Downloaded from orbit.dtu.dk on: Apr 10, 2018

Technical University of Denmark

Topology optimized nanoparticles for near-infrared enhanced photon upconversion

Vester-Petersen, Joakim; Christiansen, Rasmus Ellebæk; Julsgaard, Brian; Balling, Peter; Sigmund, Ole; Madsen, Søren P.

Publication date:
2017

Document Version
Peer reviewed version

Link back to DTU Orbit

Citation (APA):
Vester-Petersen, J., Christiansen, R. E., Julsgaard, B., Balling, P., Sigmund, O., & Madsen, S. P. (2017). Topology optimized nanoparticles for near-infrared enhanced photon upconversion. Abstract from Nanotech France 2017 Conference and Exhibition, Paris, France.

DTU Library
Technical Information Center of Denmark

General rights
Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

- Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
- You may not further distribute the material or use it for any profit-making activity or commercial gain
- You may freely distribute the URL identifying the publication in the public portal

If you believe that this document breaches copyright please contact us providing details, and we will remove access to the work immediately and investigate your claim.

Topology optimized nanoparticles for near-infrared enhanced photon upconversion

Joakim Vester-Petersen[1], Rasmus E. Christiansen[2], Brian Julsgaard[3], Peter Balling[3]
Ole Sigmund[2], Søren P. Madsen[1]

[1] Department of Engineering, Aarhus University, Inge Lehmanns Gade 10,
8000 Aarhus C., Denmark
[2] Department of Mechanical Engineering, Technical University of Denmark, Nils Koppels Allé,
Building 404, 2800 Kgs. Lyngby, Denmark
[3] Department of Physics and Astronomy, Aarhus University, Ny Munkegade 120,
DK-8000 Aarhus C, Denmark

Abstract:
This work is a part of the SunTune project which addresses efficiency improvements of solar modules by manipulating the spectrum of sunlight to better match the range of efficient current generation in silicon solar cells. Photons with energies below the band gap energy of silicon (*<1.1eV*) are (up)converted into photons with higher energies through absorption in rare earth ions (Er^{3+}) followed by radiative decay. This process converts otherwise non-absorbed long wavelength photos to shorter wavelength photons able to bridge the band gap energy and contribute to the energy generation of the solar modules.

The upconversion process is naturally inefficient, and without any enhancement of the incident light, the process is negligible. The probability for upconversion can be increased by focusing the incident light into areas doped with Er^{3+}ions, using optimized nanoparticles placed into or near these areas. Studies have shown that the intensity of the upconverted light is proportional to the intensity of the incident light raised to some power, n, [1]. Experimentally n is found to be 1.5 and the light intensity is proportional to the square of the electric field norm, $|E|^2$.

We aim to enhance the incident light using topology optimized nanoparticles. Here, the distribution of nanoparticle material is optimized to enhance $|E|^3$ in a thin Er^{3+} doped TiO_2 film. Topology optimization has previously proven successful for optimizing wave propagation in acoustics [2] and electromagnetics [3,4]. The governing physics is modeled classically using Maxwell equations in the frequency domain. The model is excited by an incoming plane wave with a wavelength, within the near-infrared absorption band of Er^{3+} (1480nm - 1560nm).

Keywords: Topology optimization, nanooptics, photolvoltaics, plasmonics, light enhancment

References:

1. M. Pollnau et al. “Power dependence of upconversion luminescence in lanthanide and transition-metal-ion systems”. In: *Phys. Rev. B* 61.5 (2000)

2. Rasmus E. Christiansen et al. “Creating geometrically robust designs for highly sensitive problems using topology optimization: Acoustic cavity design”. In: *Struct. Multidiscip. Optim.* 52.4 (2015)

3. Maria B. Dühring et al. “Plasmonic versus dielectric enhancement in thin-film solar cells”. In: *Appl. Phys. Lett.* 100.21 (2012)

4. Jacob Andkjær et al. “ Topology optimization of grating couplers for the efficient excitation of surface plasmons”. In: *J. Opt. Soc. Am. B* 27.9 (Sept. 2010)

Please mention the conference Session/Topics you are interested to :

- **Nanomaterials for solar cells and Photovoltaics**