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Shaping the future of NanoBiophotonics: the application of novel light fields

Light is incredible. 2010 marked the fiftieth anniversary of the laser. Its impact has been immense across all of the Sciences with an array of ground-breaking studies. Laser light typically emanates in what is termed a standard Gaussian beam. As we explore light propagation we see this is a “basic” solution and indeed is the form of laser light most used today. However it is becoming critically apparent to a wide range of science that this basic form of light propagation is insufficient for numerous applications and indeed that our very understanding of the propagation and application of light needs to be re-addressed particularly for turbid or complex media. Very surprising and startling results are possible. By engineering and exploiting the phase and amplitude characteristics of light – optical sculpting – we may provide a major breakthrough of how light actually propagates in a variety of media. This will lead to us many exciting questions: how might we locally overcome the diffraction limit in the far field? How might we overcome the resolution criteria in focusing? How do we obtain an optimal beam for trapping in a turbid or complex media? How might we even explore ‘sub-diffractive’ nanosurgery or multiphoton imaging of cells and tissue?

In this talk, I will describe some recent work where we apply exquisite control over the phase and amplitude of light to yield some very surprising results. By performing *in situ* adaptive optics, optical trapping of nanoparticles and microparticles through highly turbulent media becomes a reality [1]. This opens up new vistas in precision measurements in complex media and potentially studies in vivo. Separately, cell transfection is an important area of ultrafast biophotonics. The application of such ultrashort pulses from a high repetition rate laser creates a low density free electron plasma that photochemically disrupts the cell membrane in a transient fashion. Excitingly the method allows transfer of macromolecules and drugs as well as nanoscopic particles into various cells and is an emergent area in Nanobiophotonics. I will describe the latest work in this field emphasising new physics of using both ‘non-diffracting’ light beams [2] and far-field ‘sub-diffraction’ beam shaping to “clear” particles [3] and instigate transfection [4].

[1] **In situ wave-front correction: application to micromanipulation** T Čižmár, M Mazilu and K Dholakia, Nature Photonics 4, 388 - 394 (2010)

[2] **Femtosecond cellular transfection using a non-diffracting light beam** X.Tsampoula, V. Garcés-Chávez, M. Comrie, D. Stevenson, M.B. Agate, F.J. Gunn-Moore, C.T.A. Brown and K Dholakia, Appl Phys Lett 91, 053902 (2007)

[3] **Optically mediated particle clearing using Airy wavepackets**, J. Baumgartl, M. Mazilu, and K. Dholakia, Nature Photonics **2**, 675--678 (2008)

[4] **Optical Eigenmodes; exploiting the quadratic nature of the energy flux and of scattering interactions**, M. Mazilu, J. Baumgartl, S. Kosmeier, and K. Dholakia, Optics Express, 19(2) 933-945 (2011)