Super-resolution imaging through opaque layers

Light scattering is so common everywhere around us that we do not even notice it. Paint on the wall, paper, tooth, skin and clouds are all examples of strongly scattering opaque media. When we say that something is opaque, i.e. we cannot see through it, we do not realize that this is not entirely true. In a series of ground-breaking experiments in the Lagendijk and Gigan groups, it was shown that one can focus light, or even transmit images through strongly scattering media, like a thin layer of white paint or biological tissue. This means that we can look through an opaque medium if we can control precisely the wavefront of the light that is entering it. Applications of these techniques range from bio-imaging, microscopy and spectroscopy, to material science, telecommunication, and every other field where light propagates through a scattering medium.

In our research project new methods of imaging through scattering media using fluorescence correlations will be devised. Our aim is to achieve super-resolution imaging through a scattering medium. Accomplishing this goal will extend the range of applicability of super-resolution microscopy and expand the toolbox of imaging through scattering media.

The continued progress in medicine and biological sciences makes the ability to observe smaller and smaller objects crucial, for example while examining the structure, and mutual relationships between proteins in cells. In order to obtain valuable insights into biological processes, the samples examined by researchers should not differ from the structures naturally occurring in biological organisms, which eliminates the use of aggressive procedures and reagents. Because of the wavelike nature of light, a standard optical microscope does not allow imaging objects smaller than about 250 nanometres, which means that objects closer to each other than half the wavelength of light (about 250 nm for green light) cannot be distinguished. This problem, called the diffraction limit, has been one of the main difficulties in observing the smallest biological structures. Electron microscopes provide much better resolution than optical microscopes, but cannot be used for examining living organisms, because of the destructive sample preparation procedures and the fact that the imaging is performed in vacuum. This is where fluorescence microscopy is particularly useful. Two Nobel Prizes already awarded for related research – in 2008 and 2014 demonstrate the significance of fluorescence microscopy. Some methods, such as PALM, STORM or STED microscopy, offer the resolution even up to hundred times beyond the diffraction limit, which allows to distinguish objects located just a dozen or so nanometres from each other. Nevertheless, these techniques depend upon long exposure times and a complex procedure of biological sample preparation. Other methods, such as SIM or ISM microscopy, are easy to use, but offer a limited resolution improvement. Techniques based on correlations of fluorescence light such as SOFI are a compromise between the simplicity of use and the resolution.