# Coded-Illumination Fourier Transform Interferometry

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## Abstract

Fourier Transform Interferometry (FTI) is a computational imaging modality that has shown promising results in the acquisition of hyperspectral images [1, 2], especially in terms of spectral resolution for biological microscopy. An application of FTI is fluorescence spectroscopy, in which a biological sample is stained by fluorochrome dyes and indirectly scanned by the FTI device. The data is recorded by varying the Optical Path Difference (OPD) of two interfering beams illuminating the sample. This OPD is scanned between zero and a maximum value fixed by the required spectral resolution. However, the efficiency of this technique is limited by the durability of fluorochromes when exposed to illumination, since over-exposed fluorochromes suffer from fluorescence alteration called *photo-bleaching*. Therefore, the spectral resolution of a conventional FTI is limited by the lifetime of the fluorochromes, whose exposure should be minimized.

In this work, we propose a coded-illumination FTI device that reduces photo-bleaching. This is achieved by activating (coding) the illumination only during selected time intervals. The FTI scanning amounts then to an *incomplete* set of indirect spectral observations, which are processed to recover the image. However, recovering high-quality images for such incomplete data is challenging: conventional reconstruction methods (*e.g.,* inverse Fourier transform) only produce poor quality images, while generating *random* illumination coding and leveraging the recently developed theory of *compressed sensing* [3, 4] achieves conspicuous quality improvements. We also demonstrate that the illumination coding pattern highly influences the reconstruction quality. Taking into account the spectral characteristics of the fluorochromes, most of their information is distributed around the zero OPD point. Hence, we compare two random illumination coding methods, referred as *uniform* and *variable density* (see Fig. 1), the latter concentrating more illumination around zero OPD (*i.e.*, the illumination time intervals follow a power-law probability distribution). Our simulations confirm that a variable density pattern distribution, rather than the uniform one, yields superior reconstruction quality. This conclusion agrees with the notion of *variable density compressed sensing* [5] as successfully applied in magnetic resonance imaging.

## References


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## Figures

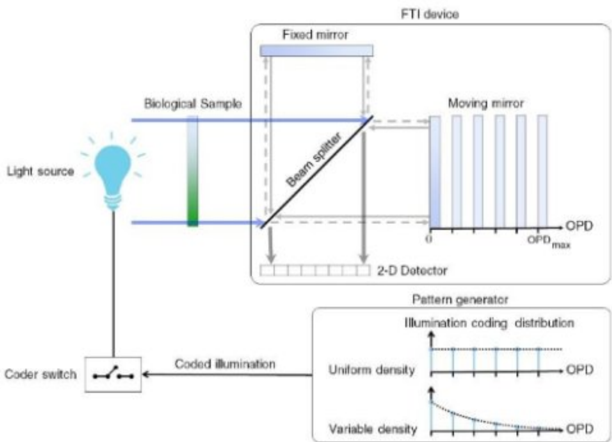



**Figure 1: (Top) Operating principle of FTI [6]. A parallel beam of coherent light is divided into two equal intensity beams by a beam-splitter. The two beams are reflected back by the respective mirrors, and interfere after being recombined by the beam-splitter. The resulting beam is later recorded (in intensity) by an imaging sensor, which captures one image per OPD. (Bottom) Two pattern generation schemes.**

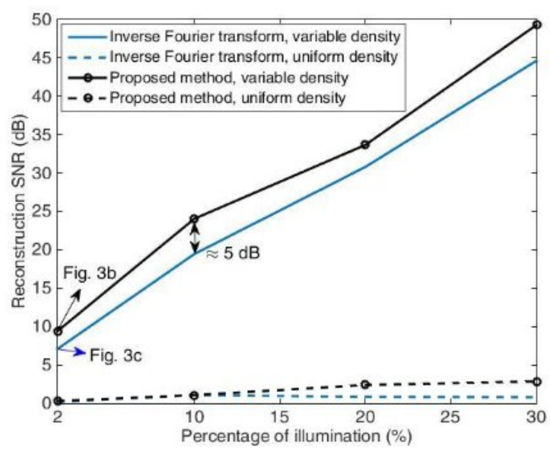
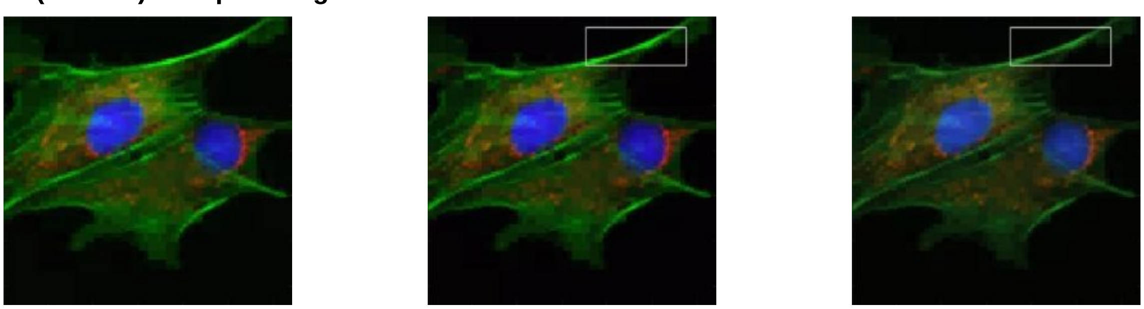



**Figure 2: Reconstruction quality of the ground truth image in Fig. 3a. Our method employs basis pursuit de-noising [4] reconstruction.**



**(a) (b) (c)**

**Figure 3: An example of reconstruction (with 3 fluorochrome spectra unmixed according to the three RGB channels) of a biological image with only 2% of illumination time intervals. (a) The ground-truth image. (b) and (c) images obtained by using the proposed method and a simple inverse Fourier transform, respectively. Our method shows superior performance especially, as highlighted, in preserving sharp edges.**