Electromagnetic wave interaction with new emerging material

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My research interest is theoretical condensed matter physics combined with optics. By combining these two fields of science, the properties of light, such as how light propagates or how light is absorbed, can be controlled by merely controlling the material properties, such as the Fermi energy $E_F$ or dielectric constant of the material. By understanding light-matter interaction, it is possible to develop some optical devices. My first research is about the emergence of giant light absorption by graphene [APEX 8,055102 (2015), JPD: App. Phys. 49, 195306, (2016)]. Undoped graphene is known to only absorb 2.3% of incident light, however we found that a doped graphene monolayer and two (non-interacting) graphene monolayers can absorb 100% GHz and THz light by using special geometry called total internal reflection geometry. The absorption is also tunable by $E_F$, allowing us to design simple optical switches controlled by gate voltage. We collaborate with experimental lab in Rice Univ. to verify these findings of giant absorption of light [ACS Photonics 4-1, (2017)]. We also expand our findings to obtain large light absorption without the necessity of doping the graphene. We found that undoped monolayer graphene can absorb 50% incident light instead of 2.3%, if monolayer graphene is put inside special designed multilayer structure of dielectric material, which we call mirror structure. By designing the special thickness of each dielectric layer, the large absorption of light can be obtain for any frequency [App. Phys. Lett. 112, 073101, (2018)]. Interestingly, as we studied the properties of light propagation inside the multilayer structure of dielectric media (without graphene), we also found that the light transmission is not random, but following some rule, which comes from the existence of hidden symmetries of multilayer structure [J. Phys. Condens. Matter, 29, 455303, (2017)].

My other research is about the propagation of light on the surface of material known as surface wave. Electromagnetic (EM) wave can propagate on the surface of material, which is useful for application such as optical digital device. We investigate the surface EM wave with transverse electric polarization in graphene and silicene (Si monolayer). We found surface wave in silicene has wider frequency range than in graphene and tunable by external electric field $\Delta z$ and Fermi energy $E_F$. It is also more confined to surface and can travel more distance [App.Phys.Lett109, 063103 (2016)].

For my current research, I am trying to understand the quantum description of surface plasmon excitation by light, which is the collective oscillation of electron on the surface of material. We understand it by quantizing the surface plasmon and calculate the interaction between light and plasmon and comparing it with optical absorption spectra of the material, such as graphene. We believe that the absorption spectra can be separated into single particle contribution and surface plasmon contribution, which will give large light absorption.