Enhanced second-harmonic generation in AlGaAs nanoantennas

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Introduction: The optical response of sub-wavelength size dielectric particles can exhibit both strong electric and magnetic optical resonances in the visible and near-IR wavelength range [1]. These optical properties make all-dielectric nanoantennas a unique opportunity for the study of nonlinear optical effects generated from both electric and magnetic resonances [2].

Computational Methods: We investigated the optical scattering of $Al_{0.18}Ga_{0.82}As$ cylinders at near-IR wavelengths by using Frequency Domain (FD) simulations in the Wave Optics Module of COMSOL. The scattered field was finally decomposed using a multipolar expansion [3].

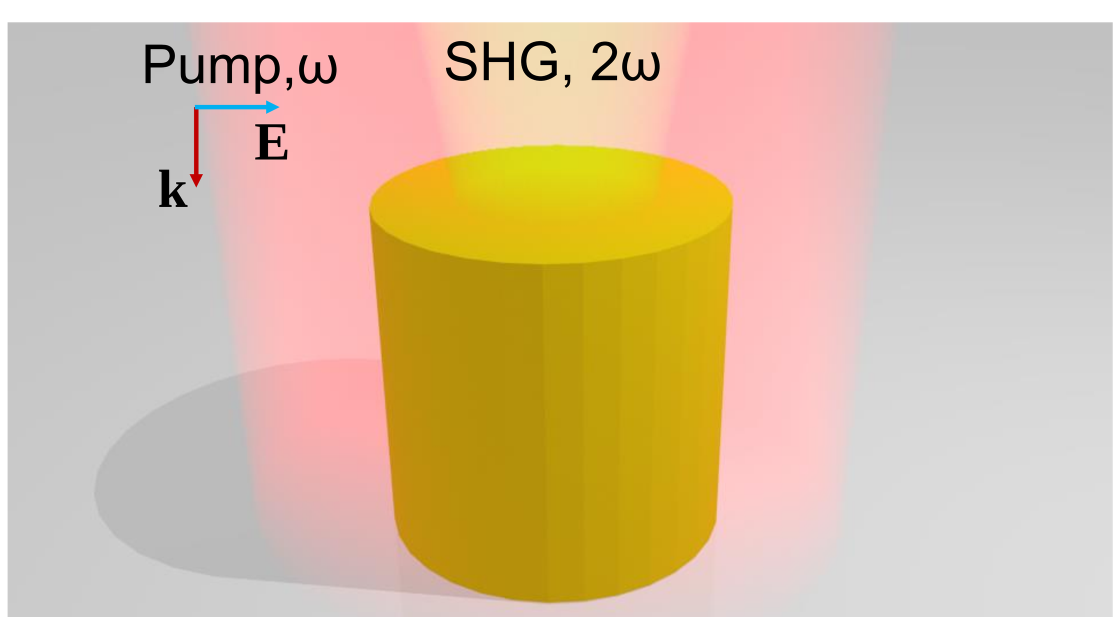


Fig. 1. Schematic representation of SHG from a cylinder. The pump beam at ω is a plane wave with wave vector, k, parallel to the cylinder axis.

In order to investigate the SHG phenomenon, we used the nonlinear polarization induced by $\chi^{(2)}$ of $[\bar{1}00]$ $Al_{0.18}Ga_{0.82}As$ as a source in subsequent FD simulations:

we solved the linear electromagnetic problem at the fundamental frequency (FF);

we solved the problem at the SH frequency ω_{SH} using the calculated fields at the FF to define the second harmonic (SH) source as external current density [2]. The i-th component of the external current density J_i was expressed as

$$J_i = j\omega_{SH}\varepsilon_0\chi^{(2)}E_{FF,j}E_{FF,k} \quad , \quad i \neq j \neq k$$

where ε_0 is the vacuum permittivity and $E_{FF,i}$ is the i-th component of the electric field at the FF.

Results: The scattering efficiency (Q_{sca}) of cylinders of different radii shows that resonances red-shift as *r* is increased (Fig. 2). The multipolar expansion of Q_{sca} shows that the magnetic dipole resonance dominates at wavelength λ=1640nm (Fig. 3).

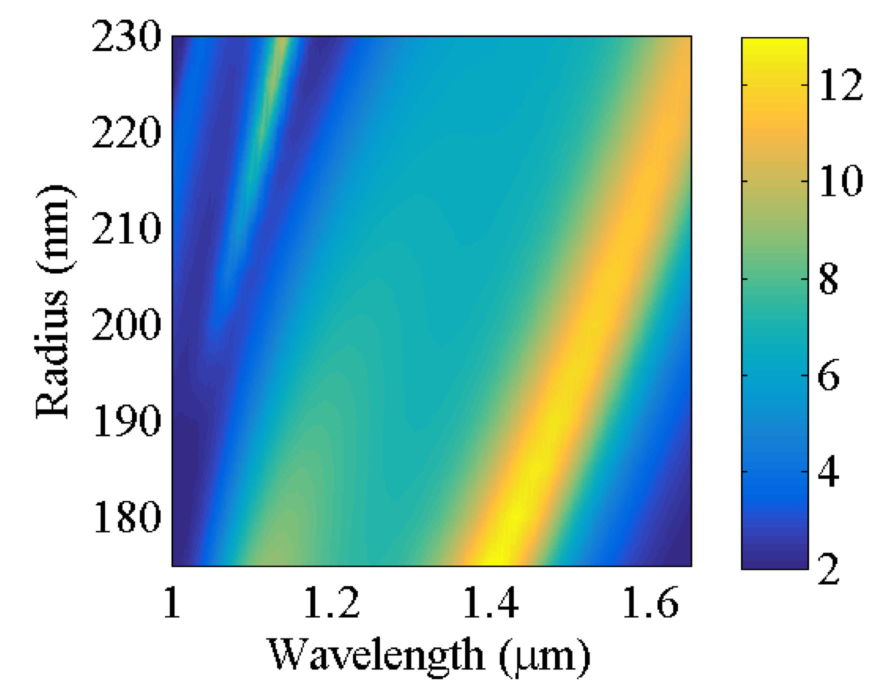


Fig. 2. Scattering efficiency at varying cylinder radius (h=400nm).

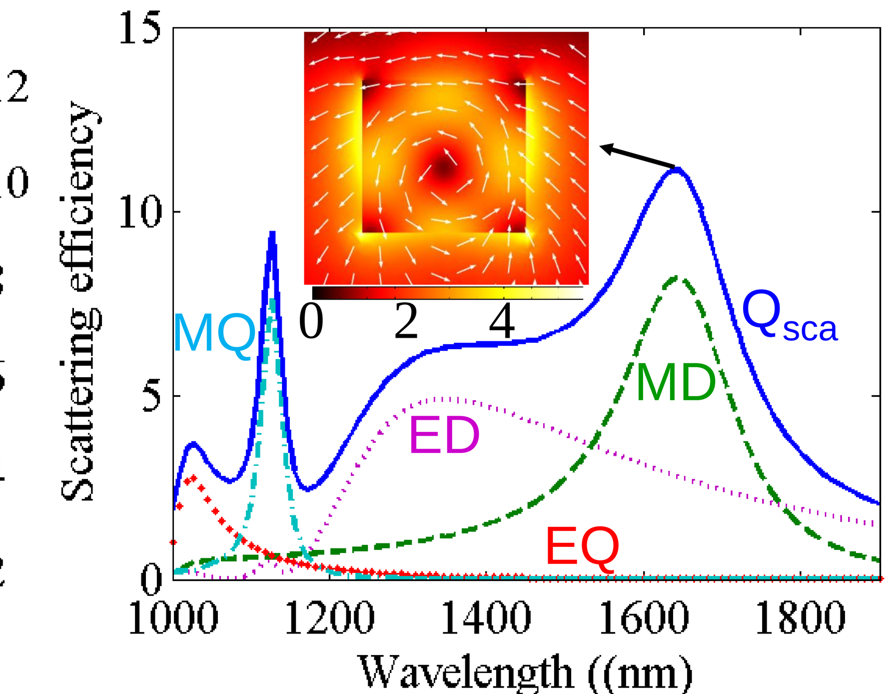


Fig. 3. Scattering efficiency for r=225nm and h=400nm with multipolar expansion.

Second Harmonic Generation:

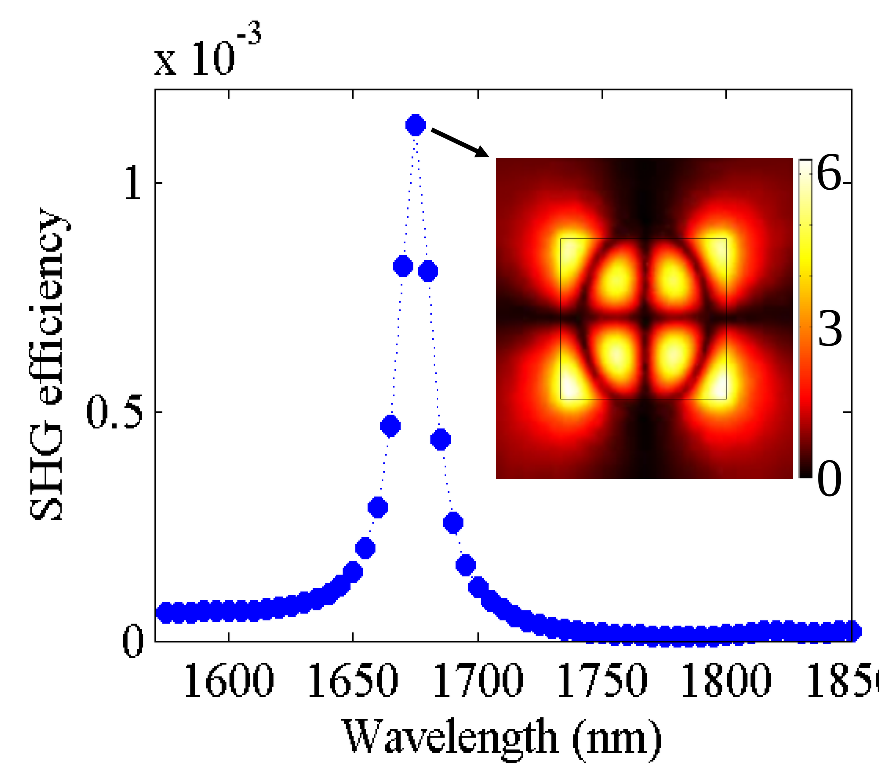


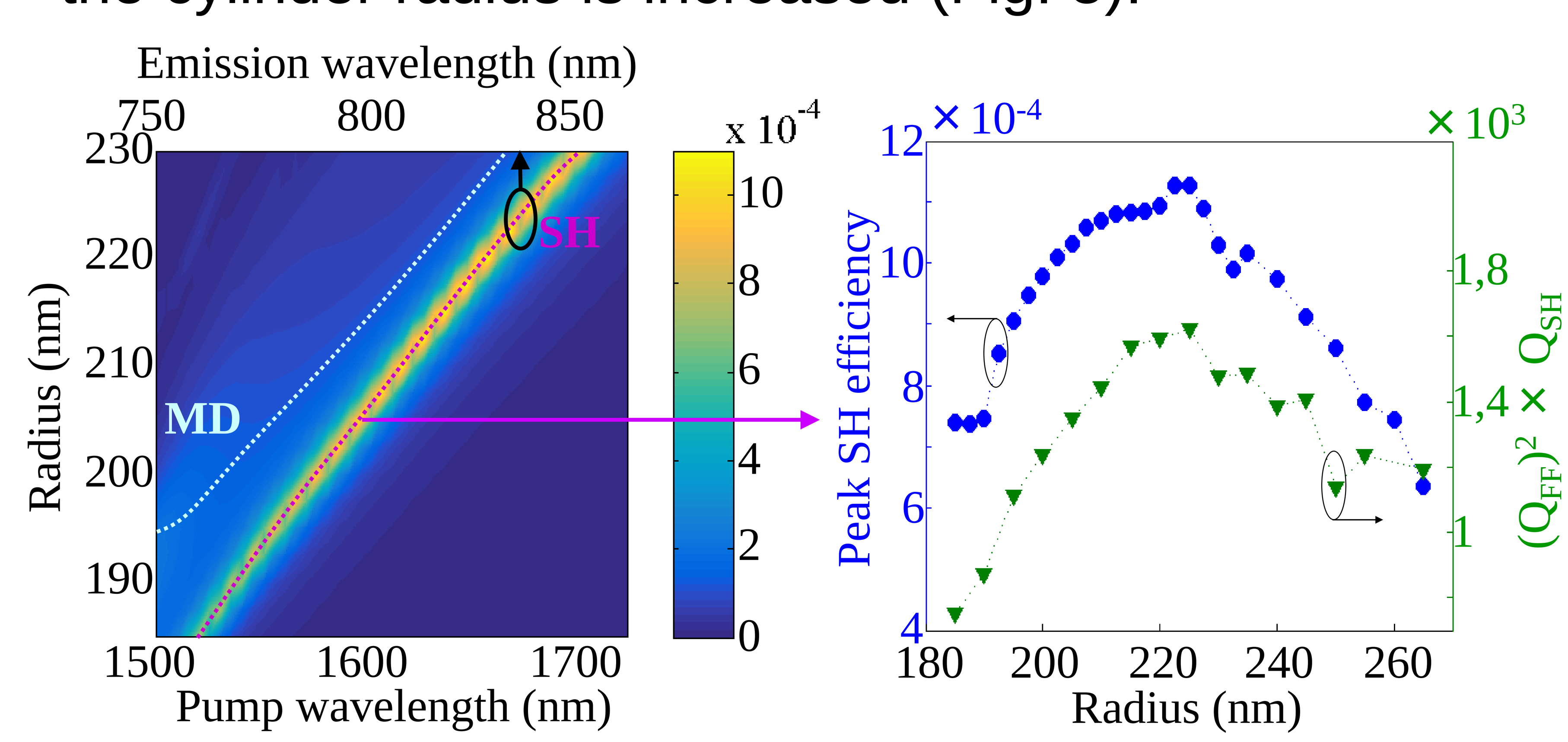
Fig. 4. SHG efficiency versus pump wavelength using pump intensity I_0=1GW/cm^2.

The SHG efficiency

$$\eta_{SHG} = \frac{\int_A \vec{S}_{SH} \cdot n\, da}{I_0 \times \pi r^2}$$

is maximum for a pump wavelength of λ=1675 nm (Fig. 4). This is due to a mode at the SH wavelength with good spatial overlap with the pump mode.

The peak wavelength of SHG efficiency red-shifts as the cylinder radius is increased (Fig. 5).



Fig, 5. SHG efficiency versus pump wavelength and nanodisk radius

Conclusions: We reported the design of AlGaAs nanoantennas with a SHG efficiency larger than 10^{-3} from a single nanodisk.

References:

1. J. Schuller et al, "General properties of dielectric optical antennas," Opt. Express 17, 24048 (2012)
2. L. Carletti et al, "Enhanced second-harmonic generation from magnetic resonance in AlGaAs nanoantennas", Opt. Express (in press)
3. P. Grahn et al, "Electromagnetic multipole theory for optical nanomaterials", New Journal of Physics 14, 093033 (2012)