Active polarization dependant probe excited under two-photon excitation in a micro-cavity

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ABSTRACT

In this paper we present two-photon excitation of MDR within a doped polymer micro-sphere. Two-photon technology can be used to induce localized physical change in materials. Due to the highly localized nature of two-photon excitation, the induction of MDR into a micro-cavity can be tightly controlled. A clear and easy separation of excitation and resonant wavelengths is inherent under two-photon excitation. It is shown that the adjacent MDR peaks have orthogonal polarized components, and can be controlled by the position of an excitation spot in a micro-sphere. It is also demonstrated that the micro-cavity MDR peaks have a good agreement with Mie scattering theory.

1. MDR UNDER TWO-PHOTON EXCITATION

Total internal reflection (TIR) microscopy has become increasingly popular for biological study because of its ability to achieve resolution beyond diffraction limit. Recently, using a laser trapped micro-bead as a near-field probe has proven its advantages over metallic or fibre probes, since the difficulties involving controlling distance between near-field probes and the sample surface do not exist under this arrangement. In addition, a trapped micro-sphere can be turned into an active probe by inducing micro-cavity effect within it. A dielectric sphere possesses natural internal modes of oscillation at characteristic frequencies corresponding to specific ratios of size to wavelength. These modes of oscillation are called morphology dependant resonance (MDR). MDR has been induced in micro-cavities via evanescent coupling from optical fibers, directly within laser-trapped micro-droplets and liquid dye-filled beads. MDR induction to date has been limited due to difficulties in separation of excitation and resonant wavelengths and the inability to confine excitation illumination precisely.

In order to overcome this problem, we use an ultra-fast femtosecond laser (Spectraphysics MaiTai) as the illumination source, whose high peak power allows the induction of two-photon excitation in a micro-sphere. Therefore the excitation and resonant wavelengths can be easily separated. Because of the intrinsic optical sectioning property of two-photon excitation, highly localized excitation in a three-dimensional space can be achieved within a trapped micro-sphere. This provides us the advantage of studying MDR effect at different illumination spots in a micro-sphere rather than the averaged MDR effect.

In Fig. 1, the fluorescence spectrums at different excitation spots in an equatorial plane of a micro-sphere are illustrated. It is shown that the spectrums at points A and B are significantly different; however the spectra at...
points A and C are quite similar. Since point B has 90 degrees difference with respect to points A and C in terms of the azimuth angle, this may be an indication that the MDR peaks are polarization dependent. Since the laser source is linearly polarized, the polarization states respected to the interface of a micro-sphere at points A and B are different. In order to verify this finding, we introduce a polarization analyzer to check the polarization dependence of the fluorescence spectrum at a given point in the equatorial plane. In Fig. 2, the fluorescence spectrums detected with different analyzer orientations are shown. It is noted that two adjacent peaks, which are respectively denoted by solid and dash arrows, changes with the orientation of the polarization analyzer. This experiment confirms that the MDR peaks are polarization-dependant and the two adjacent peaks have orthogonal polarization states, which represent TE and TM modes respectively.

![Fluorescence spectra detected with different analyzer orientations: (a) 0 degree; (b) 90 degree; (c) 180 degree.](image)

2. SUMMARY

Two-photon excitation provides a unique tool to study MDR effects in a micro-sphere. The induction of MDR can be tightly controlled under two-photon excitation, which leads to the capability of studying MDR beyond an averaged effect. It is shown that the adjacent MDR peaks have orthogonal polarized components, and can be controlled by the position of an excitation spot in a micro-sphere. In addition, a clear and easy separation of excitation and resonant wavelengths is inherent under two-photon excitation.

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