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ADAPTIVE OPTICS FROM MICROSCOPY TO NANOSCOPY

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Abstract content
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High resolution microscopy relies on the use of high quality optics with the goal of obtaining diffraction-limited operation, working at the physical limits imposed by the wavelength of the light. Yet in many cases this goal is not achieved as aberrations, distortions in the optical wavefront, blur the focus and reduce the resolution of the system. Aberrations can arise from imperfections in the optics, but are often introduced by the specimen, particularly when imaging thick specimens. One common source is a planar mismatch in refractive index, such as that between the microscope coverslip and the specimen mounting medium, which introduces spherical aberration. Biological specimens also exhibit variations in refractive index that arise from the three-dimensional nature of cells and tissue structures. In general, these aberrations become greater in magnitude and more complex in form as the focusing depth is increased. The induced wavefront aberrations distort the focus causing a reduction in resolution and, often more importantly, reduced signal level and contrast. These effects limit the observable part of the specimen to a region near the surface.

Adaptive optics systems enable the dynamic correction of aberrations through the reconfiguration of an adaptive optical element, for example a deformable mirror or liquid crystal spatial light modulator. Adaptive optics was originally introduced to compensate for the optical effects of atmospheric turbulence on telescope imaging. The overall operation is based upon the principle of phase conjugation: the correction element introduces an equal but opposite phase aberration to that present in the optical system. As the sum of these two aberrations is zero, diffraction limited operation should be restored. Various adaptive schemes have been developed for a range of different modalities including confocal, multiphoton and widefield microscopes. We review the methods and applications of these systems in biological and other areas. We also present recent developments in adaptive optical methods for super-resolution nanoscopy. In particular, this includes new image-based adaptive schemes for stimulated emission depletion (STED) microscopy.

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