Optical Trapping Dynamics of Glutamate Receptors in Cultured Neurons

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Neuronal networks in brain systems communicate through synaptic connections of each neuron. The distribution and density of neurotransmitter receptors in the brain play an important role in regulating the strength of synaptic transmission. For aiming artificial control of synaptic transmission in living neuronal networks, we have applied optical tweezers to manipulate intracellular synaptic vesicles and cell surface molecules [1]. Here, we demonstrate optical trapping of AMPA-type glutamate receptors (AMPA receptors (AMPARs)) which mediate fast excitatory neurotransmission. The optical trapping and assembling dynamics of AMPARs labeled with quantum dots (QDs) was evaluated by fluorescence imaging and fluorescence correlation spectroscopy (FCS).

Rat Hippocampal neurons were cultured on glass-bottomed dishes. When AMPARs on the cell surface were visualized by immunofluorescence staining using QDs, fluctuation of the fluorescence corresponding to lateral diffusion of AMPARs labeled with quantum dots was observed [2]. By focusing a 1064-nm YVO₄ laser into neuronal cell, the two-photon fluorescence intensity of QD-labeled AMPARs increased at the focal spot during the laser irradiation (Fig. 1(a−c)). The molecular dynamics of QD-labeled AMPARs in an optical trap was investigated by FCS. The autocorrelation function (ACF) curve of the fluorescence intensity at the focal spot had two components (fast and slow) from least-squares fitting. The ACF decay time in both fast and slow components increased with the trapping laser power (Fig. 1(d−e)). Since the optical trapping potential energy is proportional to the laser power and the polarizability of QD-labeled AMPARs, this result supports that the particle motion of QD-labeled AMPAR became slowly with the increase in trapping laser power. Conclusively, optical trapping induced particle assembly of QD-labeled AMPARs on cell surface of living neuronal cell.