# Imaging Fourier transform spectroscopy with multi-aperture telescopes

**Samuel T. Thurman and James R. Fienup**
*The Institute of Optics, University of Rochester, Rochester, NY 14627*
*TEL: (585)275-8008 FAX: (585)271-1027 E-MAIL: thurman@optics.rochester.edu*

**R. L. Kendrick**
*Lockheed-Martin Advanced Technology Center, 3251 Hanover St., Palo Alto, CA 94304*

**Abstract:** Fourier spectroscopy can be performed with multi-aperture telescopes by adjusting the optical path difference between apertures. Expressions are given for the measured intensity and the recovered spectrum for a general multi-aperture system. The transfer function of a multi-aperture spectrometer is strikingly different than for a conventional Michelson imaging spectrometer.
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## 1. Introduction

A multi-aperture optical system consists of a number of relatively small-aperture systems that work together to achieve a resolution comparable to that of a large-aperture system. The resolution enhancement is only achieved if the optical path lengths for rays traveling through each aperture are equal. Thus, multi-aperture systems typically have some mechanism for controlling the optical path delay of each aperture. Such mechanisms also can be used to intentionally introduce optical path differences (or time delays) between apertures and perform Fourier transform spectroscopy. Kendrick *et al.* [1] demonstrated such Fourier transform spectroscopy experimentally with a multi-aperture telescope.

## 2. Results

We derived general expressions for the intensity in the image plane and the optical transfer function of a multi-aperture telescope when various time delays are introduced to each aperture. These expressions are based on a physical optics model [2] and the theory of partial coherence [3]. The expressions are simplified by assuming a spatially incoherent object, since this is typically the case for both astronomical and terrestrial spectroscopy. It is shown how object spectral information can be determined by taking the temporal Fourier transform of a series of intensity measurements with different time delays between apertures.

Examples based on a three-aperture system are examined in detail and compared to a conventional Fourier transform spectrometer based on a Michelson interferometer arrangement. Factors affecting spectral resolution and sampling rates are shown to be comparable, while imaging properties are strikingly different. In particular, the spatial transfer function for the recovered spectral image in a multi-aperture system attenuates low spatial frequencies and necessarily vanishes for the DC spatial frequency. Also, one has the option of grouping various combinations of apertures and employing different relative time delay rates for each group. For some aperture configurations, having more than two groups of apertures, each with different relative time delays, substantially improves the spatial transfer function, although at a cost of variable spectral resolution for different spatial frequencies. This behavior results from the fact that one obtains spectral information only at spatial frequencies corresponding to the cross-correlations of different groups of apertures, rather than the usual autocorrelation of the entire aperture as is normally the case for imaging. The image restoration implications of the transfer functions will be discussed.

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## 3. References

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2 J. W. Goodman, *Introduction to Fourier Optics*, *2nd Edition* (McGraw-Hill, New York, 1996).
3 L. Mandel and E. Wolf, *Optical Coherence and Quantum Optics*, (Cambridge, New York, 1995).