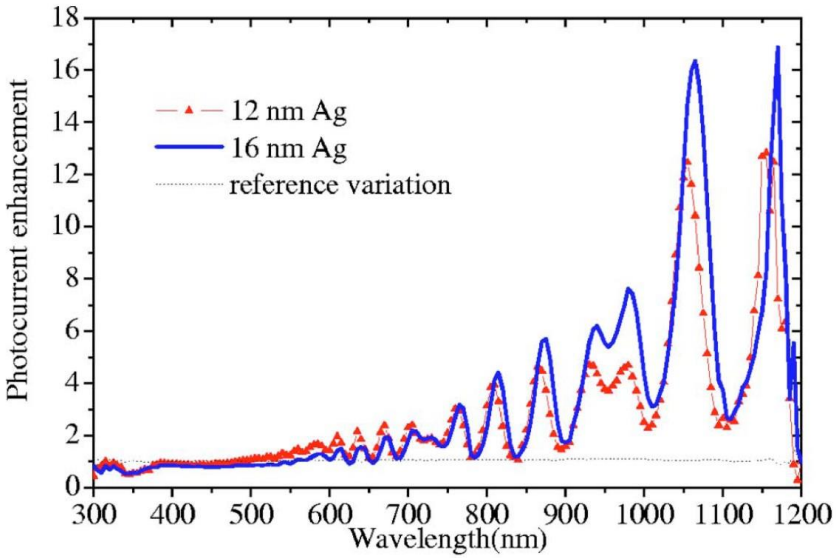
1

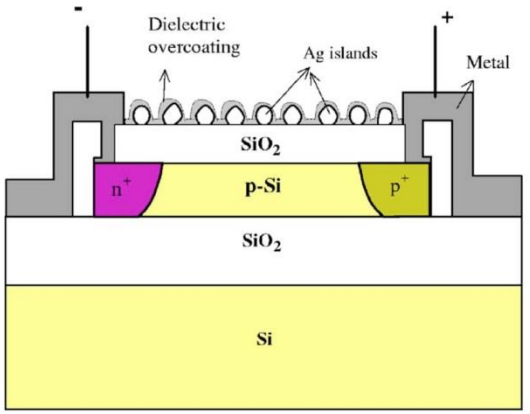
Scattering

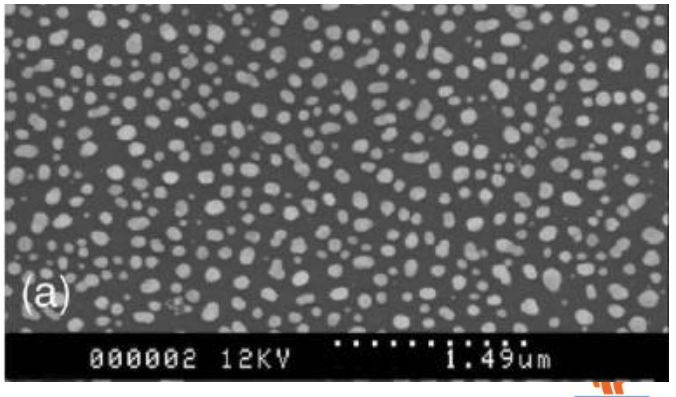
2

Enhanced field of
plasmon

Result on thin film solar cells: SOI waveguide





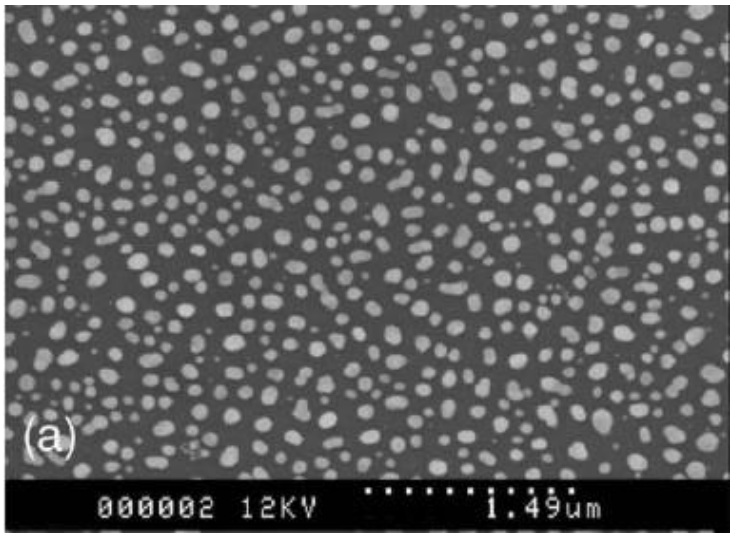


- 13 - 17 times increase in photocurrent
- 16 - 33% increase in short circuit current

[Pillai *et al*. J.Appl.Phys.101, 093105, 2007.]
[Image of SOI test device: Pillai *et al.* Appl.Phys.Lett. 88, 161102, 2006.]

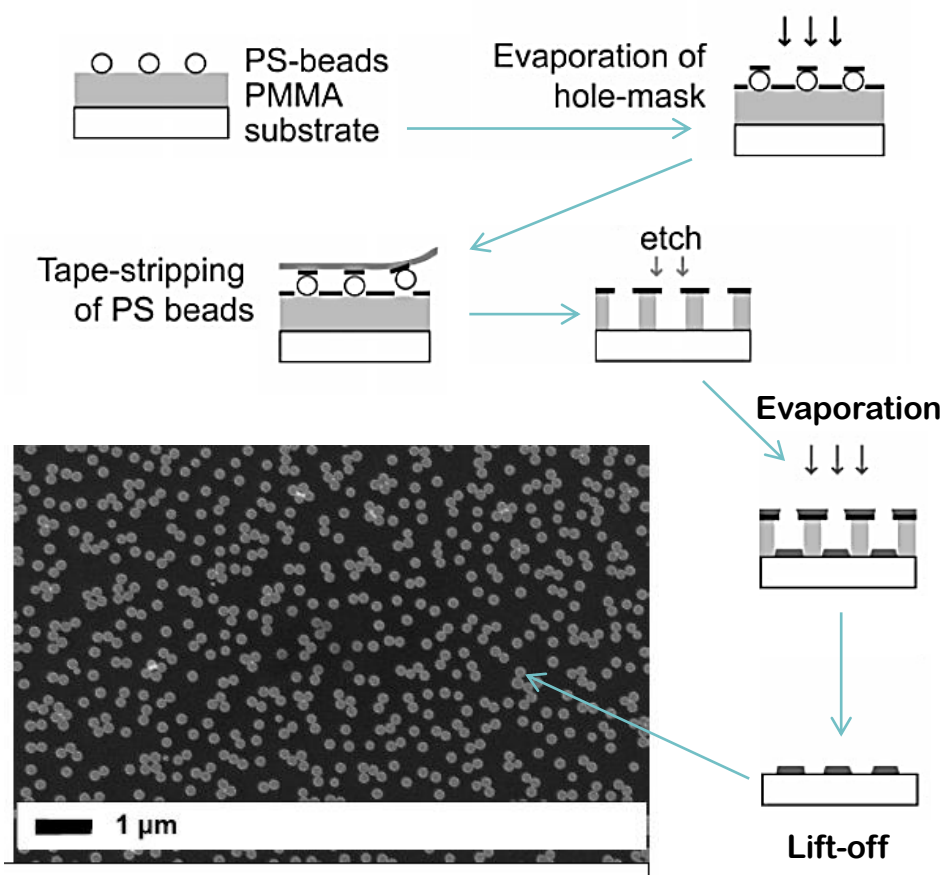
Fabrication of the nanoparticles

- Evaporation
  - Metallic island ~ nanoparticles
  - Not exact shape and size



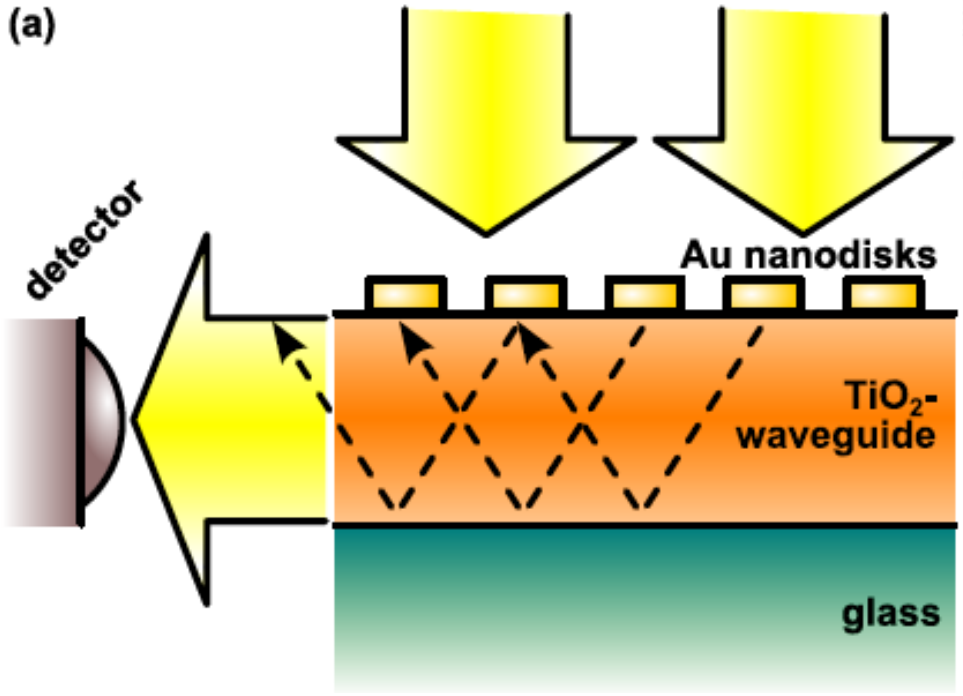
- Chemical synthesis
  - **IPHT & JYU**

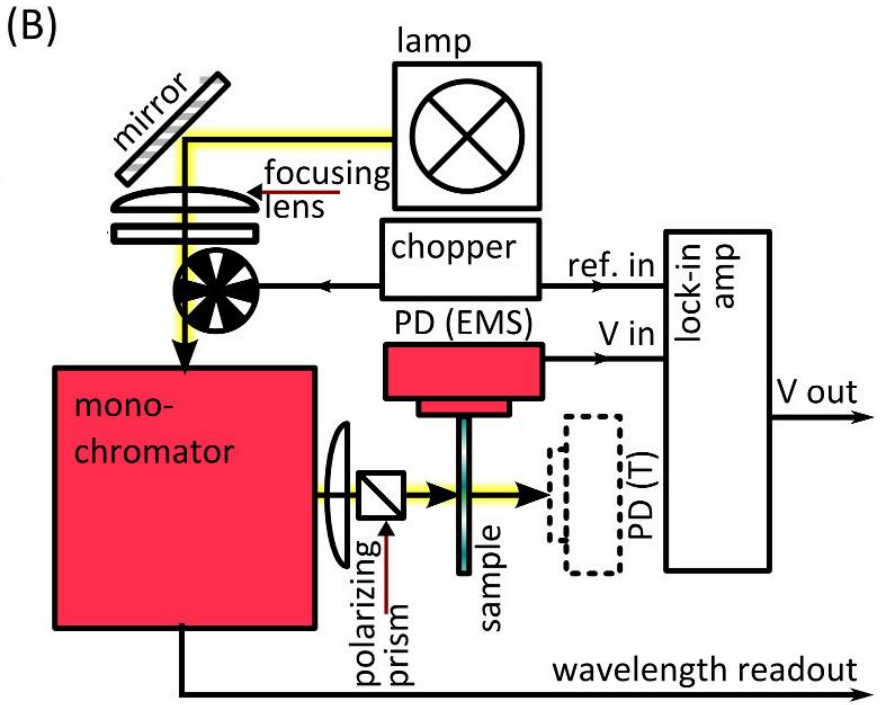
- Hole-Mask colloidal Lithography
  - Exact shape and size
  - Easy for big surface areas also



Measurement setup 1

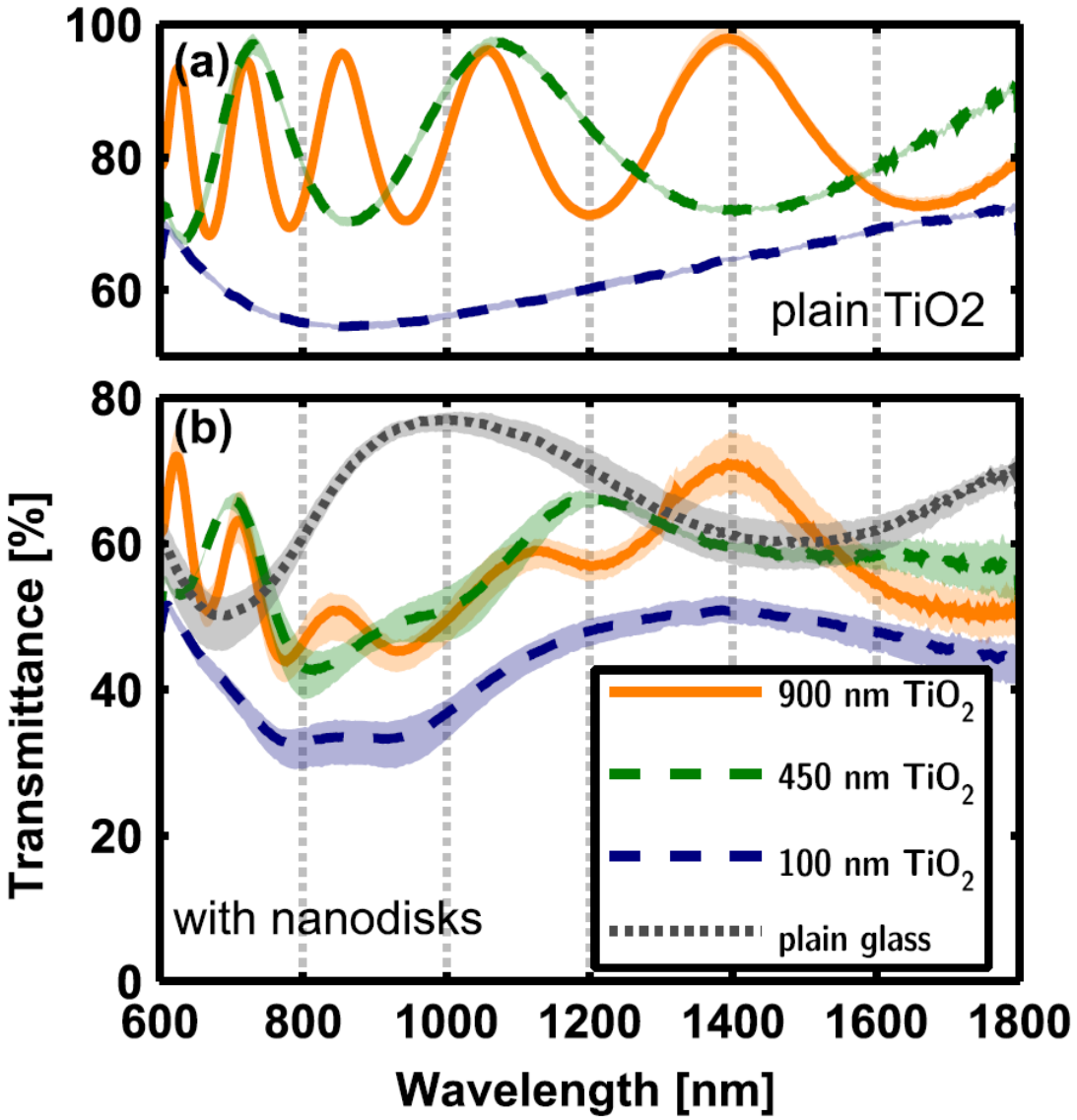
Lock-in measurement

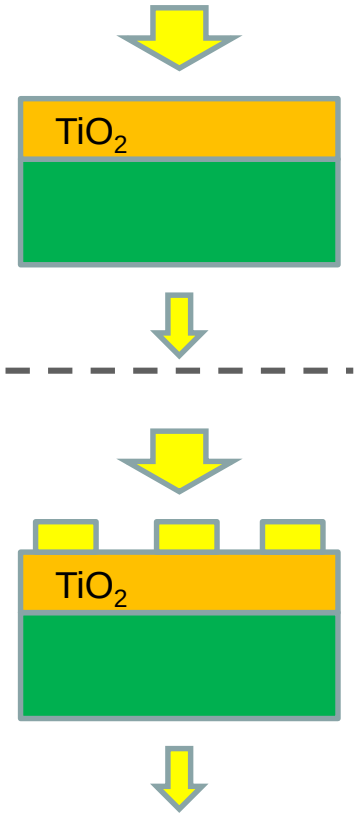




Gold nanodisks

Transmittance





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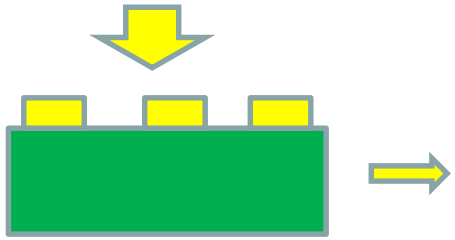
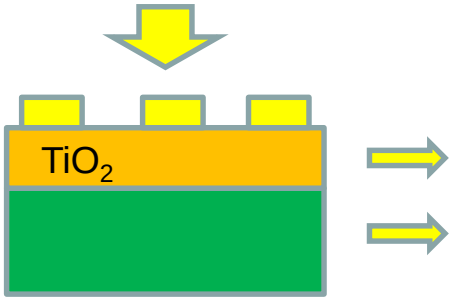
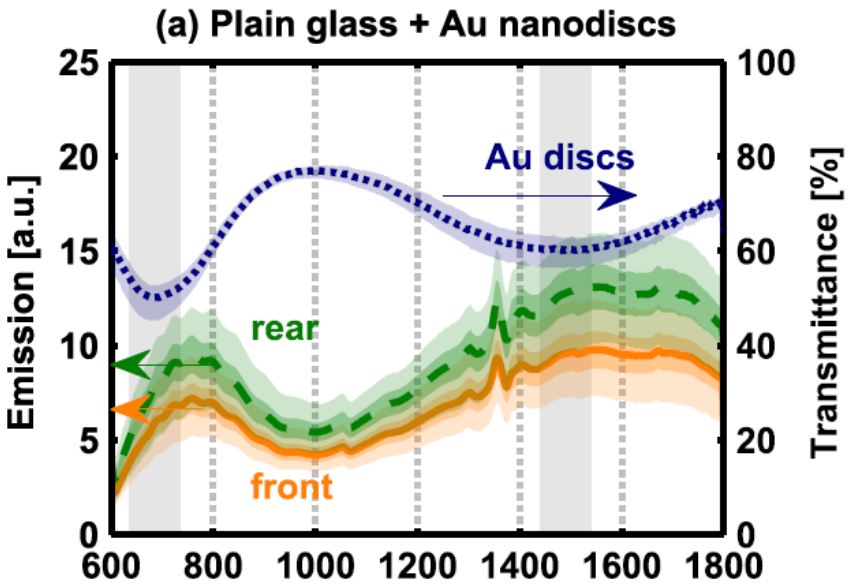
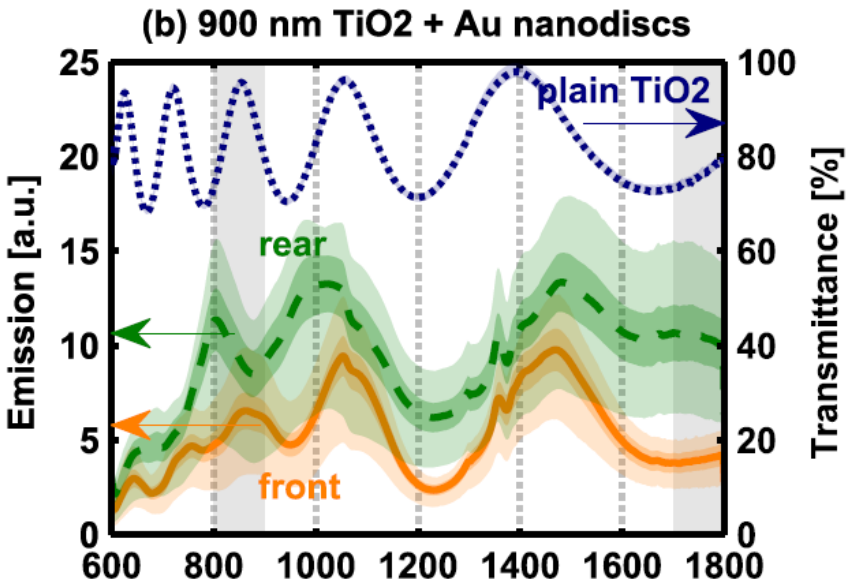
Gold nanodiscs

Emission



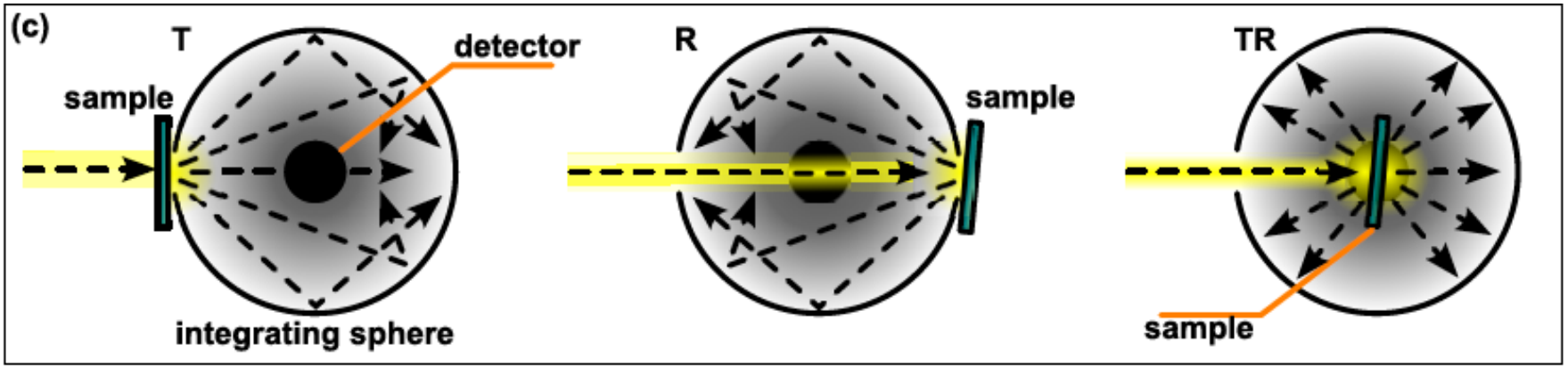






This works, but …

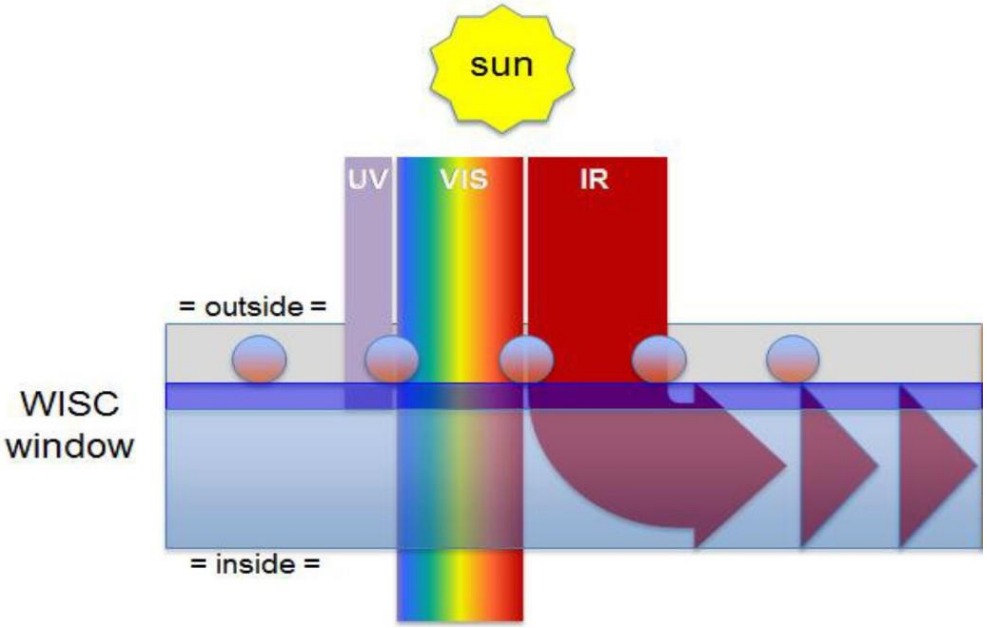
Measurement setup 2



Efficiency less than 1% ☹

Problem – poor efficiency

- Plasmonic nanoparticles should be very efficient scatterers
- Low observed emission from the edge of the window
- WHY:What's wrong in the picture?



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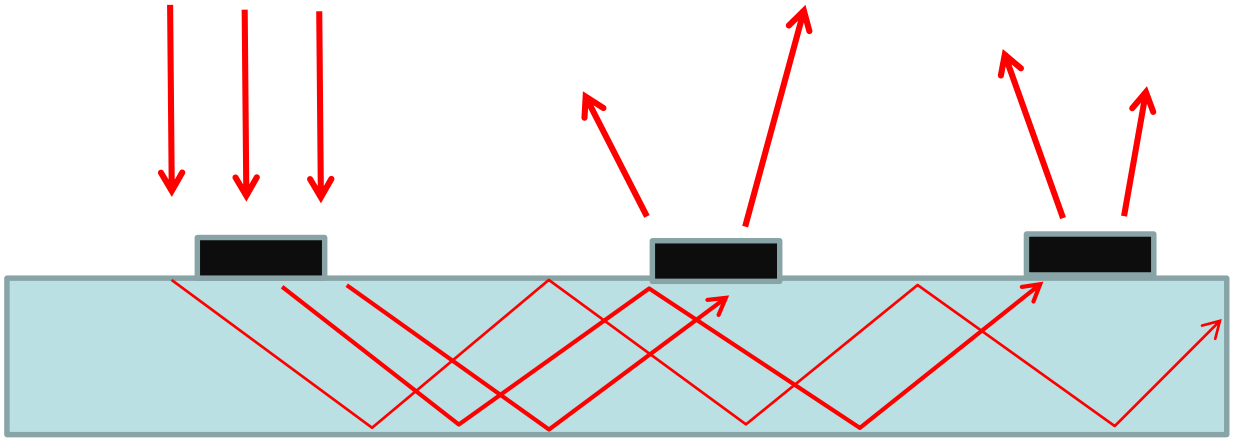
Reciprocity



?!

The metal particles also couple out the light!

- ”*If I see you, you can see me*”
- **High in-coupling efficiency always means high out-coupling efficiency, i.e. losses!**

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Ways around reciprocity

Changing the frequency of coupled light

- Frequency up/downconversion
- Fluorescence
- Second-harmonic generation etc.

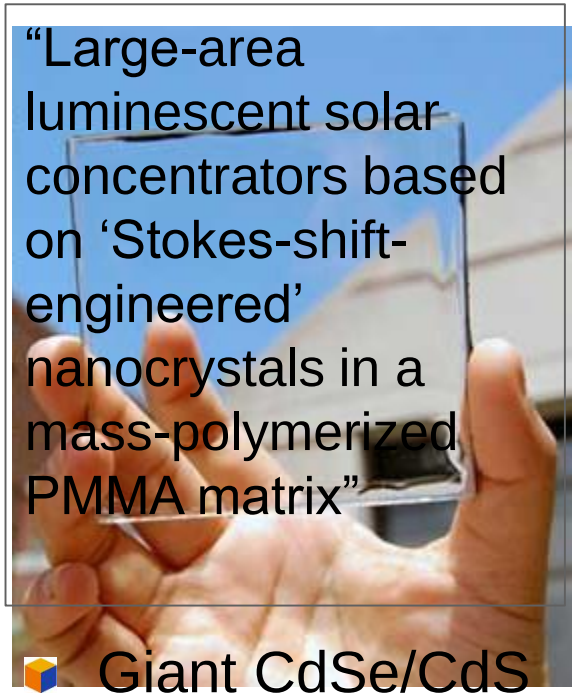
Magneto-optical effect

- Used in Faraday rotators
- Requires polarized light

Luminescent solar concentrators

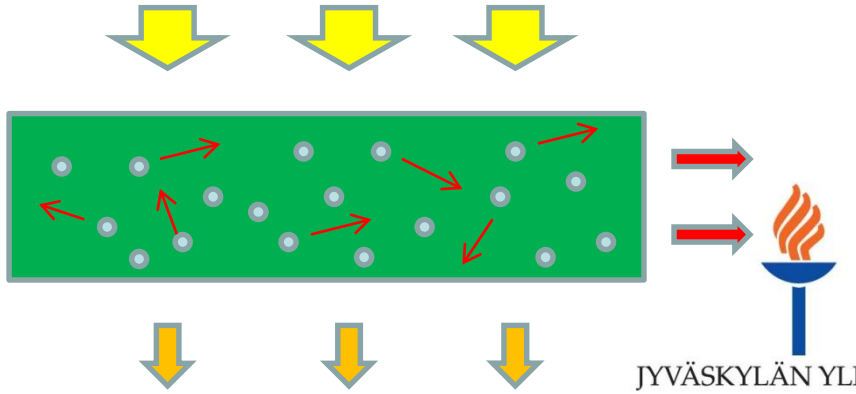
Meinardi et al., Nat. Photon. April 2014

Zhao et al., Adv. Opt. Mater., July 2014



- Giant CdSe/CdS quantum dots
- Cyanine salts
- Efficiency > 10%!
- Efficiency > 0.4%

- Incorporate luminescent materials
- Small overlap between absorption and emission spectra
- Disadvantages: high losses, low stability, colored tinting



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Outlook

- Complex structures?
- Incorporate luminescence?
- New ideas tested at the moment!

Goal: cheap, simple and durable solar window

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- Global increase in green energy production
- No extra surface area needed for solar panels
- Less need to cool buildings

Huge global impact in reducing greenhouse emissions!

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