More effective than a "super" absorption in spherical nanoparticles

Konstantin Ladutenko*
ITMO University, 49 Kronverskii Ave.,
St. Petersburg 197101, Russian Federation
and
Ioffe Physical-Technical Institute of the Russian Academy of Sciences,
26 Polytekhnicheskaya Str., St. Petersburg 194021, Russian Federation

Ovidio Peña-Rodríguez
Instituto de Fusión Nuclear, Universidad Politécnica de Madrid,
José Gutiérrez Abascal 2, E-28006 Madrid, Spain

Ali Mirzaei, Andrey Miroshnichenko, and Ilya Shadrivov
Nonlinear Physics Centre, Research School of Physics and Engineering,
The Australian National University, 59 Mills Rd, Acton, ACT, 2601, Australia
(Dated: May 14, 2015)

There is a theoretical limit for absoption by a bulk spherical partical. In order to break this limit we applied a widely used design pattern for a multilayered sphere which consist of overlapping several electric and/or magnetic resonances (dipole and higher multipoles). We used a straightforward approach to evaluate several designs from realistic materials. However, we found that due to dimension effect it can be preferable to use a properly disigned particle of smaller size with only a dipole response in order to reach the best absorption efficiency.

PACS numbers: 41.20.Jb 42.25.Bs 02.60.Pn 02.70.-c

Mie theory [] describes interaction of an electromagnetic wave with a spherical particle and is still of great interest our days [] inspite of its long history lasting more than a century. Development of Mie theory over the years [Yang, Pena] lead to possibiltity to explore properies of multilayer spherical particles []. Such particles has various applications in ... [].

The problem of scattering from a multilayered cylinder and a sphere was investigated in great details with Fan et al. [Fan-PRL, Fan-APL]. In his work he defined a "super" scatterer as a subwavelength object having a scattering cross section that far exceeds the single-channel limit of the maximal total angular momentum involved. From spectral point of view this means the overlapping several electric and/or magnetic resonances.

There was some recent fuzz about "superscattering" effect, which is about to design a structure such a way, that several multiple (electric and/or magnetic) resonances are overlapped. This breaks the theoretical limit we can achieve using a single resonance, that's why it is called "super". Our initial idea was to show the same effect in absorption, and R=63 with R=81nm are such 'super-absopting' designs. However, in 3D case (in contrast to 2D investigated with Ali) it turned out that sometimes it is preferable to use a smaller particle with single resonance to achieve the best efficiency. This way, in 3D case using real materials for a multilayer spherical particle "superabsorbing" design do not always leads to best absorption efficiency. Moreover, same effect exists for scattering from SiAgSi optimized structure. At WL=500 nm "super" scattering mode with two resonances gives the best efficiency, however, at WL=400 nm a single resonance small particle has a better scattering efficiency compared to larger particles with "super" design.

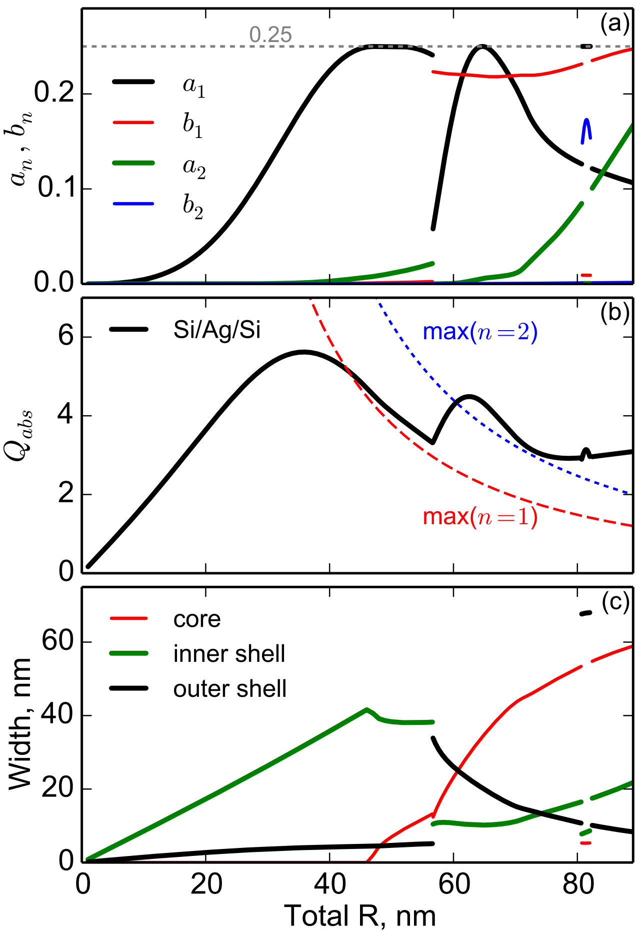

Figure 1. Optimized designs overview at working wavelength λ = 500 nm. (a) Expansion coefficients (b) Absorption efficiency with best value at total R=36 nm and Ag/Si design (zero sized core) and "super" designs at R=63 nm and R=81 nm. (c) Used layers width

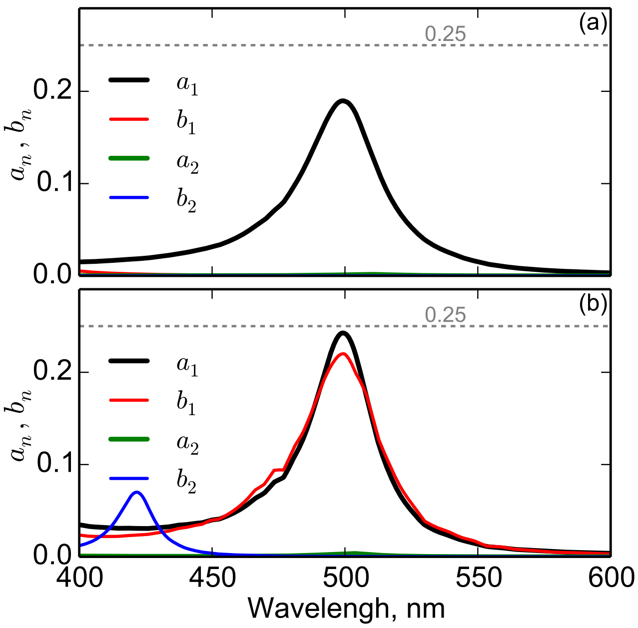

Figure 2. Expansion coefficients spectra of (a) efficient and (b) "super" design.

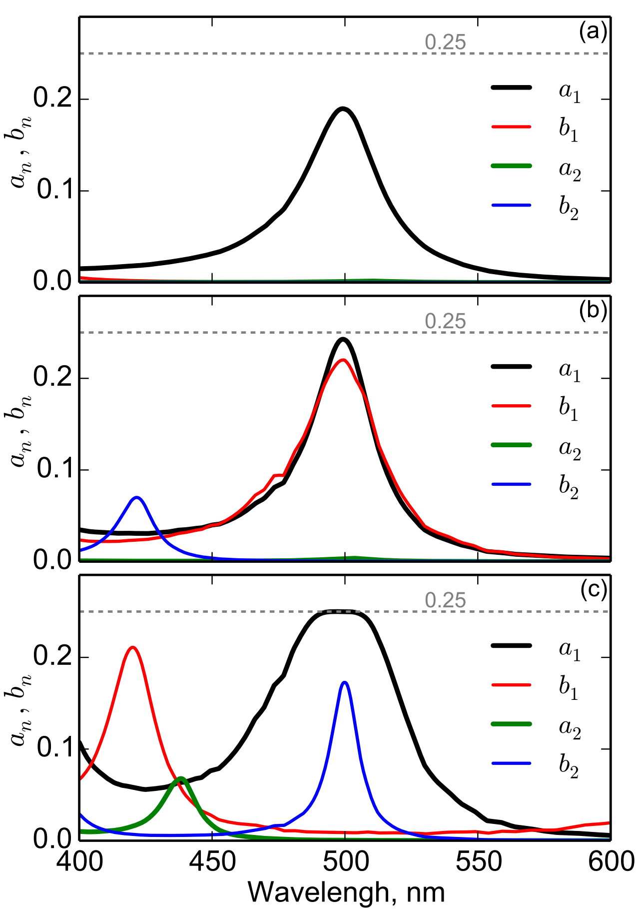

Figure 3. (Or we can use) Expansion coefficients spectra of (a) efficient and (b-c) "super" design.

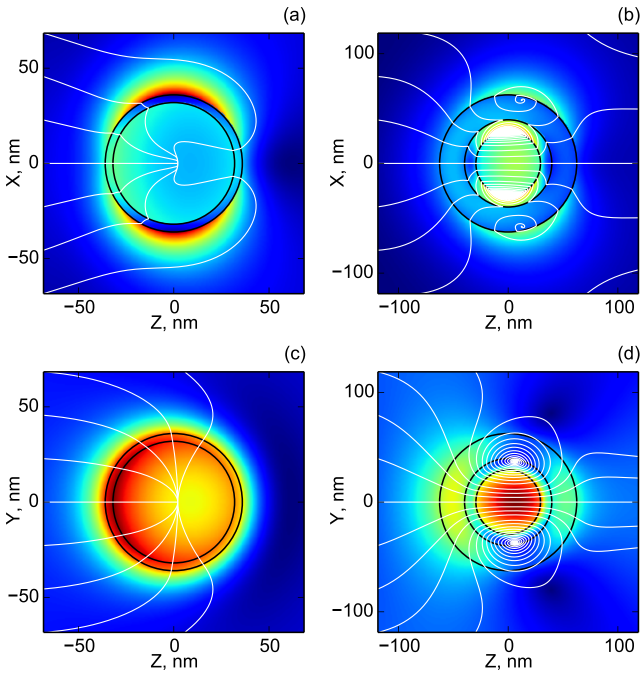

Figure 4. (Main field figure. The following figures are given for reference and should be removed from the manuscript). Electric field for efficient (a,c) and "super" (b,d) designs in E-k (a-b) and H-k (c-d) planes.

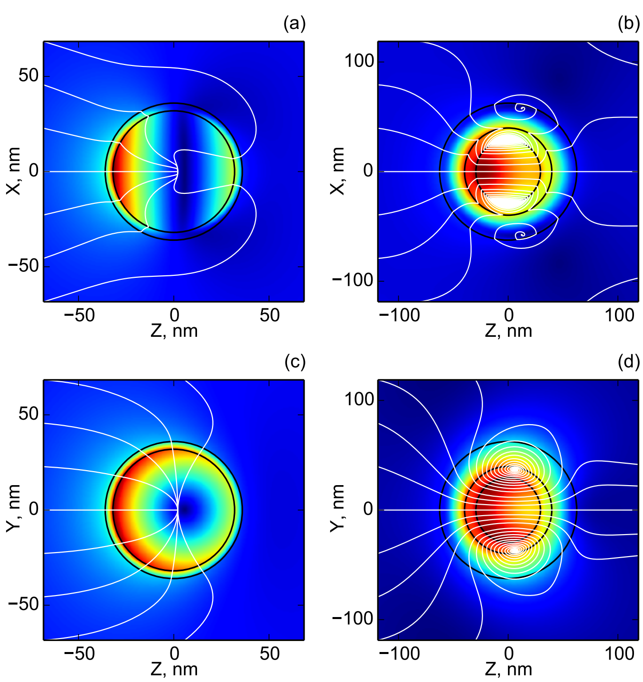

Figure 5. Same as Fig. 4 for magnetic field.

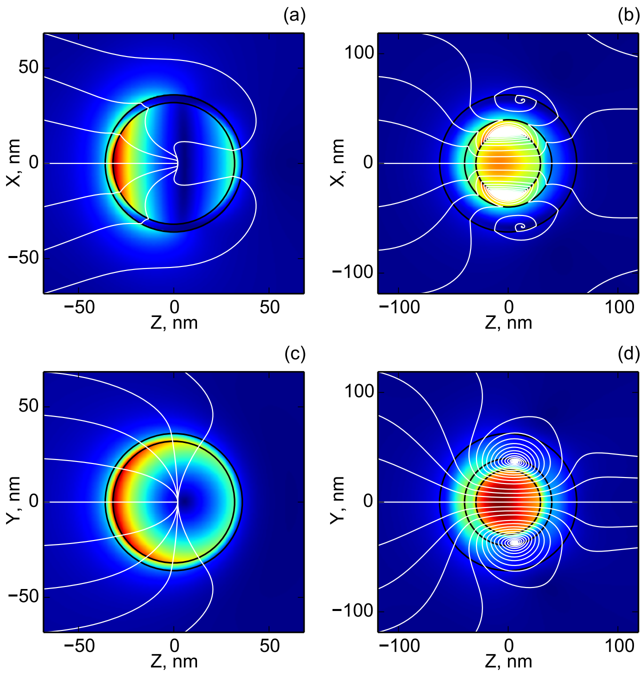

Figure 6. Same as Fig. 4 for Poynting vector.

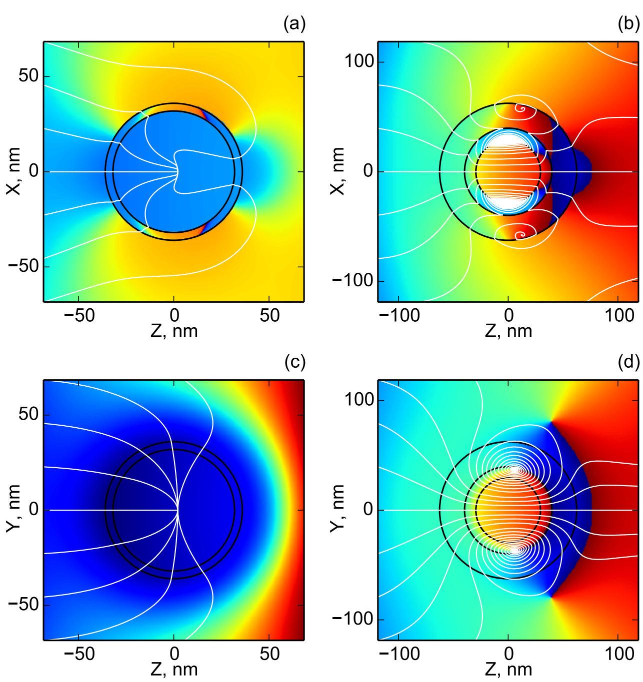

Figure 7. Same as Fig. 4 for phase of the electric field (x component).

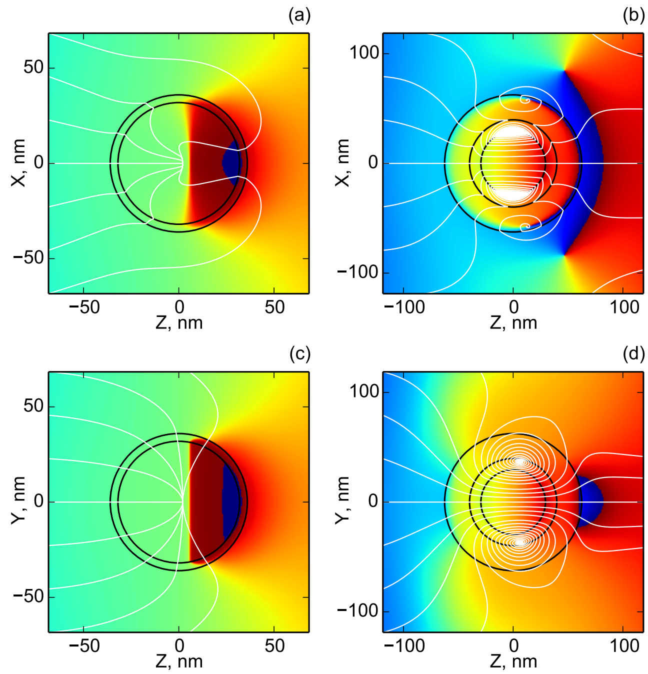

Figure 8. Same as Fig. 4 for phase of the magnetic field (y component).