The manipulation of intracellular assenblies of proteins by Terahertz wave irradiation

テラヘルツ光を利用した細胞内タンパク質構造体の操作

Dr. Shota Yamazaki

Special postdoctoral researcher

Terahertz Sensing and Imaging research team,
RIKEN Center for Advanced Photonics

Abstract

Because the frequency range of the terahertz (THz) band is three orders lower than that of visible light, irradiation of living cells with THz waves can induce different phenomena from those induced by optical lasers. The THz photon energy is insufficient to alter molecular structures, but can affect the intramolecular dynamics of macromolecules, such as protein complexes and cytoskeletal structures. To reveal the effect of THz irradiation on biological molecules, we focused on the morphology of actin proteins. Actin has two functional forms, actin monomer and polymerized actin filament. Recently, we discovered that THz irradiation changes the morphology of actin filaments in living cells.

In our previous study, we found that THz irradiation enhances the formation and stabilization of actin filaments in living cells. A significant increase in the number of actin filaments was observed in the cytoplasm of HeLa cells when irradiated with THz waves (0.4 THz, CW, peak power=0.6 W/cm^2). In this exposure condition, THz waves directly affect the dynamics of actin molecules and activate actin filamentation.

On the other hand, we also found that shockwaves were generated by irradiation of intense THz pulse (4 THz, pulse, peak power=16 MW/cm^2). The intense THz pulses are absorbed at the water surface and the energy concentration results in shockwave generation. Interestingly, the shockwaves propagate for a few millimeters in the aqueous medium, and disrupt the morphology of actin filaments in living cells. Our finding of the diametrically opposite effects of THz irradiation on actin filament suggests a novel possibility of artificial manipulation of biomolecules and living cells using THz waves.

Assemblies of actin filaments have pivotal roles in various cell functions, such as cell motility and division, and also determine the cell shape. Moreover, recent studies have revealed that actin filaments in the cell nucleus are required for transcriptional regulation, DNA repair, and gene reprogramming. Therefore, we propose that THz irradiation can be used for the optical manipulation of cellular functions via the modulation of actin dynamics, leading to a better understanding of the function of actin and to the development of new therapeutic strategies.

shota.yamazaki.fc@riken.jp