Efficient directed scattering of XUV radiation using high-density spherical clusters

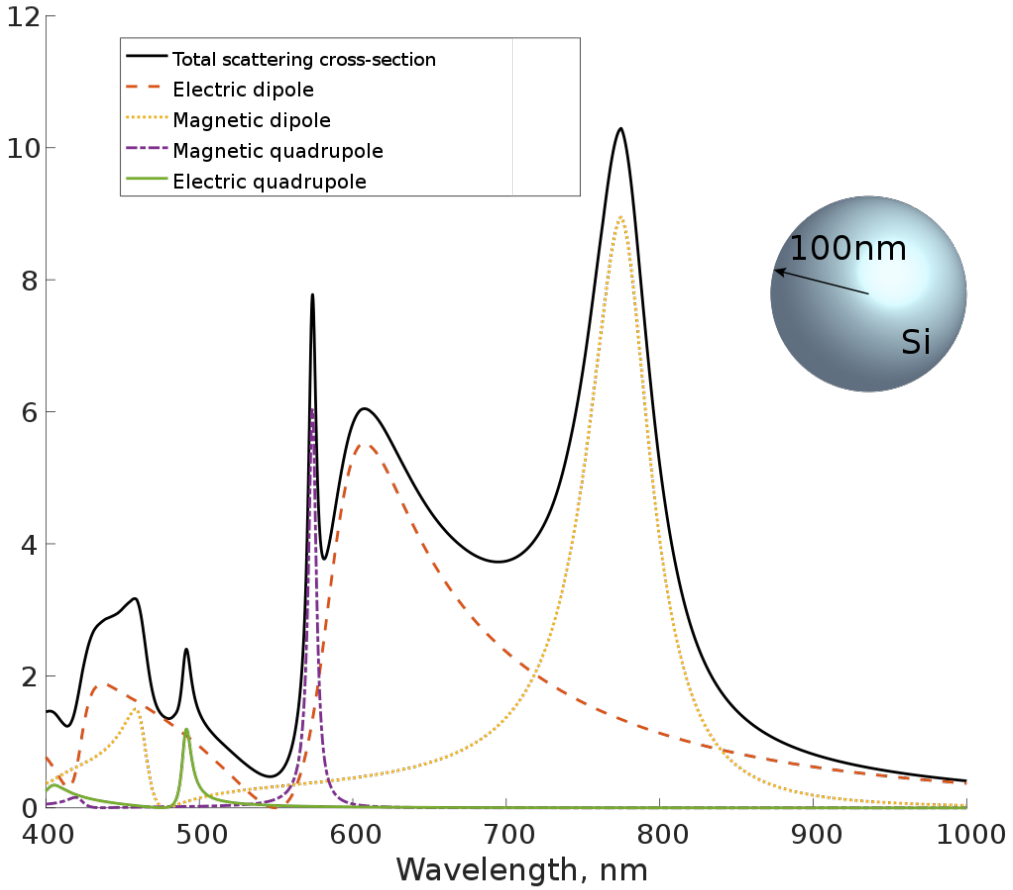
L.A. Litvinov, A.A. Andreev

December 27, 2021

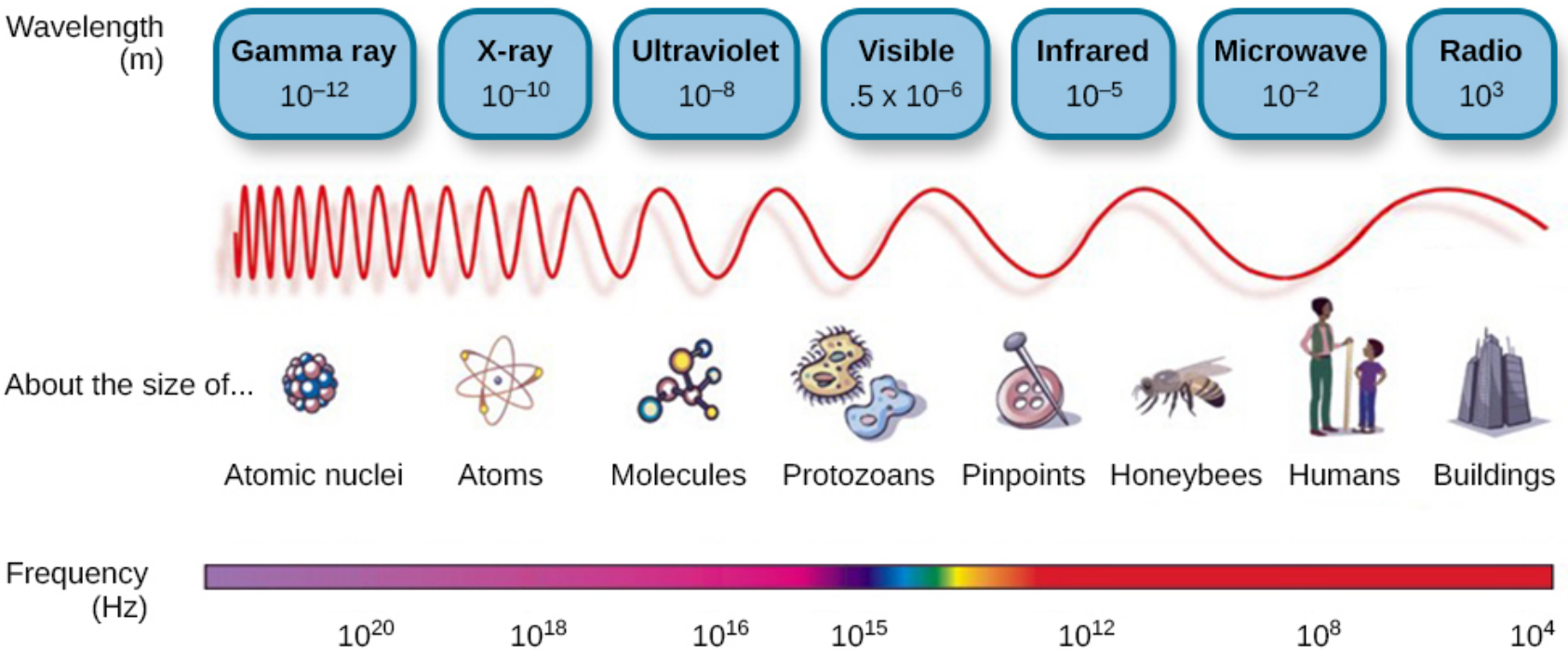
Department of General Physics I
Saint Petersburg State University

Introduction

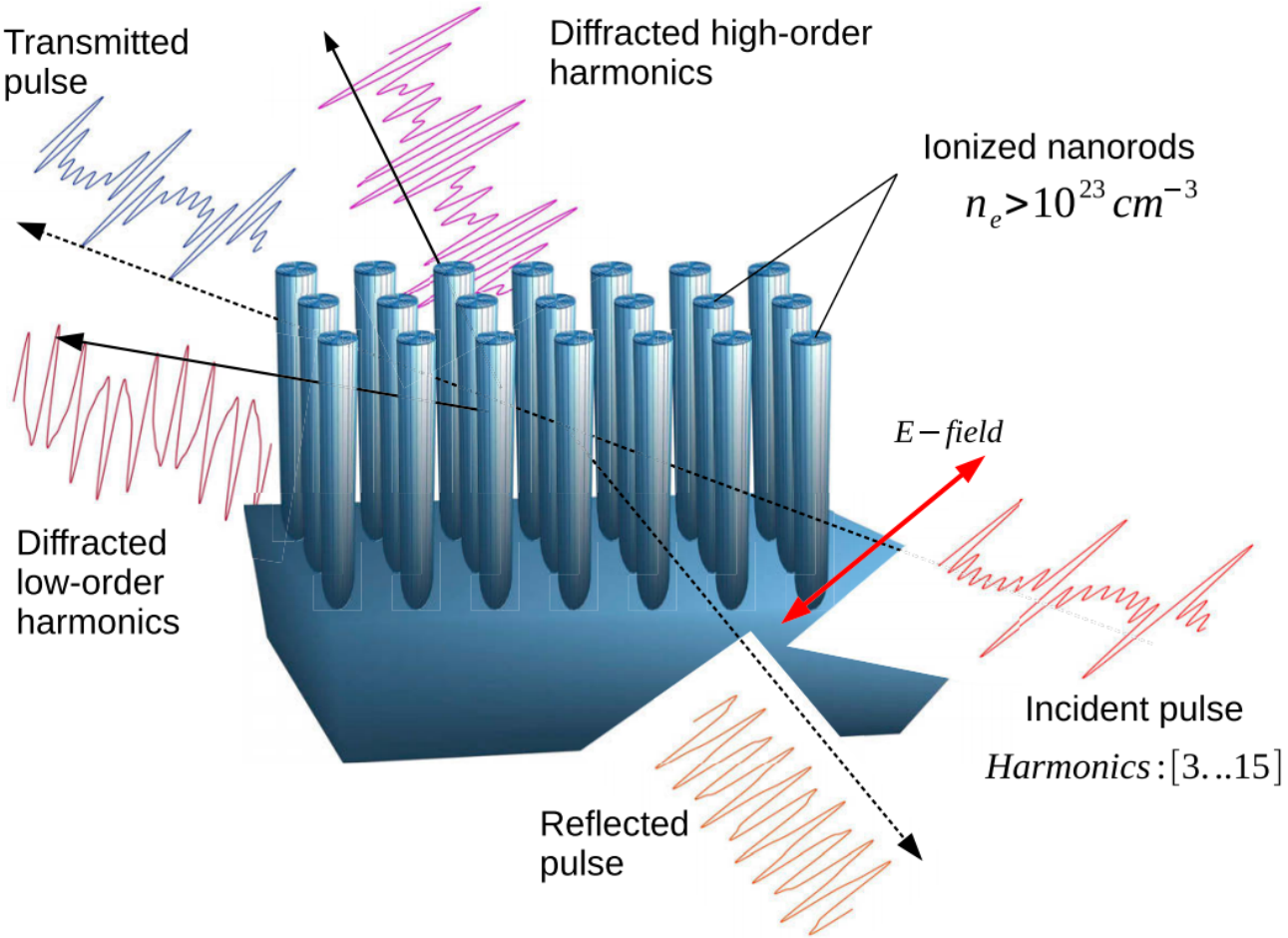
Mie theory


Total scattering cross-section
Electric dipole
Magnetic dipole
Magnetic quadrupole
Electric quadrupole
100nm
Si
12
10
8
6
4
2
0
400
500
600
700
800
900
1000
Wavelength, nm

XUV wavelength range



Spherical vs cylindrical



Ionized cluster gas

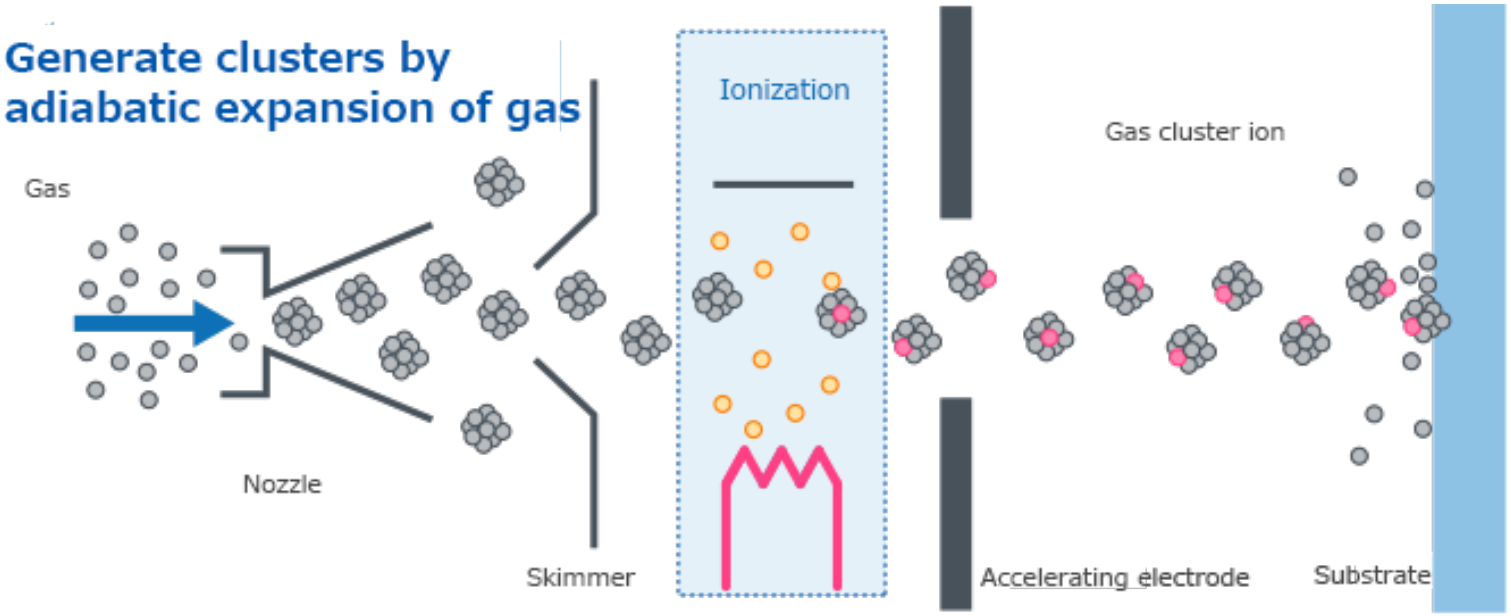


Figure 1: Ionized cluster gas generation process.

Interaction scheme

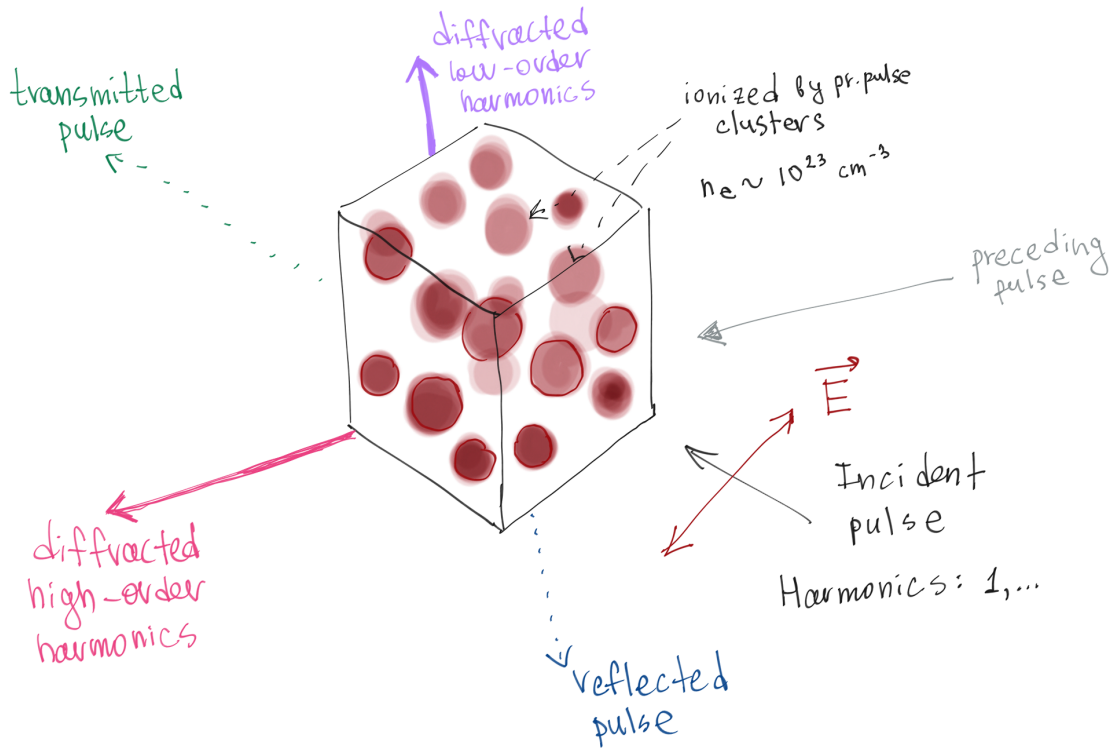


Figure 2: The plane of polarization is parallel to one of the faces of cubic region. The dimensions of spherical clusters are about a few nanometers, distance between them is at least wavelength. In general, the distribution of clusters within a cubic region is arbitrary without intersections.

Base model

Base model scheme

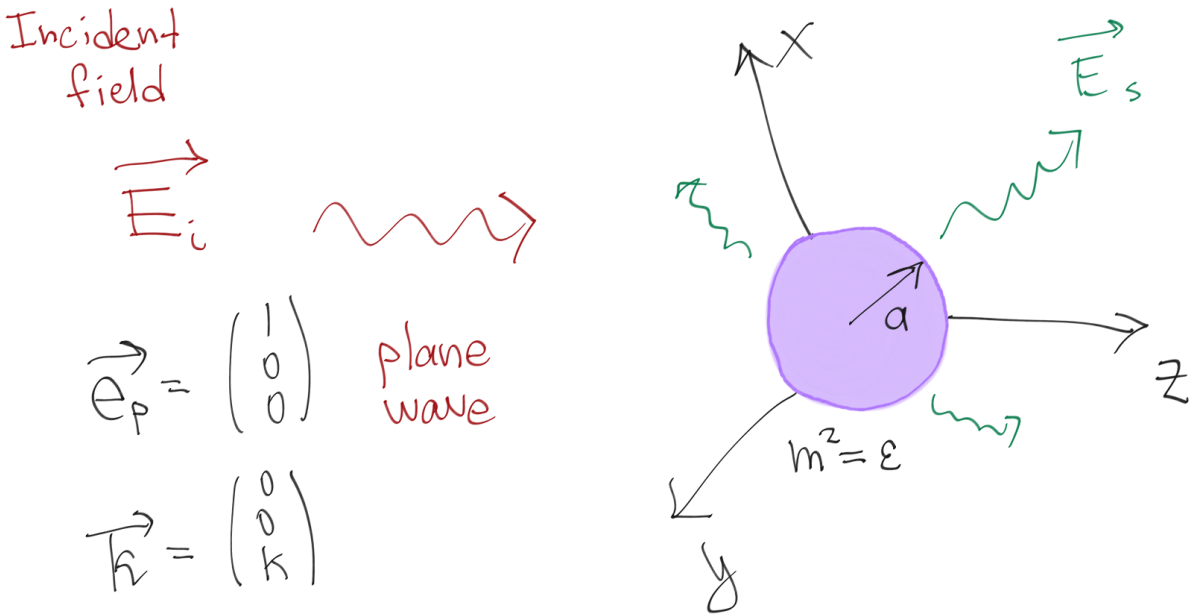


Figure 3: Base model scheme.

Zero-order approximation

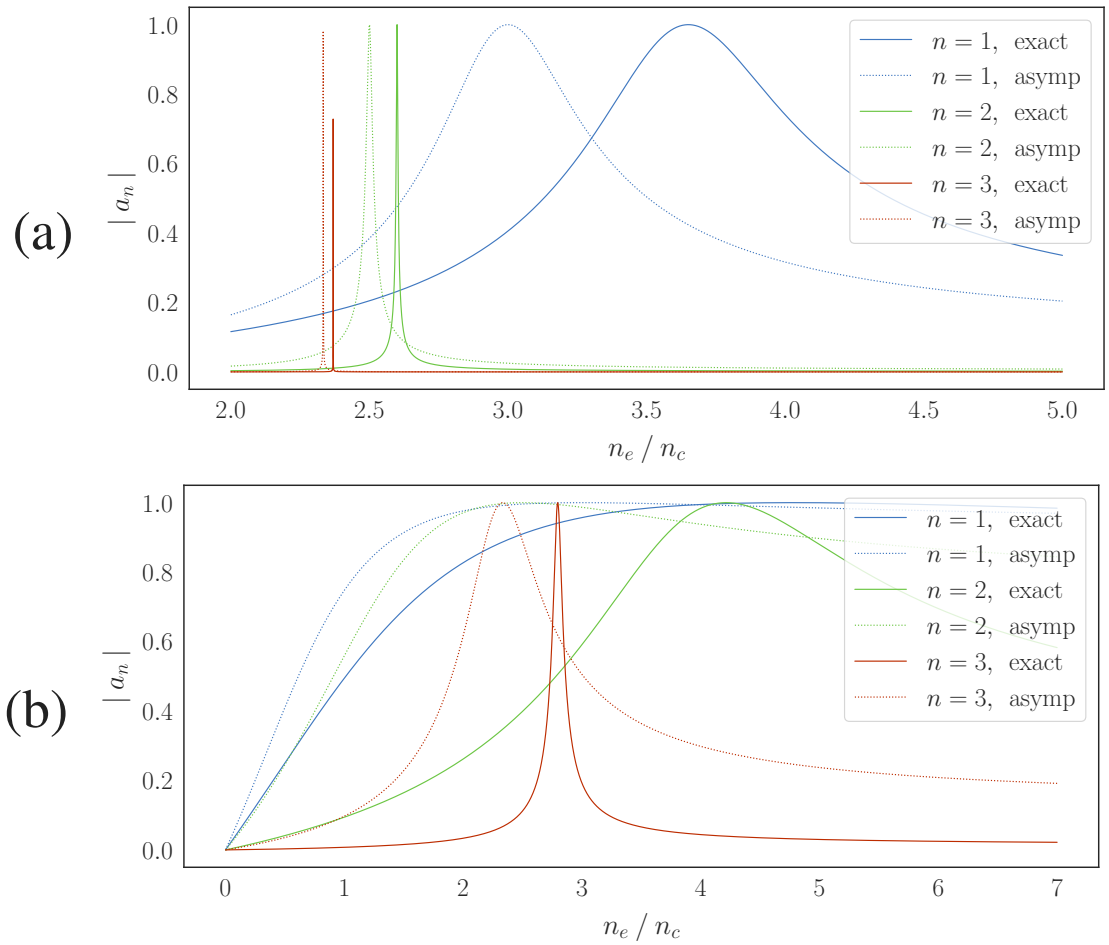


Figure 4: Spherical harmonics coefficients. $ka = 0.5$ (a), $ka = 1.5$ (b) in zero-order approximation, $\beta_e = 0$.

First-order approximation

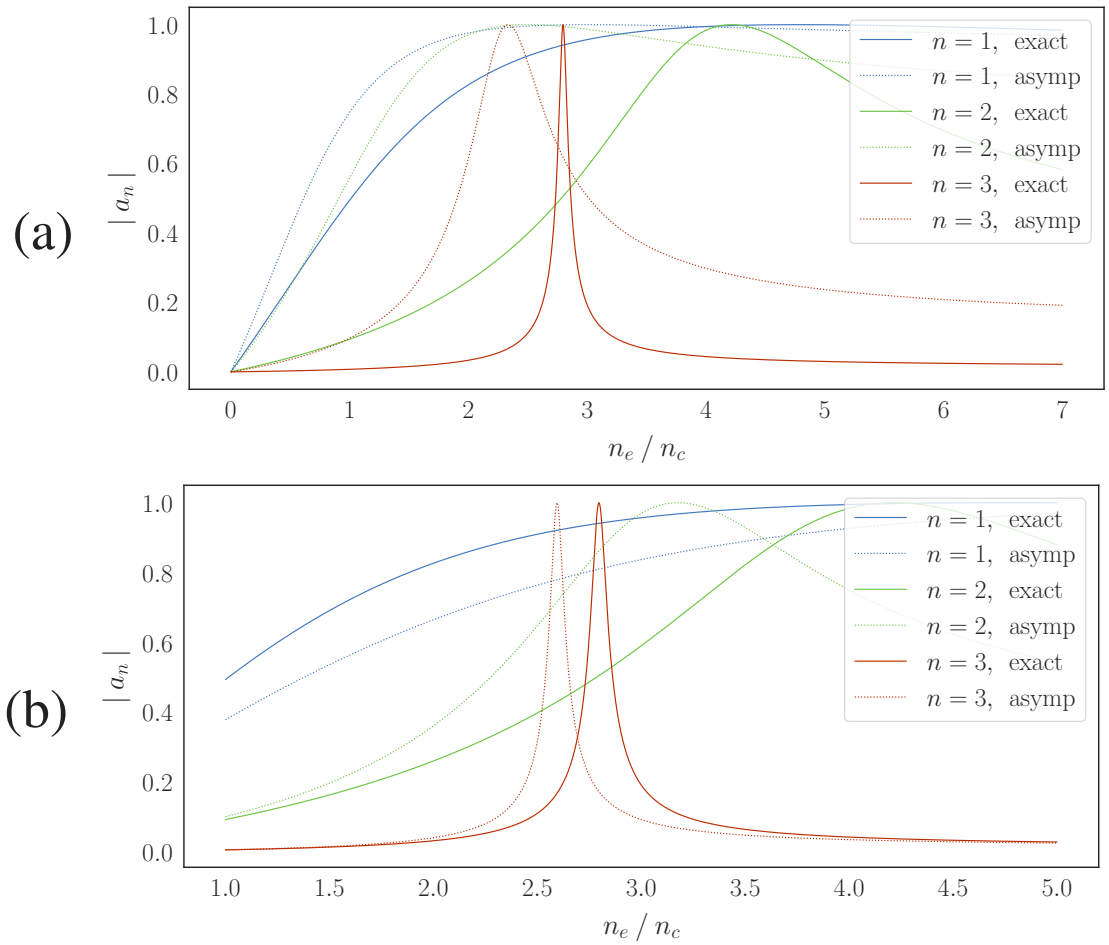


Figure 5: Spherical harmonics coefficients. $ka = 1.5$, (a) — in zero-order approximation, (b) — in first-order approximation, $\beta_e = 0$.

Resonance electron density

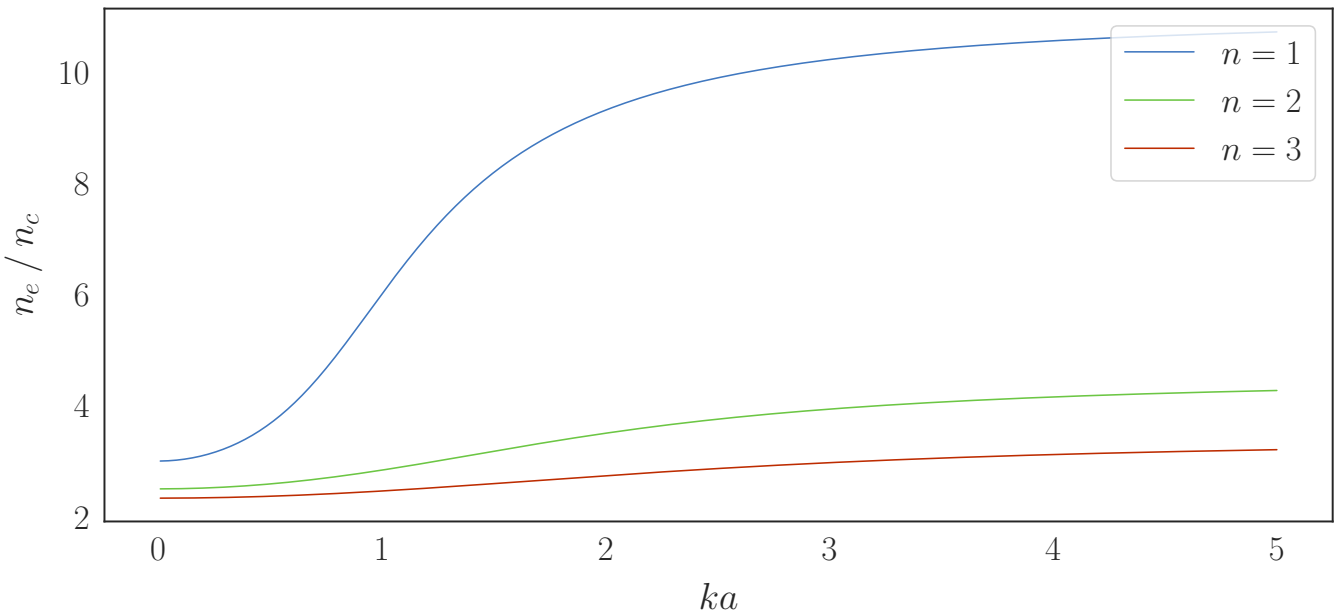


Figure 6: Resonance electron density depending on radius. Curves were calculated for resonant m values, $\beta_e = 0$.

Single cluster

Considered cases

- $\lambda = \lambda_L = 830$ nm, $\lambda = \lambda_{10} = 83$ nm;
- $ka = 0.5, 0.7 \Rightarrow m_{0.5} = 1.635i$, $m_{0.7} = 1.851i$.

$ka = 0.5 \ (a \approx 6.4 \ nm); \ \lambda = \lambda_L = 830 \ nm$

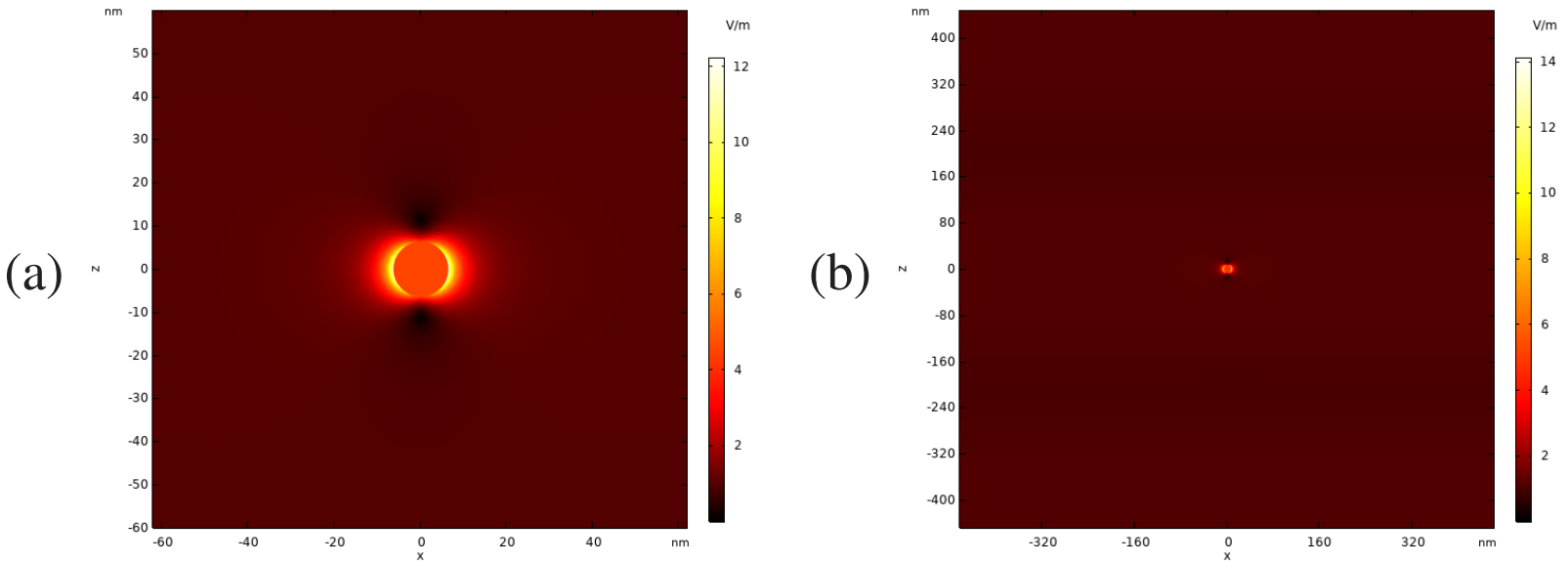


Figure 7: Laser harmonic scattering by a single cluster. $|\vec{\mathbf{E}}|$ plotted in the plane of polarization, near-field (a) and far-field (b).

$ka = 0.5 \ (a \approx 6.4 \ nm); \ \lambda = \lambda_{10} = 83 \ nm$

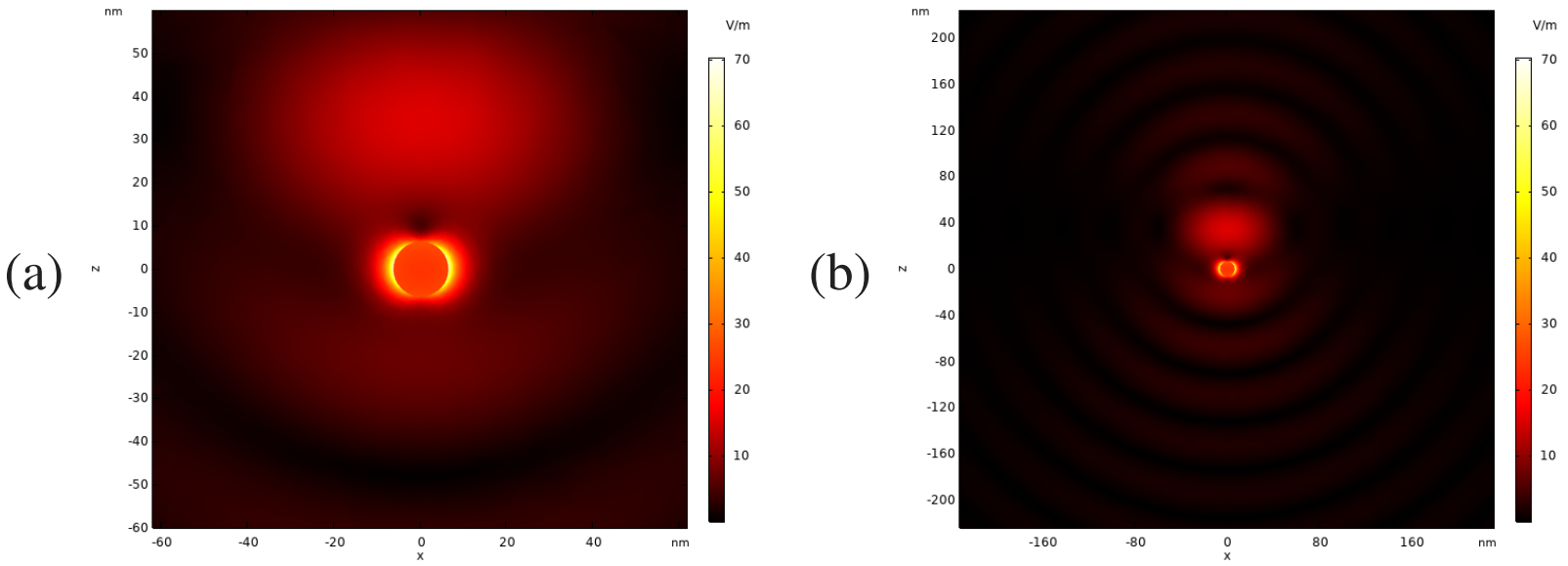


Figure 8: 10-th harmonic scattering by a single cluster. $|\vec{\mathbf{E}}|$ plotted in the plane of polarization, near-field (a) and far-field (b).

$ka = 0.7 \ (a \approx 8.9 \ nm); \ \lambda = \lambda_L = 830 \ nm$

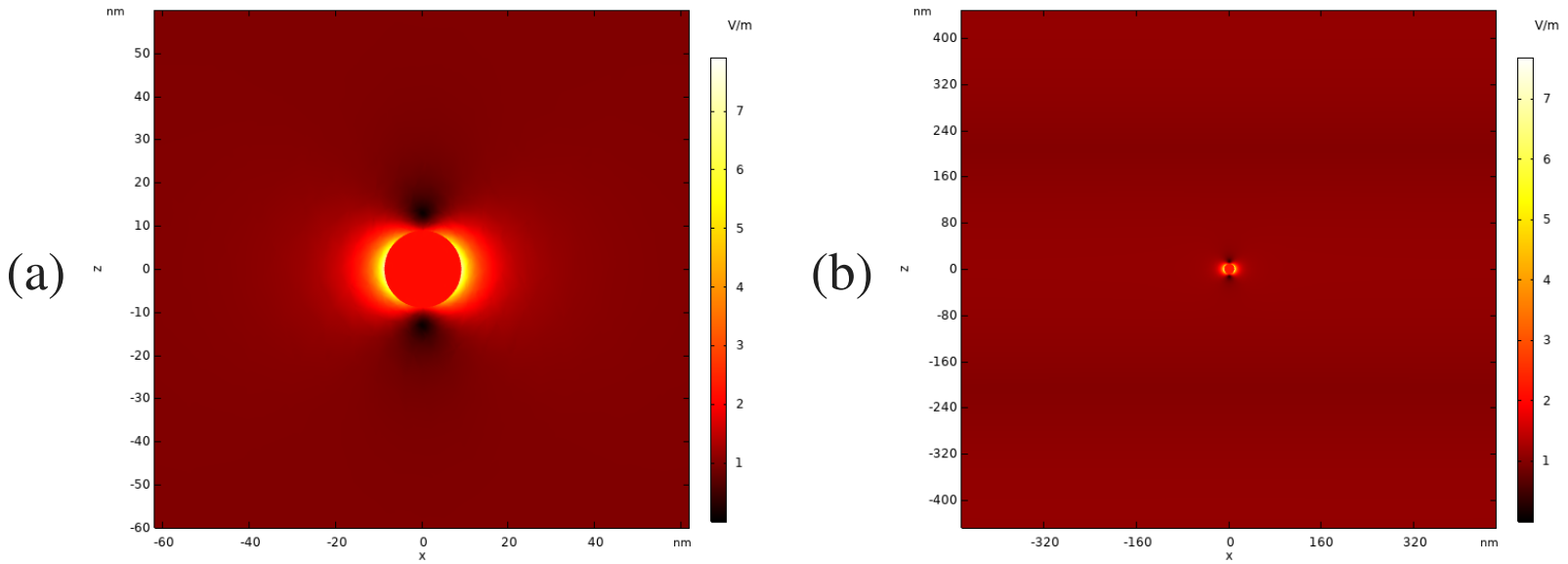
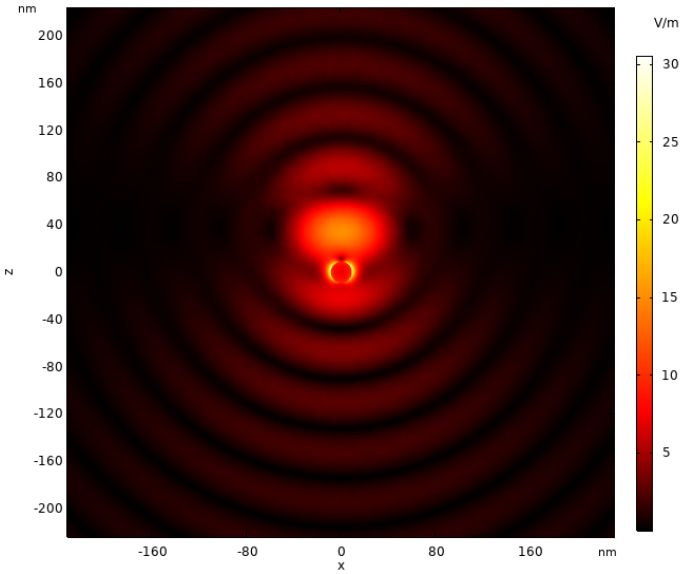


Figure 9: Laser harmonic scattering by a single cluster. $|\vec{\mathbf{E}}|$ plotted in the plane of polarization, near-field (a) and far-field (b).

$ka = 0.7 \ \ (a \approx 8.9 \ nm); \ \ \lambda = \lambda_{10} = 83 \ nm$

(a)



(b)

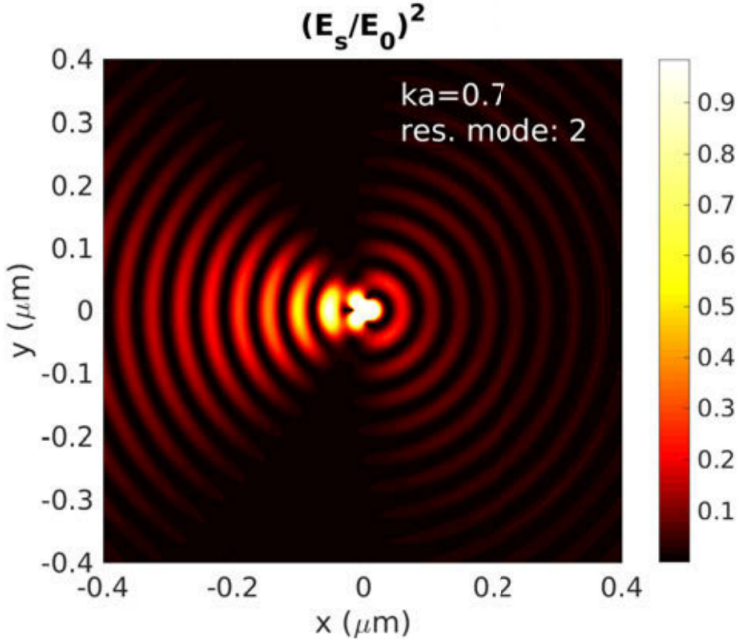


Figure 10: 10-th harmonic scattering by a single cluster. $\lambda = \lambda_L$, $a \approx 8.9$ nm ($ka = 0.5$); $|\vec{\mathbf{E}}|$ plotted in the plane of polarization far-field (a). For qualitative assessment field scattered by a single nanocylinder with the same ka added (b) — here the incident wave propagates from right to left (along negative x axis direction), polarization is along y axis.

Multiple clusters

Configuration

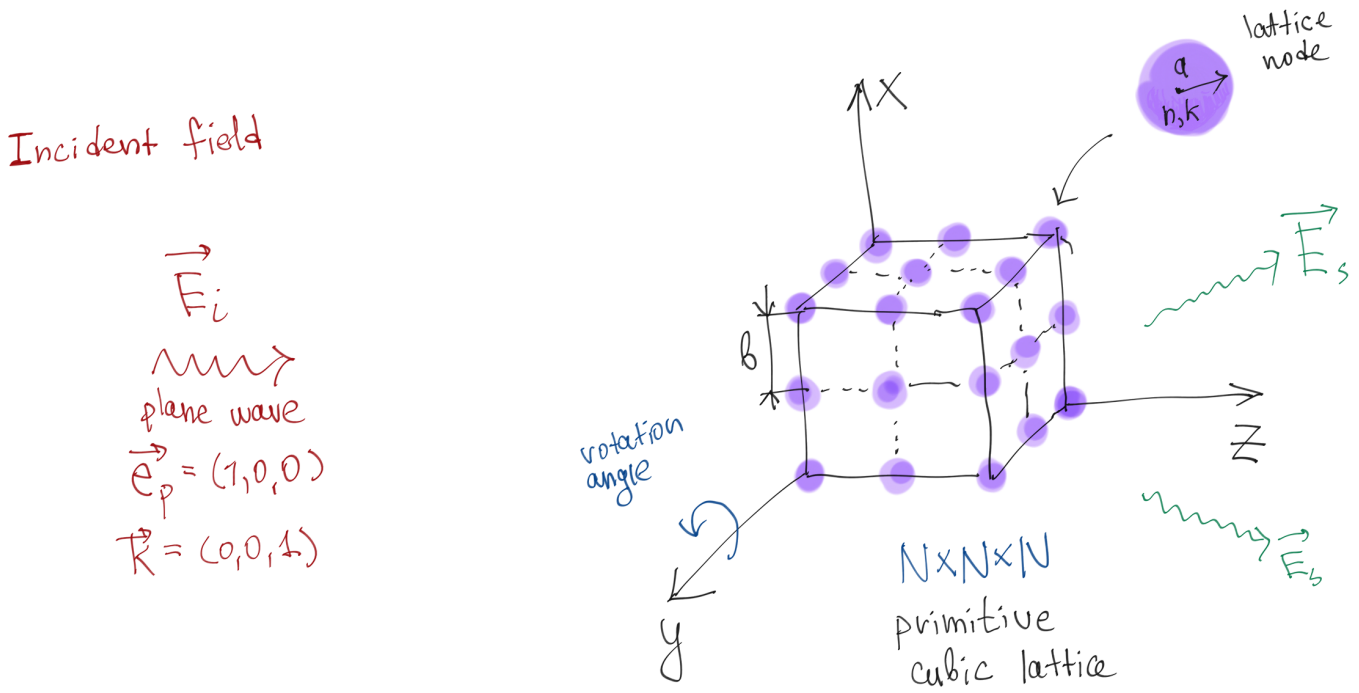
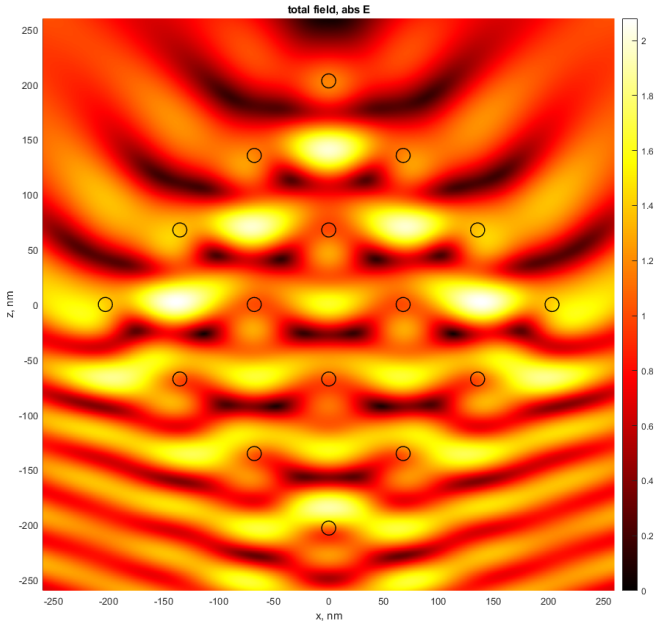


Figure 11: Model scheme, generalized target geometry.

$ka = 0.5 \ (a \approx 6.4 \ nm); \ \lambda = \lambda_{10} = 83 \ nm, \ b = \lambda_{10}$

(a)



(b)

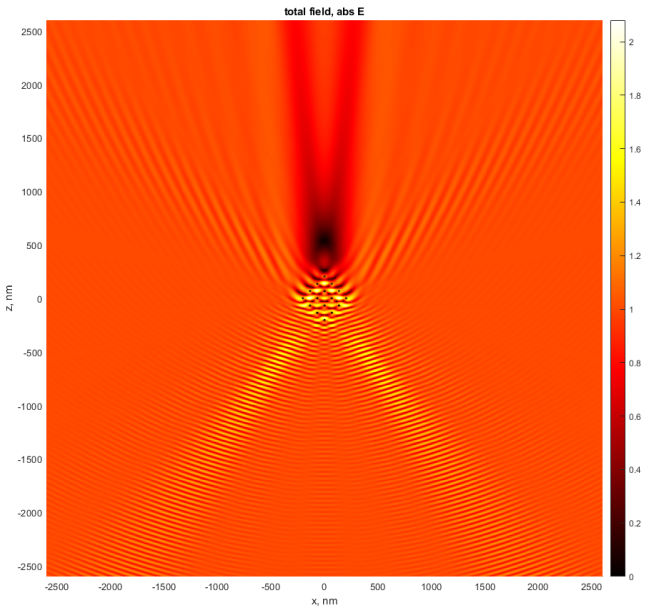
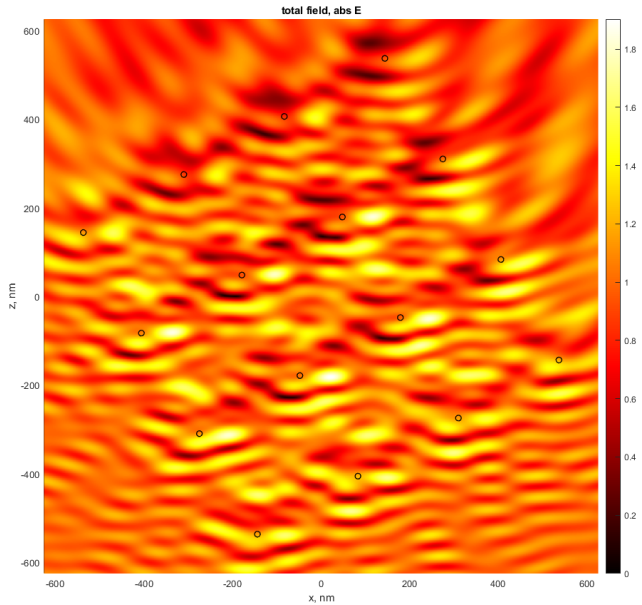


Figure 12: 10-th harmonic scattering by multiple clusters. Incidence at 45° angle; a — near-field; b — far-field.

$ka = 0.5 \ (a \approx 6.4 \ nm); \ \lambda = \lambda_{10} = 83 \ nm, \ b = 3\lambda_{10}$

(a)



(b)

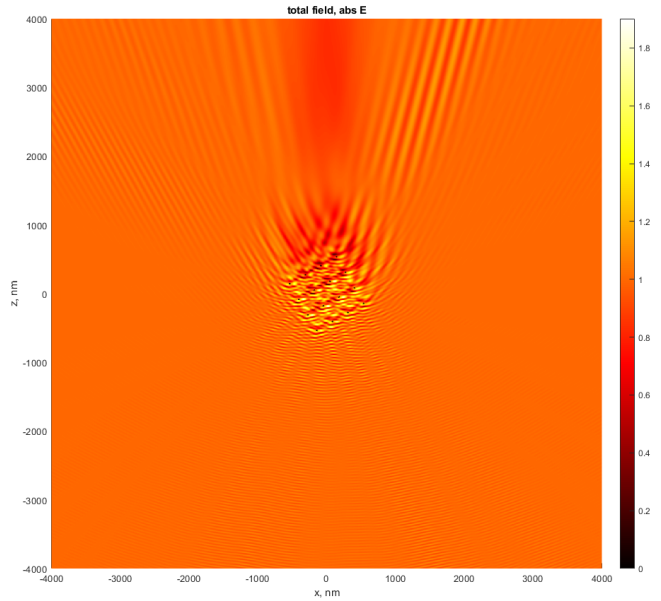


Figure 13: 10-th harmonic scattering by multiple clusters. Incidence at 30° angle; a — near-field; b — far-field.

Thanks for your attention