What are the main challenges to achieve efficient solar energy harvesting?

Michele Midrio
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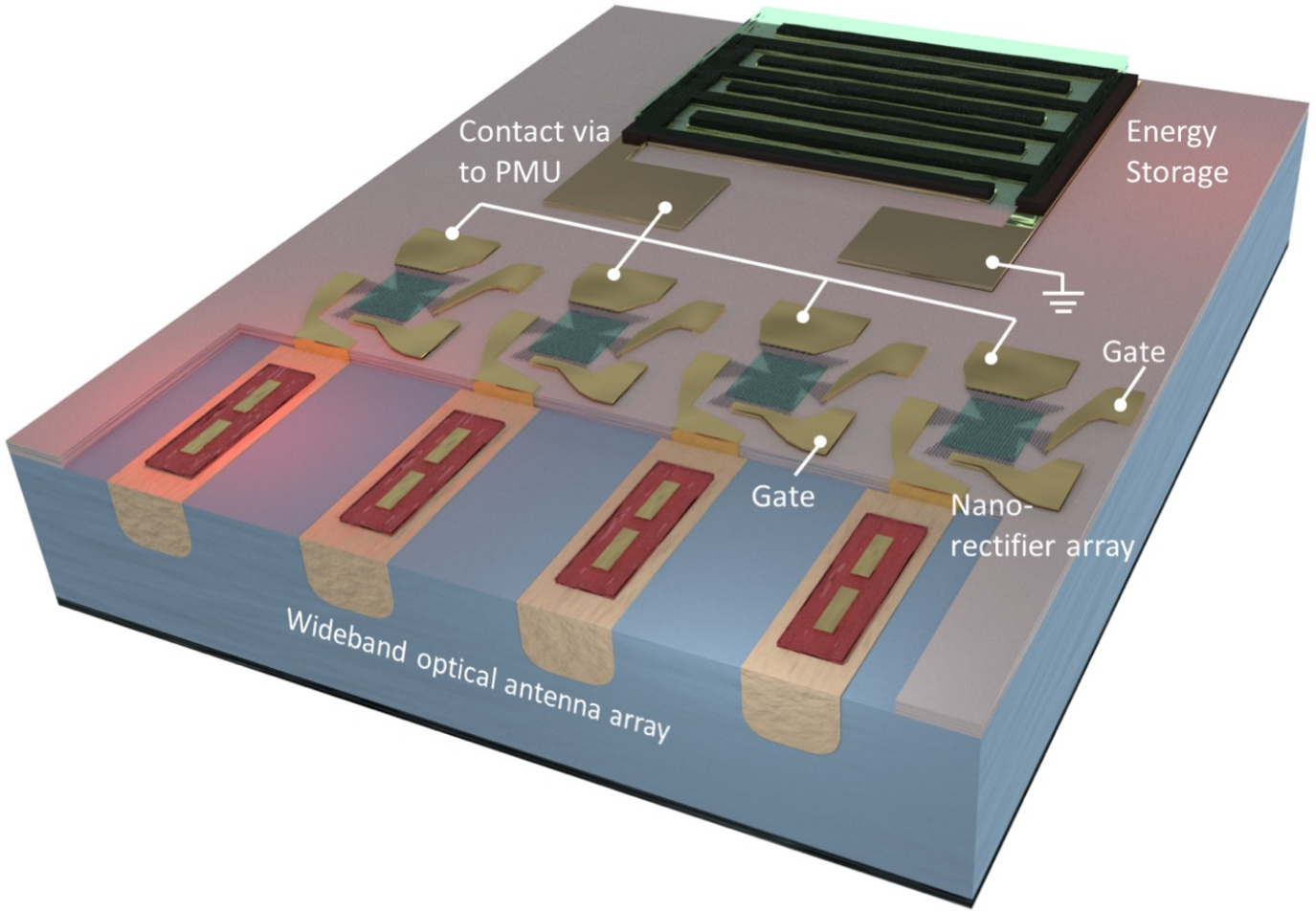
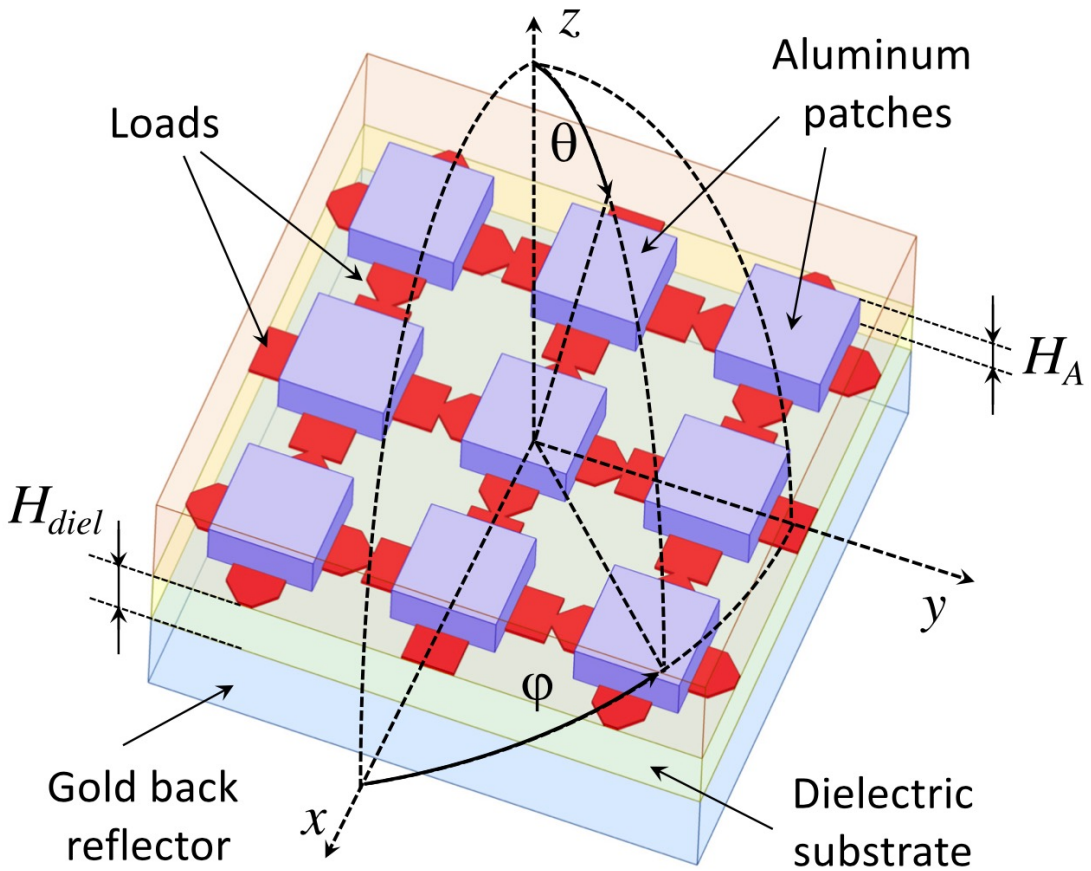
Università Politecnica delle Marche

GreEnergy

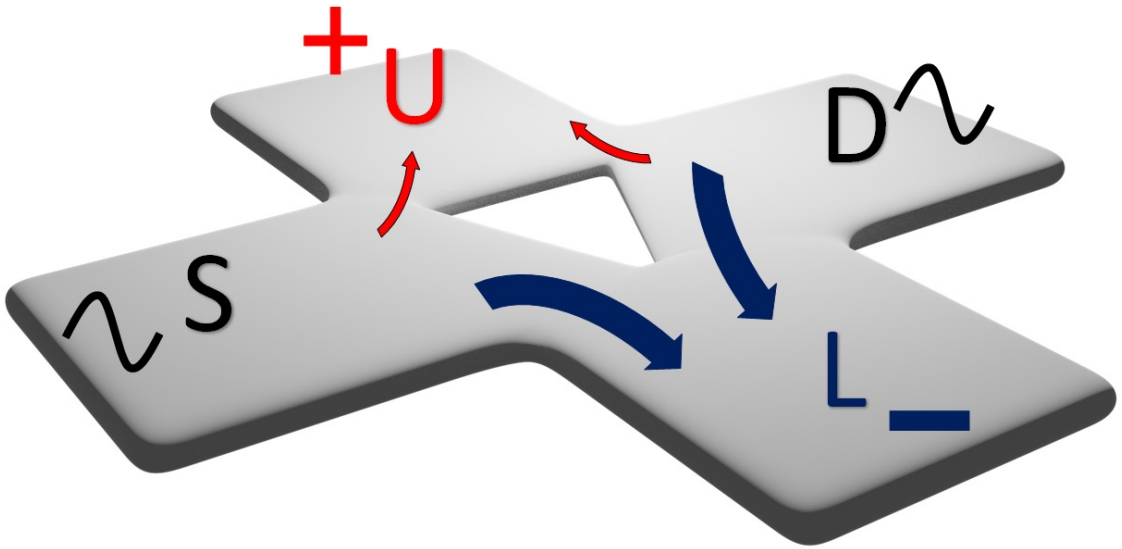
The GreEnergy Project



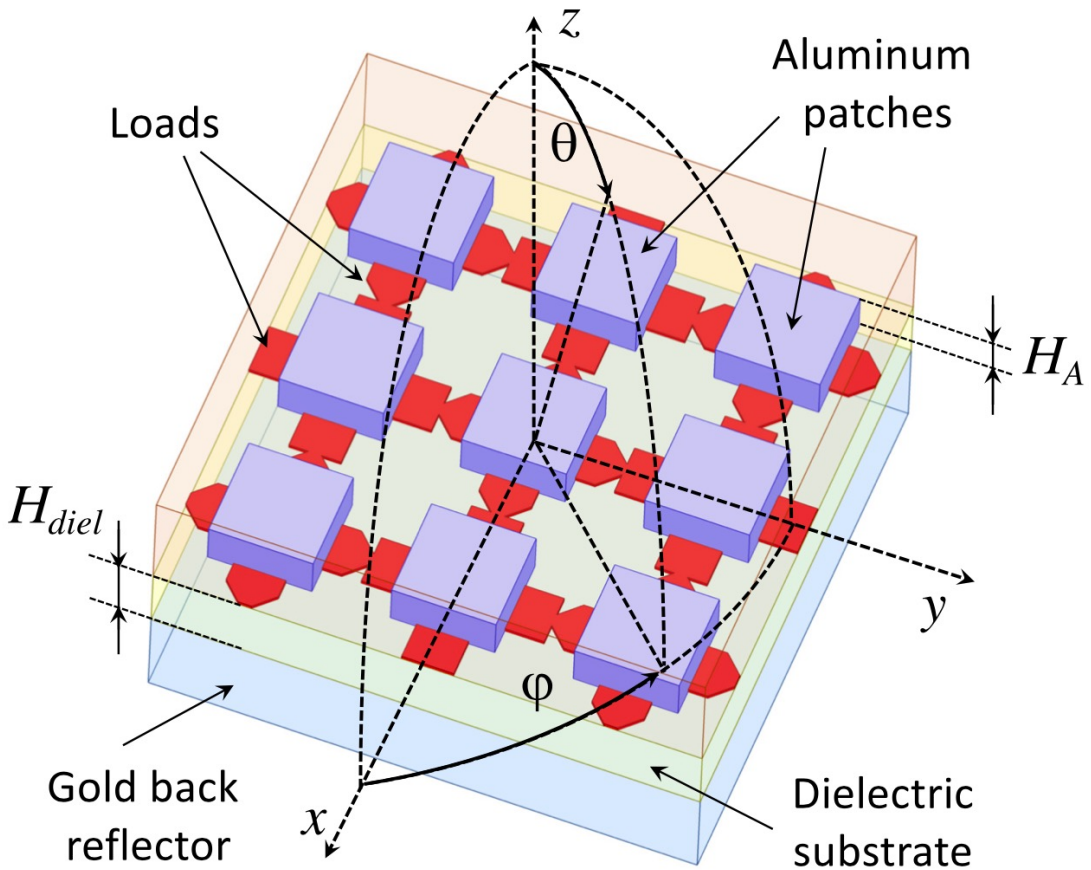
Optical Antennas (M. Midrio)



THz rectifying diodes (D. Mencarelli)



Optical Antennas



The work done so far is on the THEORETICAL SIDE

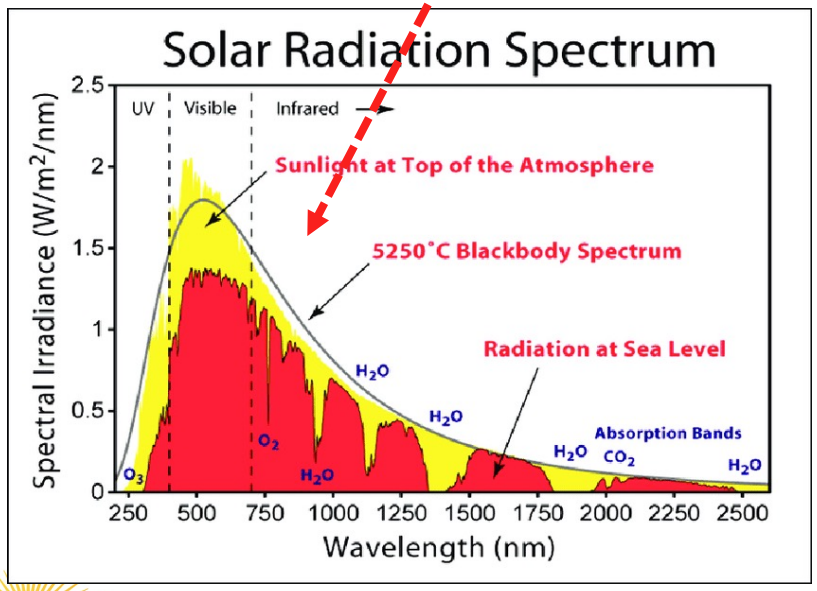
- How can one define CORRECTLY the «efficiency» of an optical antenna (a flaw in the existing literature)
- What is the best «efficiency» we can obtain for the whole spectrum of the solar light

On the “efficiency” of broadband optical antennas

Definition and estimation of antenna efficiency
State of the art prior to GreEnergy Project

The definition of antenna efficiency

$$\eta_{TOT} = \frac{\int P(\lambda)\eta_A(\lambda)d\lambda}{P(\lambda)d\lambda}$$



Prior to GreEnergy Project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RAPID COMMUNICATION

Upper bounds for the solar energy harvesting efficiency of nano-antennas

Guy A.E. Vandenbosch*, Zhongkun Ma

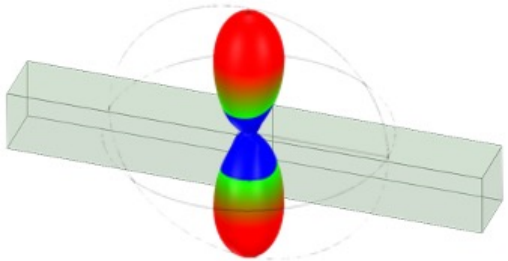
“Record” efficiency equal to 59.6%

On the “efficiency” of broadband optical antennas

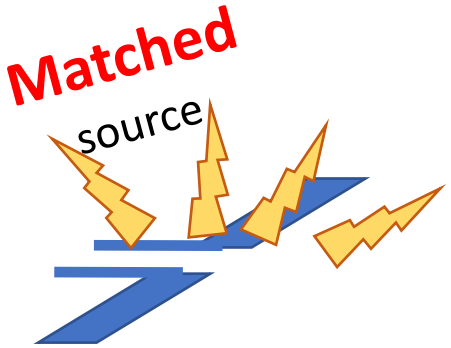
Definition and estimation of antenna efficiency - State of the art prior to GreEnergy Project

Transmitting vs receiving efficiency

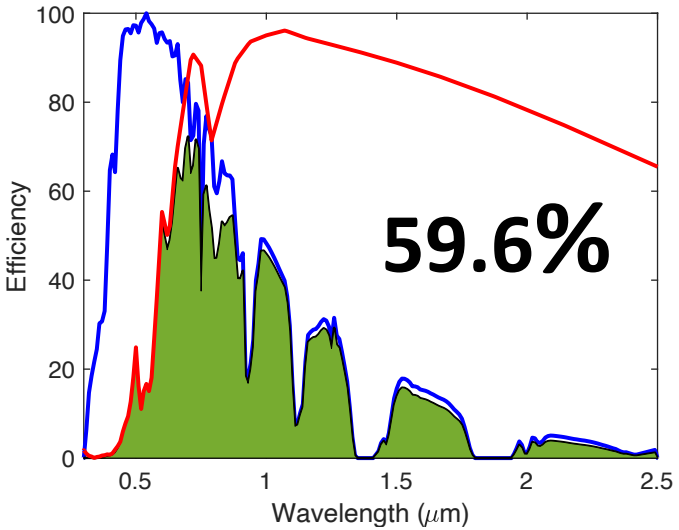
$$\eta_A(\lambda)=\begin{cases}\dfrac{P_{RAD}(\lambda)}{P_{RAD}(\lambda)+P_{LOSS}(\lambda)} \\ \dfrac{P_{LOAD}(\lambda)}{P_{INCIDENT}(\lambda)}\end{cases}$$



Problem #1. Source impedance (or load) has no role?



Transmitting **efficiency**



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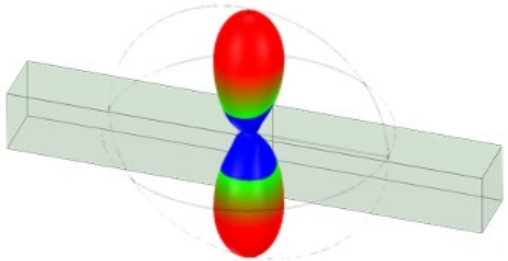

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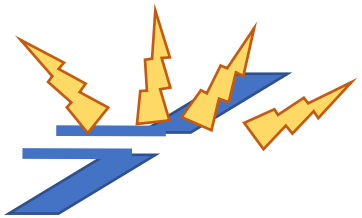
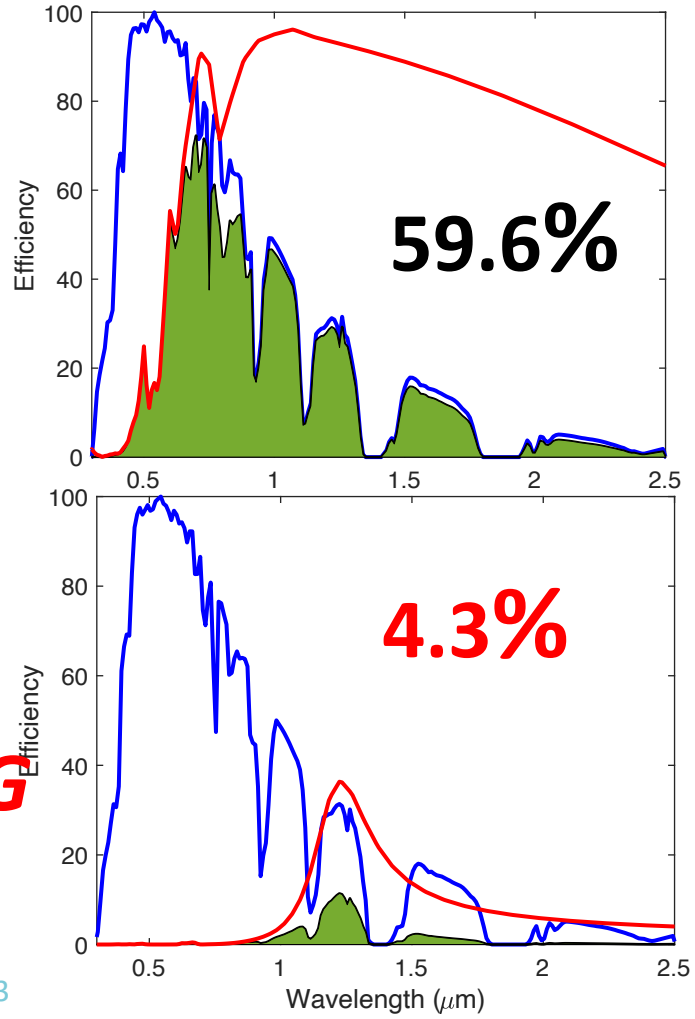


Transmitting **efficiency**

RECEIVING **efficiency**



On the “efficiency” of broadband optical antennas

Transmitting vs receiving efficiency

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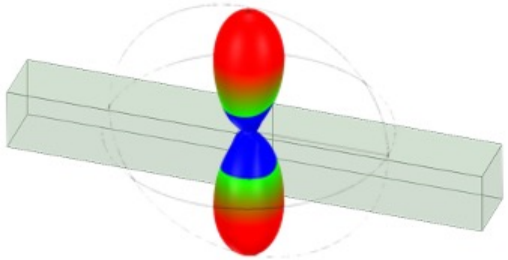
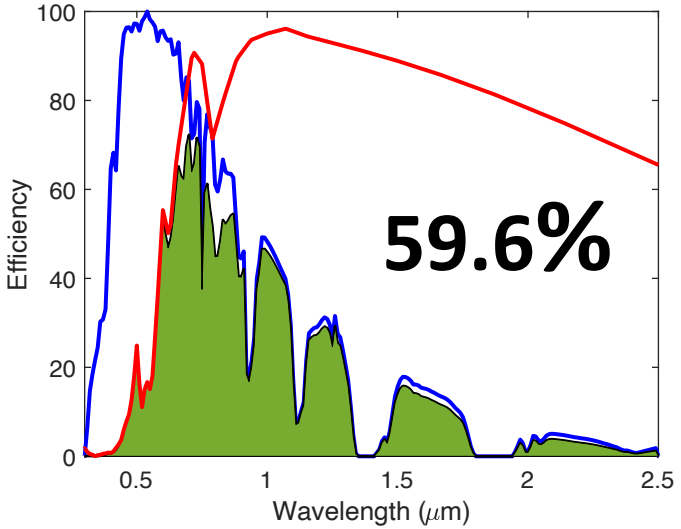
The receiving area of an array of antennas and matched loads:

- **can not be larger than half its physical size;**
- **can equal its physical size only in the presence of a ground-plane (back-reflector)** [S. A. Schelkunoff and H. T. Friis, Antenna Theory and Practice (John Wiley and Sons, 1952)]

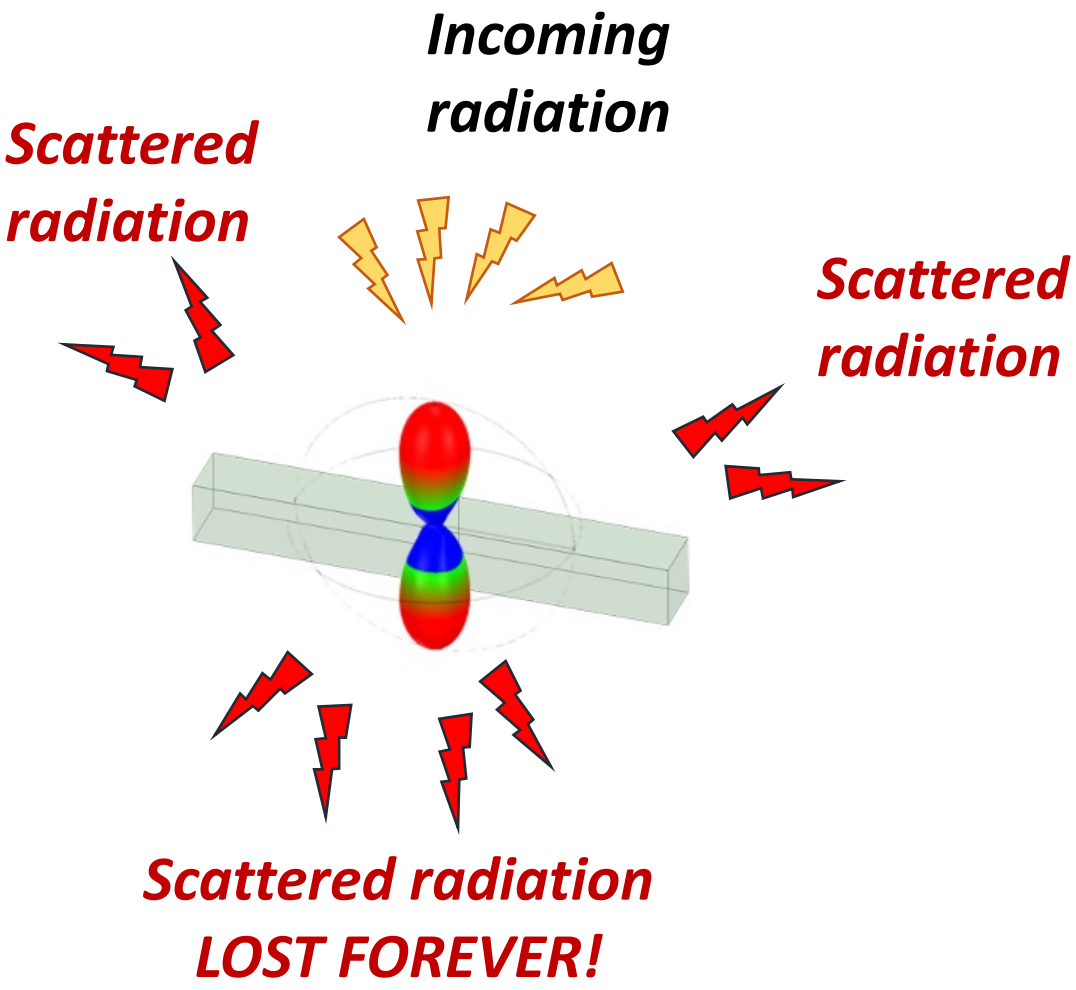




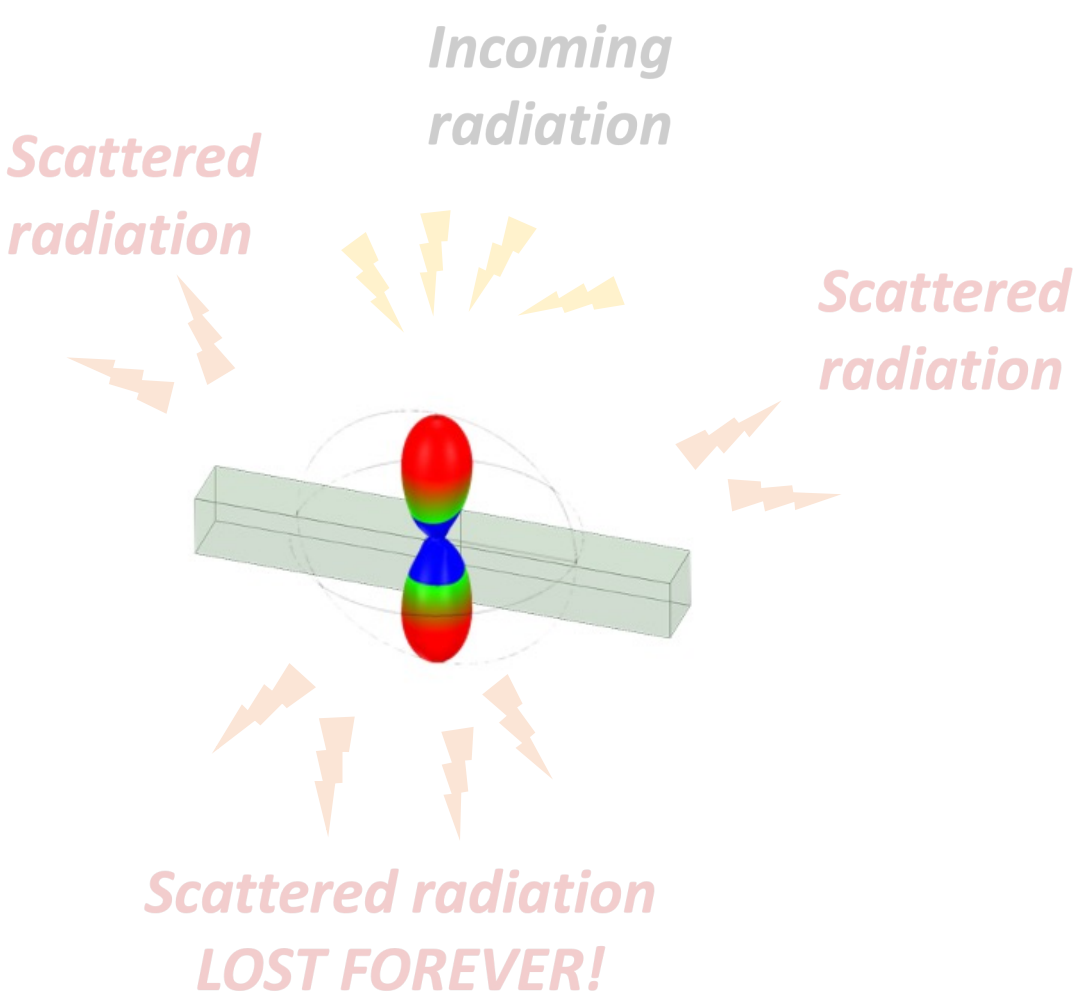
Problem #2. Larger than 50% efficiency with a dipole in free space????

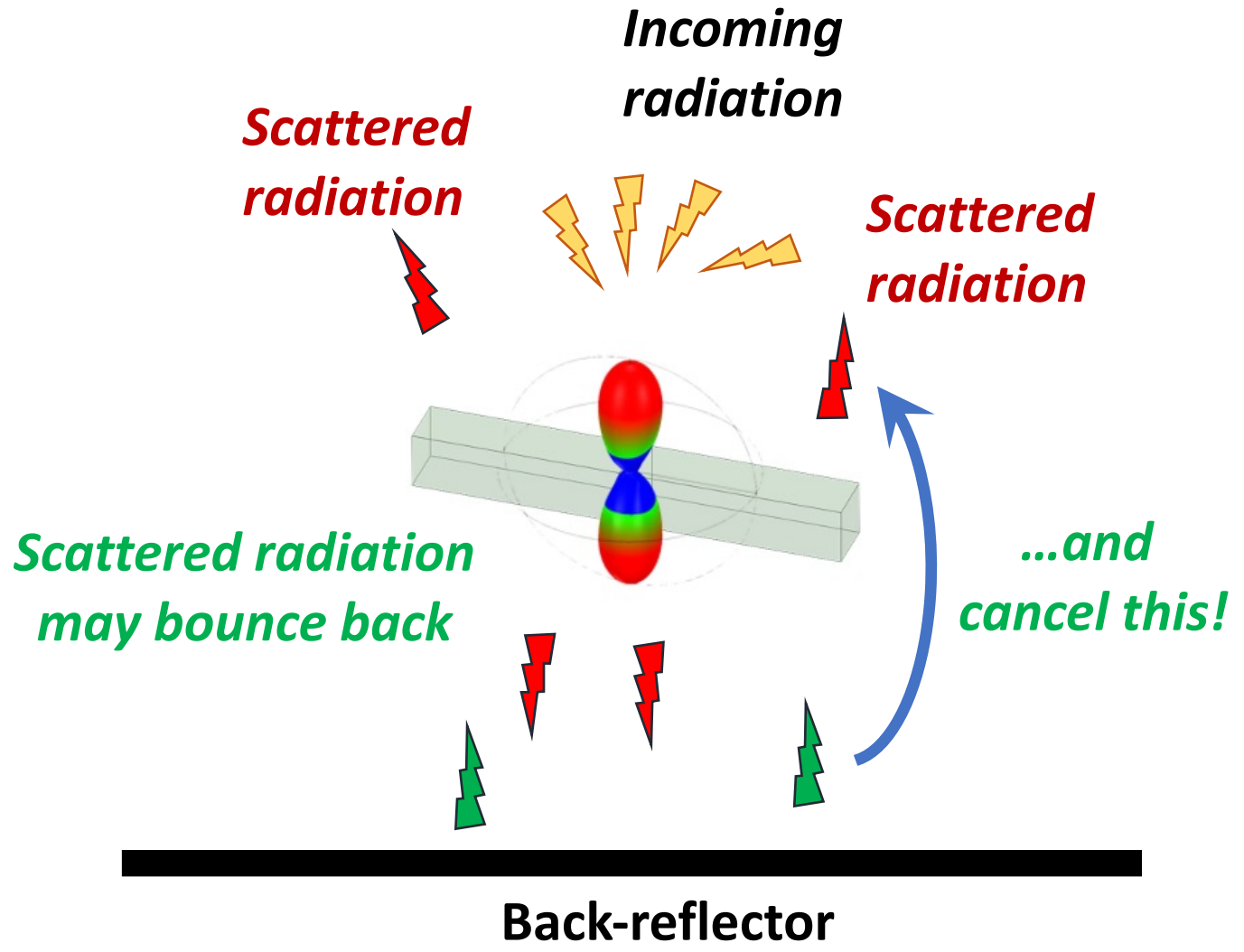
By NO MEANS can an antenna like this (that is: with no ground plane) have a “real” (receiving) efficiency larger than 50%.

On the “efficiency” of broadband optical antennas

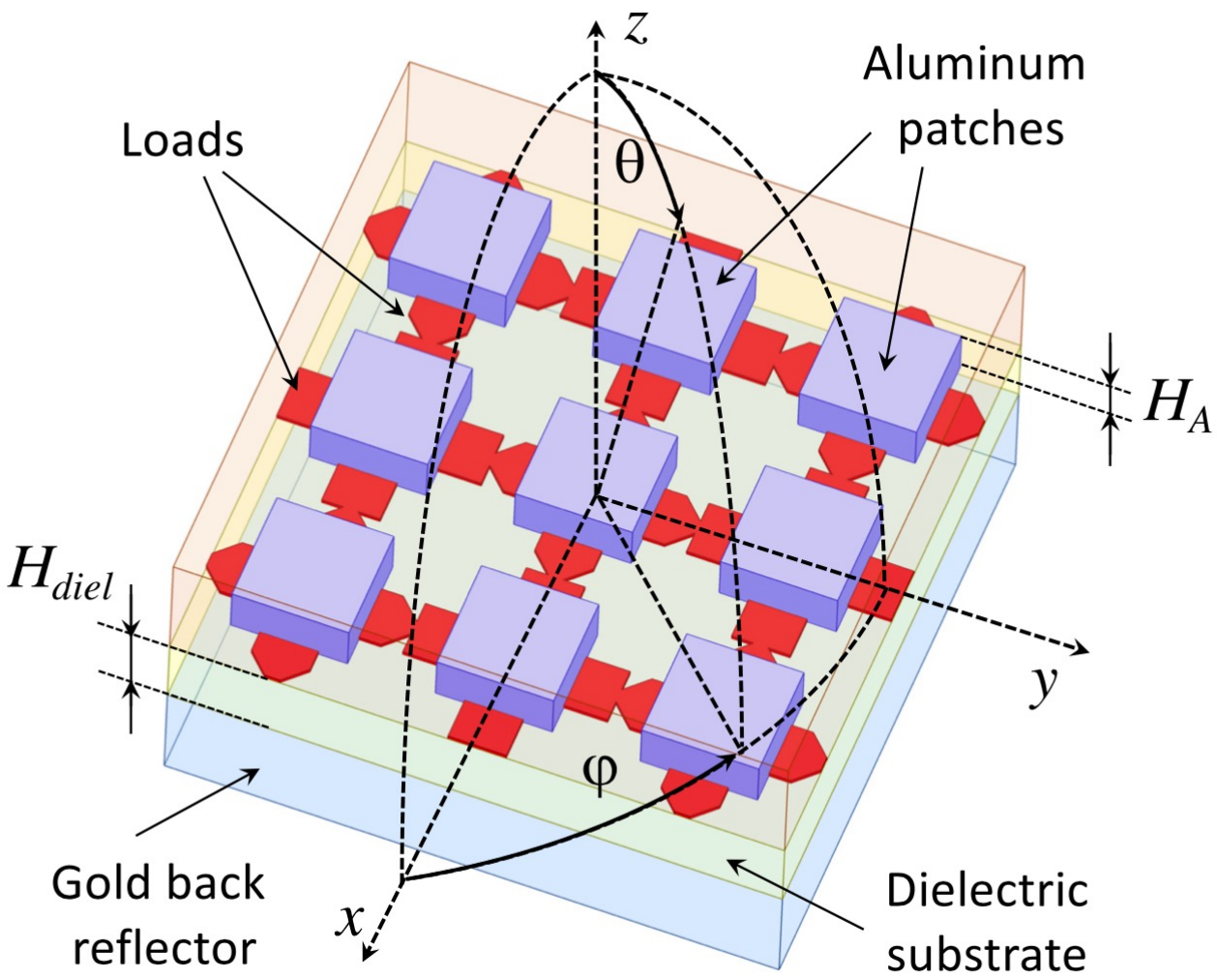


On the “efficiency” of broadband optical antennas



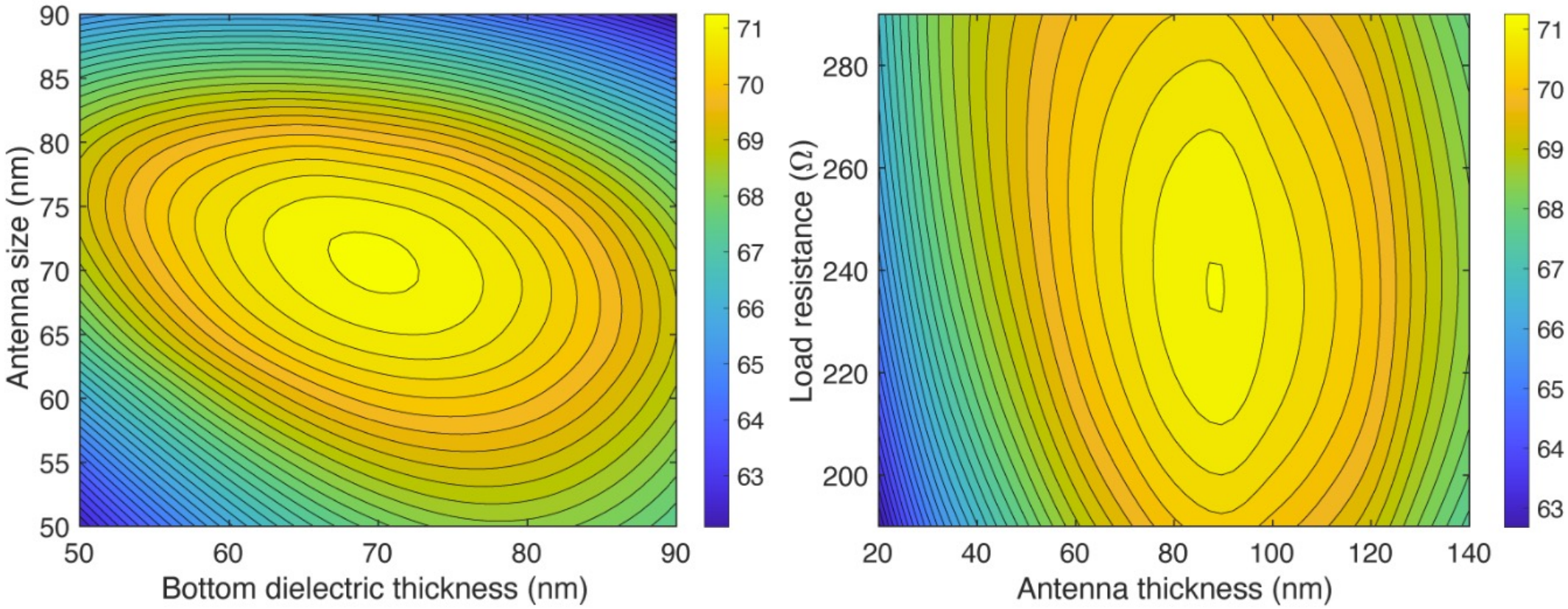


The GreEnergy proposed solution



- Correct definition of antenna efficiency
- Backreflector!
- Lattice
- Small interelement spacing (140 nm pitch)
- Extremely careful optimization of dimensions, thicknesses, choice of materials

The GreEnergy proposed solution



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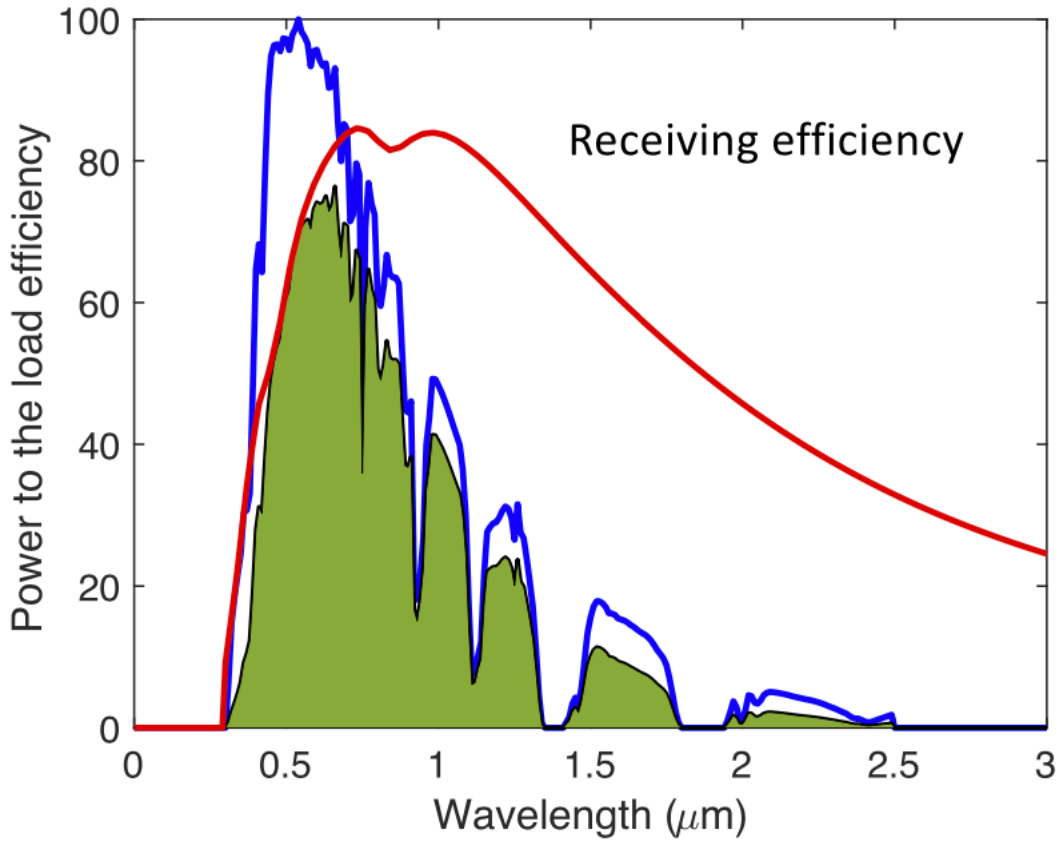
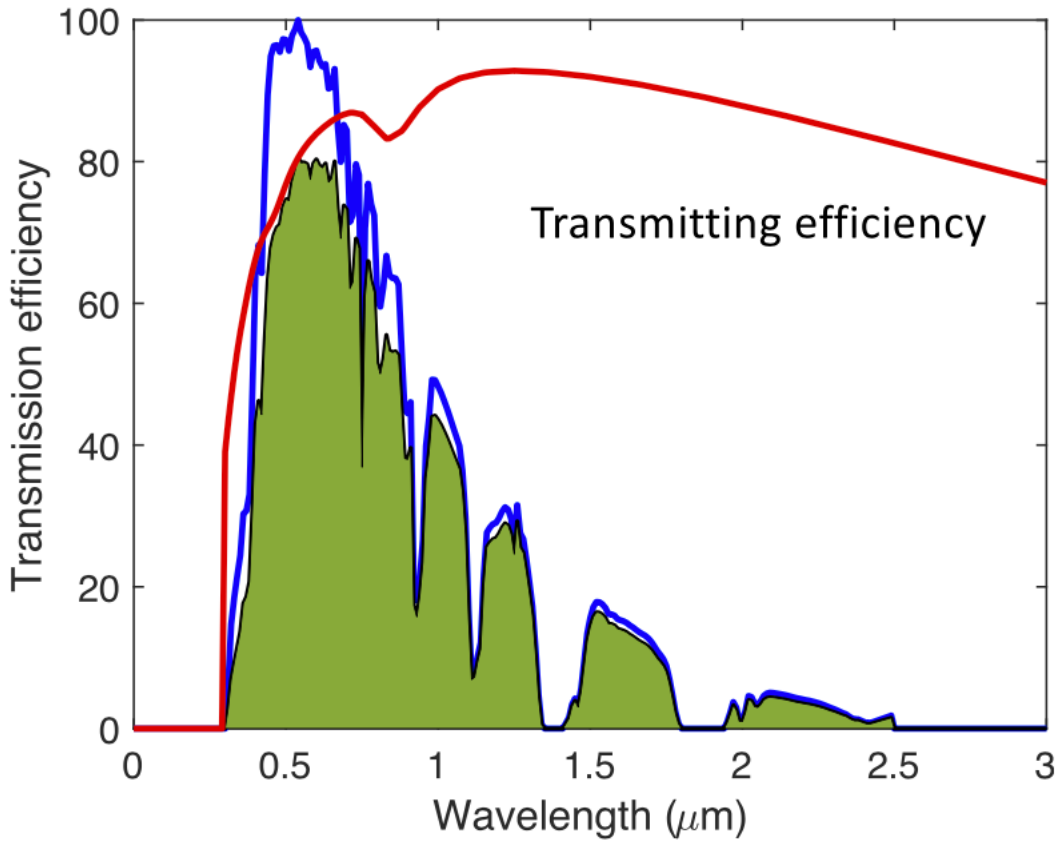
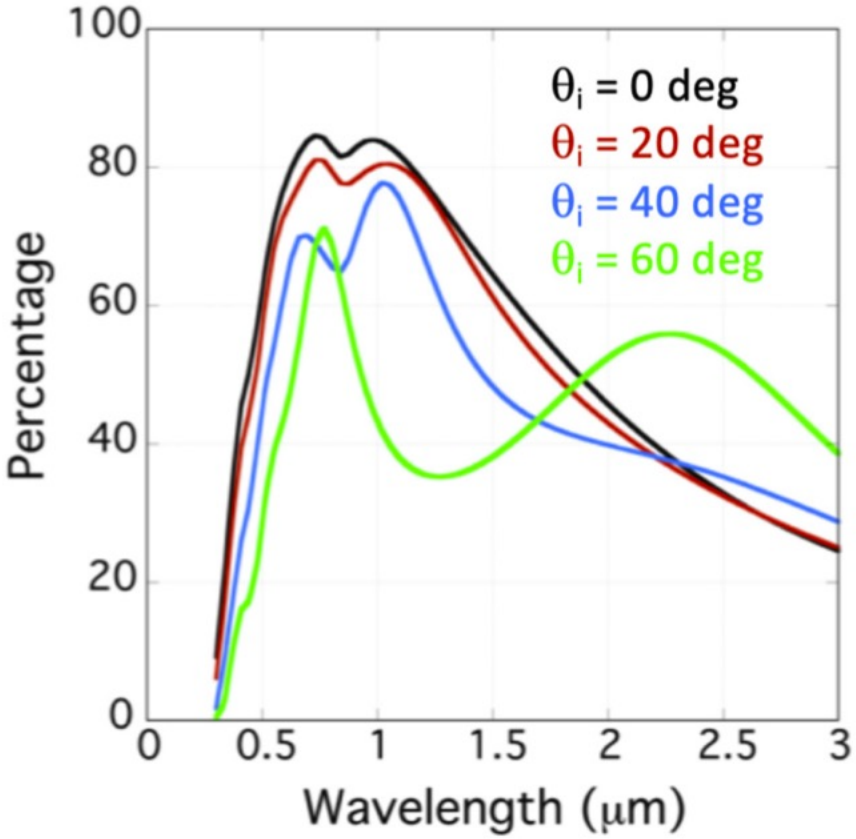
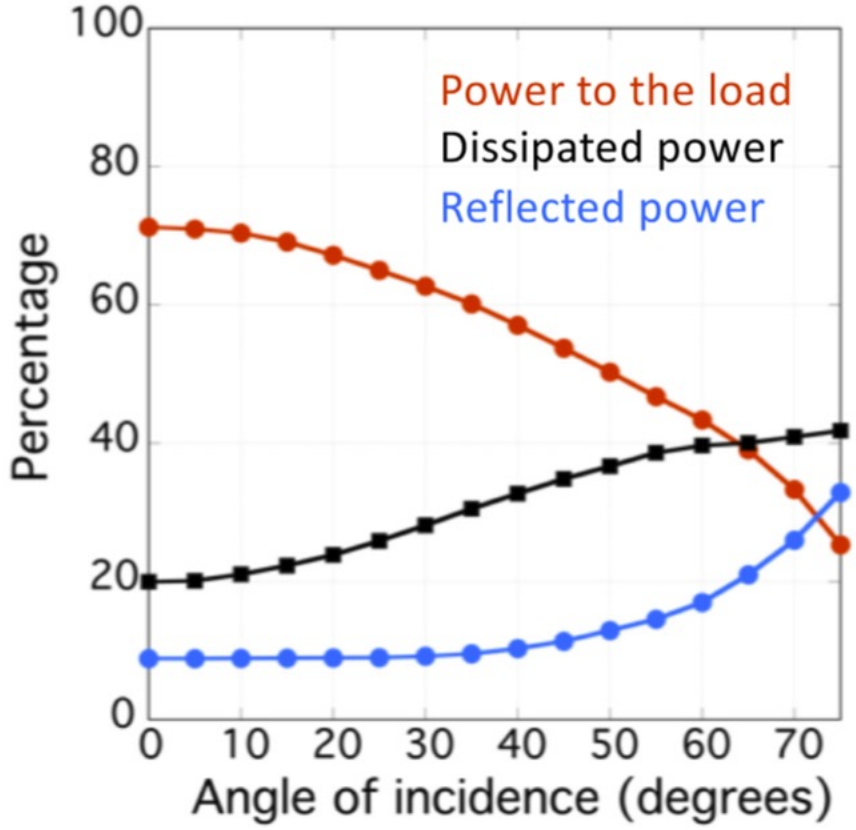




World record, 71.2% receiving efficiency

The GreEnergy proposed solution





Decently stable vs. angle of arrival

Optical antennas: what are the challenges?

- Extremely tiny dimensions (array pitch ~150nm, patch dimensions ~75nm)
- Graphene patterning in between antennas
- Graphene quality: as we shall see, ”ballistic” behaviour of charges in graphene is (almost) compulsory.

THz rectifying diodes

Davide Mencarelli

More information is available at **www.greenergy-project.eu**

GreEnergy

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101006963 (GreEnergy).

On the “efficiency” of broadband optical antennas

Definition and estimation of antenna efficiency
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How does one measure the efficiency of an antenna?

- Transmitting vs receiving efficiency

- A real flaw: greater than 50% efficiency with no reflecting ground???