Microscopy with illumination and detector arrays

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Images can be formed in two basically different ways: either by directly imaging and recording the image on a detector array, or by projecting a patterned illumination (for example a scanning spot) and detecting a signal with a single-pixel detector. A more general case is to combine these two basic approaches. Then effectively we can record a four-dimensional (4D) signal from a 2D object. The 2D image of the object must then be generated from the 4D signal. The illumination and detection arrays can be positioned in either image planes or in Fourier planes. Placing the detection array in the back-Fourier plane gives imaging by differential phase contrast, or by ptychography. Placing the illumination array in the front-Fourier plane gives so-called Fourier ptychography. In ptychography, the resolution is determined by the apertures of both illumination and detection arrays. The 4D image signal also contains sufficient capacity to reconstruct 3D image information. These approaches can be used for a scattering object in reflection or transmission. In fact, it is known that 4D scattering data reduces in some special cases to 3D. If both illumination and detection arrays are situated in image planes, fluorescent objects can also be imaged. An example is in confocal microscopy, where the illumination and detection are each scanning spots, or arrays of spots. A second example is structured illumination microscopy (SIM), where a series of structured illumination patterns are used to generate a series of images. A third example combines a scanning spot, or array of spots, with a detector array. The programmable array microscope (PAM) is a more general arrangement, using a patterned or stochastic illumination array. In image scanning microscopy (ISM), the image is reconstructed by the process known as pixel reassignment. This gives the advantage over confocal microscopy that the resolution improvement and optical sectioning are retained, while the detection efficiency is much greater.