Engineering optical fields in the far-field and near-field

Name: Ran Chen, Michael Cada, Yuan Ma
Dalhousie University

Abstract:

Engineering of complex optical fields has drawn tremendous amount of research interests in various fields of applications. High-resolution imaging, optical trapping, and particle manipulation are made possible by the laser beam shaping or the focusing field shaping technologies. Specially engineered optical fields enable researchers to better understand the biophysics and colloidal dynamics through trapping, guiding or patterning of molecules, cells, or Nano/micro particles. In this work, we investigate how different properties of light can be utilized to engineer the optical fields in both near-field and far-field. Specifically, we systematically study how the wavelength, the amplitude and phase distribution, and the states of polarization of light affect the focusing optical fields.

In the far-field, this research work mainly focuses on illumination beams with spatially variant states of polarization such as radially polarized mode or azimuthally polarized mode. Laser beams with cylindrical symmetry of spatially variant states of polarization are usually called cylindrical vector beams (CVBs) [1]. In this study, the focusing performance of radially polarized doughnut Gaussian (DG) beams and radially polarized Bessel–Gaussian (BG) beams in a high numerical aperture (NA) system are numerically investigated. Together with carefully designed spatial filters, it is possible to engineer the focusing fields and achieve unique properties for interesting applications. For example, an "optical tube" [2] with a long depth of focus and a long "optical chain" [3] with both high axial and high lateral resolutions were successfully obtained in the study. The research results were reported in publications. Potential applications of laser focusing in fields such as laser direct writing, super-resolution optical microscopy, as well as particle trapping, alignment, and transportation along the optical axis were enhanced or enabled by taking advantage of the special properties of these unique optical fields.

In the near-field, a highly localized optical field called photonic nanojet (PNJ) has been studied to achieve super-resolution imaging. PNJ emerges directly behind a dielectric microsphere when it is properly illuminated [4,5]. Individual spherical particle can confine light inside the cavity leading to strong resonant properties. It can also diffract incident beams and form a highly localized sub-diffraction-limited "hot spot" in the near-field. This effect can be exploited to perform super-resolution imaging and researchers believe that evanescent wave is the key in this phenomenon. The study results [6-8] show that the particle size, shape, and material can affect the quality of the obtained PNJs. In the meantime, the incident illumination conditions play an important role in engineering the PNJs. Therefore, different illumination states especially CVBs are thoroughly examined in this project.

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Biography:

Ran Chen is a PhD candidate in the Electrical & Computer Engineering department at Dalhousie University. His primary research interests are in the general areas of optics and photonics. Currently he is working on projects to achieve super-resolution in optical imaging utilizing carefully designed structures such as nanofabricated spatial filters or microspheres. When they are properly designed, these structures can achieve comprehensive spatial engineering of light wave properties such as polarization, intensity and phase in the far-field or near-field. These engineered optical fields can then be exploited in various applications including the development of super-resolution imaging capabilities, novel nanophotonic and plasmonic devices, particles and living cells manipulation tools etc. Aside from optics and photonics, his research interests also include machine learning, and lab-on-a-chip systems etc.