

Using Light to Attract

C. T. Chan *

Department of Physics, Hong Kong University of Science and Technology, Clear Water Bay, Hong Kong

Can a forward propagating light beam pull a particle backward? As a photon carries momentum, we expect that light should push any object standing in its path. Is it really possible to pull an object using a beam of light, as a “tractor beam” does in Sci-Fi fictions and movies? It turns out that for some special “non-diffraction beams”, the Poynting vector can be opposite to the k -vector, but we find that a reversed Poynting vector is by no means a sufficient condition for realizing an “attractive” photonic force. Our results indicate that using light to attract is very difficult, but not impossible and light can indeed attract an object if the object has some special properties. For example, non-diffracting beams can attract particles with simultaneous electric and magnetic responses. For dielectric particles, such attractive forces can only happen in the Mie regime. For metamaterial particles with both electric and magnetic resonances, it is possible to attract particles even in the Rayleigh regime. In addition, we would like to show that attractive light forces that are strong in magnitude with a reasonable power of the incident light can be achieved. One possible configuration is to use a near field approach and employ the evanescent field of a plasmonic excitation. For example, we can use light to excite the plasmonic resonance of a configuration that is the counterpart of high-impedance “meta”-surfaces. The attractive forces are strong for a modest incident laser power when the system is in resonance. Although this indirect attractive effect may not be as exotic as the demonstration of far field attractive light forces mentioned in the last section, this type of light induced plasmonic force may be strong enough to find applications in optical micro/nano-manipulation.

* Work supported by RGC Hong Kong, in collaboration with J. Ng, S.B. Wang, H. Liu, J. Chen, Z.F. Lin