Superresolved Multiphoton Microscopy with Spatial Frequency-Modulated Imaging

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The basis of my senior design will be expanding upon the existing technology of SPIFI microscopy. SPIFI stands for Spatial Frequency-Modulated Imaging, and it's a method of scanning an entire object with a single laser, then resolving the data collected at a single point into a full image of the object. The way this works is typically modeled as a signal transfer problem, rather than strict optics. We first start with some input function representative of the initial laser, $u[x, y]$. Then the laser passes through a grating which applies a spatial frequency mapping $m[x, y]$, finally it passes through the object which has some absorbency as a function of position $a[x, y]$. See Figure 1 for an example system taken from Dr.Squier's reference material. Combined with the initial amplitude of the laser E_0, the intensity incident on the detector is

$$I[x, y] = E_0^2 \left| u[x, y]m[x, y]a[x, y] \right|^2$$

Obviously, the key component here is the modulation function, because by distributing frequencies through space, we gain the ability to retrieve the form of the object scanned through $a[x, y]$ by deconstructing the intensity $I[x, y]$ into constituent frequencies (that is, by taking the Fourier transform). In general, it's difficult to give a catch-all form of the function that represents the grating, because any bijective mapping of frequencies onto space will serve the intended purpose, but in general there is one mapping which is favored as it can easily be represented in either circular or cartesian form. Figure 2 shows the more common circular representation. In any case, the transfer function takes the form:

$$\frac{1}{2} + \frac{1}{2} \cos \left[2\pi f_m kRt\right]$$

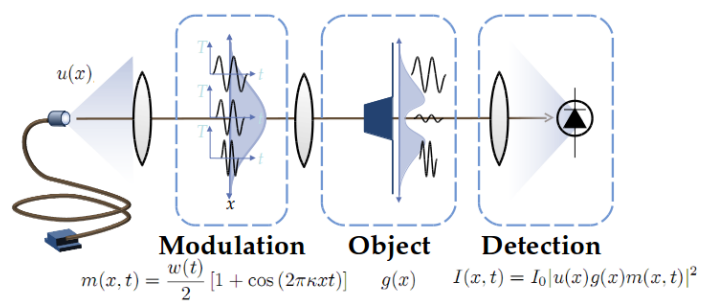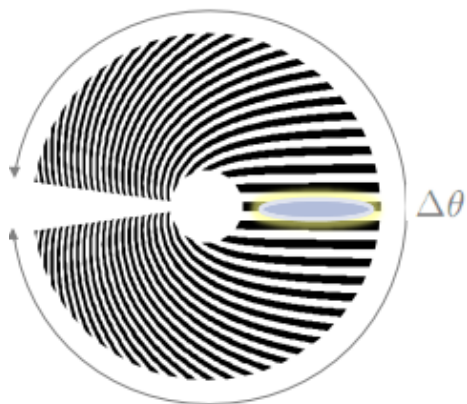when expressed as a strict function of time and radius for some frequency of rotation f_m.

Figure 1: Example System

Figure 2: Circular Frequency Modulation Mask