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Dealiased Spectral Images from Aliased Fizeau Fourier Transform Imaging Spectroscopy Measurements

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Abstract: Transfer functions for spectral images obtained through Fizeau Fourier transform spectroscopy can be asymmetric, which permits the opportunity to form dealiasised images from spatially aliased intensity measurements, provided certain design and operation tradeoffs are met.

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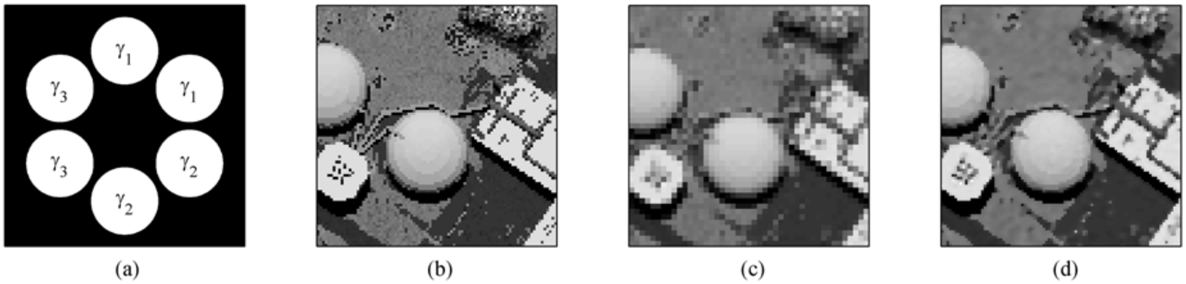
1. Introduction

Fizeau Fourier transform imaging spectroscopy (FTIS) is performed by introducing phase delays between groups of subapertures in a multi- or segmented-aperture system, recording a series of panchromatic intensity measurements, and post-processing [1]. The imaging transfer functions for the resulting spectral images, called *spectral optical transfer functions* (SOTF's), are given by cross-correlations between generalized pupil functions for subaperture groups that have different phase delays during data collection. The unique nature of the SOTF's permits additional post-processing techniques that are not applicable to conventional imaging systems. One example of this is the ability to generate dealiased spectral imagery from aliased panchromatic intensity measurements. The following section outlines the technique, describes associated design and operation tradeoffs, and shows simulation results.

2. Technique

Dealiased spectral images can be formed from aliased intensity measurements by isolating aliased spatial frequency components and mapping them back to the proper spatial frequencies. This can be accomplished in a Fizeau FTIS system by: (i) simultaneously introducing different phase delays for each subaperture group during data collection, (ii) sufficiently limiting the spectral bandwidth of the scene, and (iii) choosing the arrangement of the subaperture groups such that individual SOTF terms do not overlap when aliased. The first two requirements ensure that data associated with various SOTF terms are separable, while the third requirement ensures that data associated with an individual SOTF term is not corrupted when aliased. Benefits of this technique are increased signal-to-noise ratio (SNR) and larger field of view due to the ability to use larger detector pixels, while retaining fine resolution.

The simulation is based on a six-aperture telescope array divided into three subaperture groups for FTIS data collection. The phase delay for the q^{th} subaperture group is proportional to $\gamma_q \tau$, where γ_q is a relative delay rate parameter, τ is a time-delay variable, and $\gamma_1 = 0$, $\gamma_2 = 1/3$, and $\gamma_3 = 1$. DIRSIG simulation data [2], limited to the wavelength range $\lambda = 1.12$–1.40 μm, was used for the object. The intensity measurements were Nyquist sampled for $\lambda = 2.24$ μm and had an average SNR of 110. Figure 1(d) shows a dealiased reconstruction of the FTIS data using a nonlinear sharpness metric [3]. Notice that fine object details, which are not apparent in an aliased version of the object, have been faithfully reconstructed.



(a) (b) (c) (d)

Fig. 1. Simulation results: (a) FTIS pupil configuration, (b) object data, (c) aliased object data (does not include diffraction effects), (d) dealiased reconstruction. Note that (b) (c) and (d) are panchromatic views of the same scene subsection, magnified to show detail.

3. References

[1] S. T. Thurman and J. R. Fienup, "Multi-aperture Fourier transform imaging spectroscopy: theory and imaging properties," Opt. Express, **13**, 2160-2175 (2005), http://www.opticsexpress.org/absract.cfm?URI=OPEX-13-6-2160.

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