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Modification of Point-Spread Function in Confocal Microscopy by Nonlinear Plasmonic Light Scattering

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Recently, we reported that the localized surface plasmon resonance (LSPR) could strongly affect to the nonlinear light scattering from a single gold nanoparticle. The saturation and reverse satiation effect of light scattering were observed under the laser irradiation at the resonance [1, 2], but not under the off-resonance conditions.

In this study, we have investigated the modification of point-spread function (PSF) in confocal microscopy induced by saturation and reverse saturation of the light scattering from a gold nanoparticle. We observed gold nanoparticles immobilized on a glass cover slip with different excitation intensities to obtain the relationship between the excitation intensity and the shape of PSF.

Fig.1 shows the images of single gold nanoparticles acquired with three different excitation intensities [2]. With the low excitation intensity (Fig.1a), the each particle image fits well to Gaussian, so no obvious saturation effect is seen with this excitation condition. With increasing the excitation intensity, the particle image shows a dip at the center (Fig.1b). With further increase of the excitation intensity, the center of the image rises up again and the size of the image becomes smaller than that with the low excitation intensity (Fig.1c).

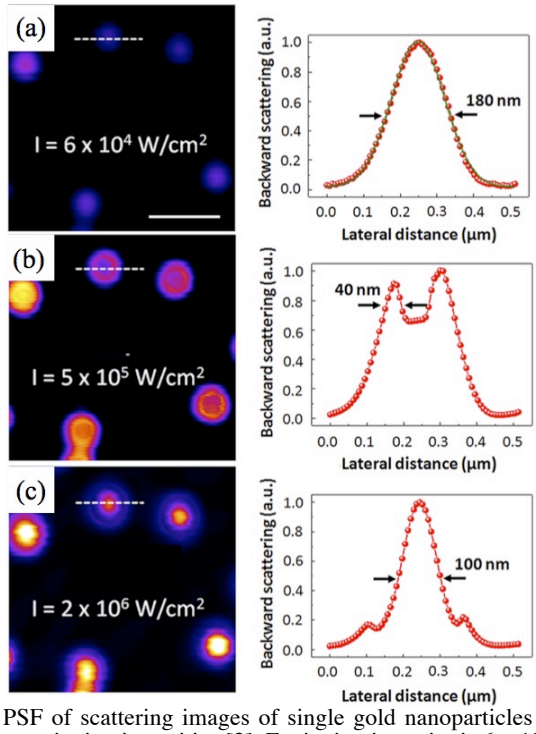

Fig.1 PSF of scattering images of single gold nanoparticles with various excitation intensities [2]. Excitation intensity is 6 x 10^4 (a), 5 x 10^5 (b) and 2 x 10^6 W/cm^2 (c). Green line shows a Gaussian profile. I: excitation intensity. Scale bar: 500 nm.

To confirm the relationship between The shape of the particle images and the nonlinear scattering response, we plotted the scattering intensity at the center of a gold nanoparticle with various excitation intensities as shown in Fig.2 [2]. The excitation intensity of Fig.1b and Fig.1c correspond to the saturation region and reverse saturation region in the response curve, respectively, and this nonlinear response of the scattering affects strongly to the PSF of the confocal microscope.

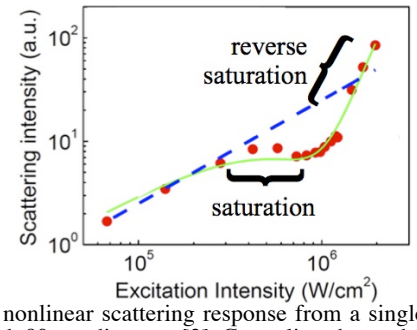

Fig.2 The nonlinear scattering response from a single gold nanoparticle with 80 nm diameter [2]. Green line shows the polynomial fitting.

Since the results shown above are the sum of the linear and nonlinear scattering, we extracted only the nonlinear components by the harmonic demodulation technique [3] to emphasize the contribution of higher-order nonlinear responses to the point-spread function of the microscope [4]. As the result, we observed that the harmonic signal by the nonlinearity is strongly appeared at the center of the PSF when the excitation intensity was in the saturation region. With the further increase of the excitation intensity, the harmonic signal at the center was decreased and appeared in peripheral predominantly. The behaviors can be used for the further increase of the spatial resolution of confocal microscopy.

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