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Photothermal Method for Single Nanoparticle Detection Using Single Element Interferometer

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1. Introduction

Recently there has been considerable interest in metal nanoparticles which are less than a few ten nanometers as labels for biomolecule detection in the field of molecular biology [1]. However, it is difficult to detect weak scattering light from nanoparticles with an optical microscope. To overcome this problem, a detection method for nanoparticles magnified lager than diffraction limit in diameter by using photothermal effect with local surface plasmon resonance (LSPR) has been developed. To detect minimal phase shift around nanoparticles by photothermal effect, a single element interferometer using a beam splitter cube has been developed. This paper reports the phase shift by the photothermal effect and LSPR of metal nanoparticles has been observed by the single element interferometer.

2. Nanoparticle detection principle by the photothermal effect and the LSPR

Fig. 1 shows the magnifying process of metal nanoparticles by the photothermal effect. The photothermal effect is an effect that an excited material transforms light energy to thermal energy. In Fig. 1(a), nanoparticles are dispersed in the solvent. Then the absorption of excitation light by nanoparticles leads to a rise in temperature of nanoparticles by the photothermal effect as shown in Fig. 1(b) and (c). Metal nanoparticles shows strong absorption at certain wavelength region by the LSPR. Therefore, irradiating excitation light at appropriate wavelength, the temperatures of the nanoparticles rise efficiently. After that, since the heat diffuses to the solvent, the refractive index around the nanoparticles is shifted as shown Fig. 1(d). Detecting variation in the refractive index produced by the photothermal effect, a magnified image of nanoparticles can be obtained.

Fig. 2 shows the single element interferometer to detect refractive index shift by the photothermal effect. The half of the detection beam incidents on a sample. The sample is irradiated by an excitation light source for the photothermal effect. The detection light after transmitting the sample incidents a beam splitter cube set at 45 degrees to optical axis. The detection light is split into an object light and a reference light in the beam splitter cube. The object light and the reference light are superimposed in the beam splitter cube. Then the refractive index distribution is obtained by analyzing the phase of interference light.

3. Detection of carbon microparticle and gold nanoparticles

Fig. 3 shows the photothermal image of a carbon microparticle and the phase shift by photothermal effect of gold nanoparticles dispersed in the water. A moving carbon microparticle with 5.5 μm in diameter dispersed in the water was detected as shown in Fig. 3 (a). Fig. 3 (b) shows phase shift by the photothermal effect of gold nanoparticles with 21 nm in diameter with two different excitation light sources. The green and red dots were obtained by Nd: YVO_4 laser at 532 nm and laser diode at 808 nm respectively. The power density of the Nd: YVO_4 laser was 4 times smaller than the LD. However, the phase shift by irradiation of Nd: YVO_4 laser was almost 50 times larger. Therefore, the absorption of gold nanoparticles by LSPR has been observed.

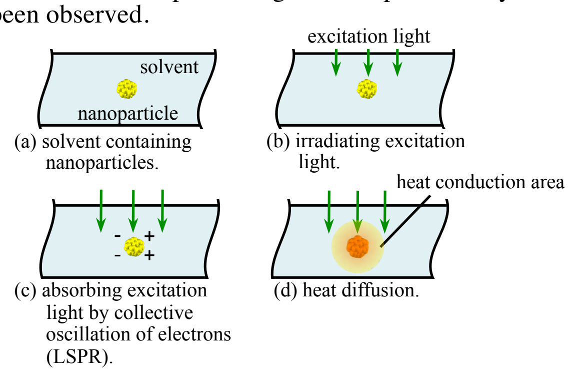

Fig. 1 Visible process of metal nanoparticle by photothermal effect.

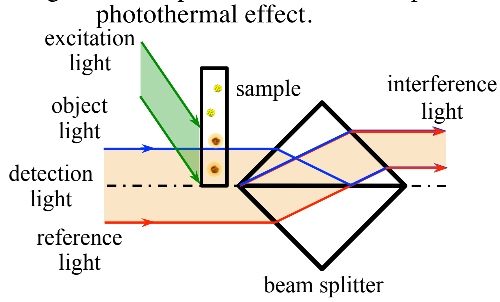

Fig. 2 Detection principle of nano particles using single element interferometer.

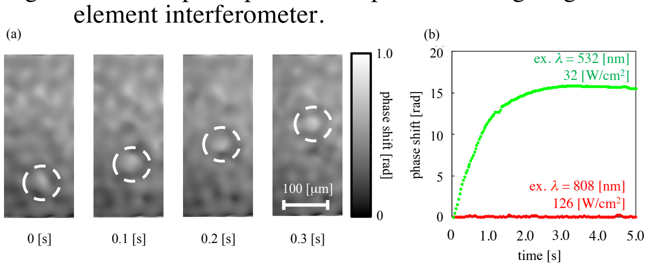

Fig. 3 Photothermal image of microparticle and phase shift by photothermal effect of nanoparticles in water. (a)phase image of moving carbon microparticle with 5.5 μm diameter in water, (b) phase shift by absorption gold nanoparticles with 21 nm diameter.

4. Conclusion

The photothermal imaging system for single nanoparticle has been developed. In this paper, the absorption of gold nanoparticles by LSPR was observed. To detect single nanoparticle image, a higher magnification and NA of the imaging system is necessary. Therefore, the single element interferometer will be constructed in infinity corrected microscope system.

References

[1] D. Boyer et. al., Science **297** (2002) 1160.