Diffractionless Fourier Domain Microscopy

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KEY WORDS: diffractionless microscopy, spatial frequencies, structured illumination, coherent optics, Fourier Domain Microscopy;

Several methods have been proposed and realized to increase the lateral resolution in microscopy and ultimately to beat the actual diffraction limit as stated by Abbe. Structured illumination for example enhances the lateral resolution by virtually extending the spatial frequency support of the system transfer function. Higher spatial frequencies are in fact mapped into the range covered by the detection transfer function. The set of spatial frequencies can be further enhanced by decoupling illumination and detection and by employing concepts similar to synthetic apertures. We present a novel method for diffractionless microscopic imaging – Fourier Domain or k-Microscopy[1] (FDM). Again we decouple illumination from detection to achieve a lateral resolution that is independent of the detection numerical aperture. Similar to structured illumination we produce a set of fringes covering a band of spatial frequencies on the sample. However, instead of detecting with an area sensor we use a simple PIN detector: By tuning the spatial frequency of the illumination we obtain the Fourier coefficient from the measured total backscattered or transmitted intensity for the particular spatial frequency in the sample dimension normal to the fringe orientation. The fringe pattern is obtained from two collimated coherent beams that are superimposed. The spatial frequency of the pattern is controlled via tuning the wavelength. In order to obtain an unambiguous Fourier representation of the one dimensional sample structure it is necessary to record at least two π/2 phase shifted copies of the frequency response signal. The lateral resolution is then determined by the tuning bandwidth of the laser as well as the subtended angle and the central wavelength of the laser. This relation is in fact very similar to the concept of Fourier Domain Optical Coherence tomography, only that it acts on the transverse instead of the longitudinal resolution. We give first experimental proof of the concept in one dimension using a slowly tuning broad-bandwidth Ti:Sapph laser. We resolve the defined structure of a resolution test target. A particular feature of the method is that the reconstructed sample will appear spatially band-pass filtered due to the finite spectral support given by the tuned fringe frequencies. Hence only the edges of the test target lines are visible. We believe that the concept of FDM will greatly benefit from new developments in rapidly- wavelength tuning source technology that recently entered the field of OCT.