Stationary Fourier Transform Spectrometer
Erez N. Ribak
Department of Physics, Technion - Israel Institute of Technology

Abstract: We develop an interferometer for measurement of narrow atmospheric spectral lines, mainly in the infra-red. The bias and background are dominant, but irrelevant for the measurement. Hence we employ an optical band-pass filter tuned to the expected width of the spectral lines: Instead of scanning the full path delay with a single detector, we image the fringes on a two-dimensional camera. Applications are for our own atmosphere, and for search for life on exoplanets.

Selective FTIR: Fourier transform infrared (FTIR) spectroscopy is a well-known and widespread technique used to probe matter. Its range of use goes from analytical chemistry to high resolution spectroscopy in the gas phase, covering a large spectral range (thousands of wavenumbers). Analysis of the spectrum of a source with emphasis on different types of spectral characteristics, for example, choice of a specific region of the interferogram can enhance sensitivity to particular line widths [1]. A typical line width δk contributes to the interferogram out to path difference 1/δk. This can be used to search for small amounts of known molecules.

Measurement paradigm: We spread hundreds of fringes across a two-dimensional detector. Since the central (white-light) fringe increases the dynamic range of the detector, we exclude it, with the fringe benefit, that we also exclude the DC part of the spectrum. Thus we enhance the side fringes, where the information on narrower spectral features lies (Fig. 1). The furthest fringes (with the largest optical path difference) set the actual resolution (Fig. 3).

Properties: + A zero-shear interferometer is not sensitive to turbulence and aberrations outside the device. + The two complementary outputs mean that all light is measured, and can serve to improve SNR, or be measured by two cameras of different wave lengths. + Fringe modulation is also possible, albeit at the camera frame speed. + The interferometer is extremely stable and very compact, with no moving parts. + Wave length calibration is performed through the other input port. - The spectral resolution drops with wider field. - The fixed delay needs to be custom made and calibrated.

Interferometer: We employ the Ribak-Lipson interferometer [2] operated at zero lateral shear. A telescope produces a collimated beam, which crosses two consecutive beams splitters. Four beams are formed, where each two interfere as a pair (Fig. 2). Between the beam splitters we insert a delay which varies in steps. Each step shifts the fringes on the facing camera rows, and allows for a much larger number of fringes. If the first rows measure the first hundred fringes, the following rows measure the next hundred, etc. The staggered fringes thus allow a higher spectral resolution (Fig. 3).

Experiments: Using the Fourier spectrometer we confirmed the ideas presented in an observatory, and showed that we can easily see fainter and narrower lines (Fig. 3). We are now modifying the device for the infra-red region for measurements of atmospheric gases (Fig. 4). All measurements were taken within seconds, without scanning.

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1. E Schwartz, S G Lipson and E N Ribak, Astrophysics and Space Science 361, 166 (2016)