Field-Portable LWIR Imaging FTS

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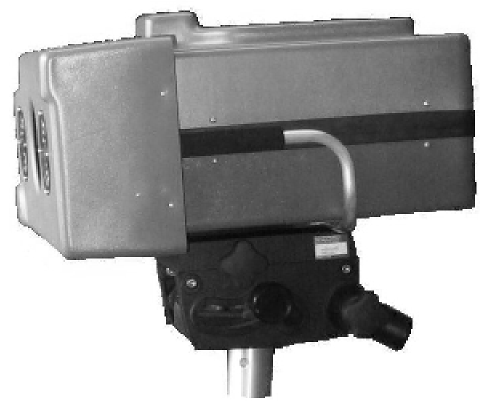
Abstract: This paper presents the design and performance of a LWIR imaging FTS. The imaging size is 320x256 in the 8-12 μm region. The spectral resolution can be set as low as 0.25 cm^{-1}. An overview of the key design features will be presented along with the test results.

OCIS codes: (000.0000) General

1. Introduction

Advancements in infrared detector focal plane arrays have spawned a proliferation of infrared sensors. Telops has developed a field-portable hyperspectral imager. The imager, called Field-portable Imaging Radiometric Spectrometer Technology (FIRST), is the first hyperspectral imager specifically designed for chemical imaging using Fourier transform technology. This paper presents the FIRST and performance test results.



2. System overview

The instrument is a lightweight and compact imaging radiometric spectrometer. It uses a 320x256 LWIR PV-MCT focal plane array detector that can be windowed and formatted to fit the desired size and to decrease the acquisition time. Spectral resolution depends on the operating parameters and ranges from 0.25 to 150 cm^{-1}, with optimal system designed for 4 cm^{-1}.
The configuration, monitoring and real-time housekeeping data collection is performed using an Ethernet link. A bore-sight video camera takes simultaneous visible images aligned with the imaging FTS. The instrument outputs the measurements on a high-speed CameraLink interface. The instrument supports two operating modes: FTS mode and Camera mode. In Camera mode, the instrument generates standard digital video and supports up to 300 fps with the full 320x256 pixels of the focal plane array area. In FTS mode, the interferograms are transferred along with a header containing all configuration parameters and monitored values to be stored on the computer. The key specifications are presented in Table 1.

Table 1. Key specifications of the FIRST

Parameter	Value
Spectral Range	7.7 – 11.6 μm
Spectral Resolution	0.25 – 150 cm^{-1}
Scan Rate	0.028 – 16 Hz
Instantaneous Field of View	0.35 mrad
Array Size	320 x 256
Input voltage	28 VDC, 250 W
Size	0.45 x 0.44 x 0.25 [m]
Weight	21 kg

3. Imaging Performance

To produce a high-quality image of the IR scene, Telops designed a lens assembly such that the blur is smaller than the diffraction from this f/2 system. The FPA has 30 μm pixels and the focal length is 86 mm, giving 350 μrad IFOV per pixel. The lens produces a pupil image in the interferometer (close to the cube corner) in order to minimize vignetting and maintain high sensitivity without increasing the size of the interferometer. In order to maintain the high quality of the image for variations of temperature, Telops implemented an automatic focus adjustment. The “autofocus” is made by an electronic servo, which keeps the lens focused independent of the temperature, maintaining the diffraction limited performance over a wide range of temperatures. The optical blur of the system was measured by looking at a collimated hot source. The divergence of the hot source was 78 µrad, i.e. less than ¼ of a detector pixel. The result presented in Figure 1 shows that the blur is 386 µrad FWHM at the center of the FPA. Similar measurements give the blur in the corners to be between 420 and 490 µrad FWHM.

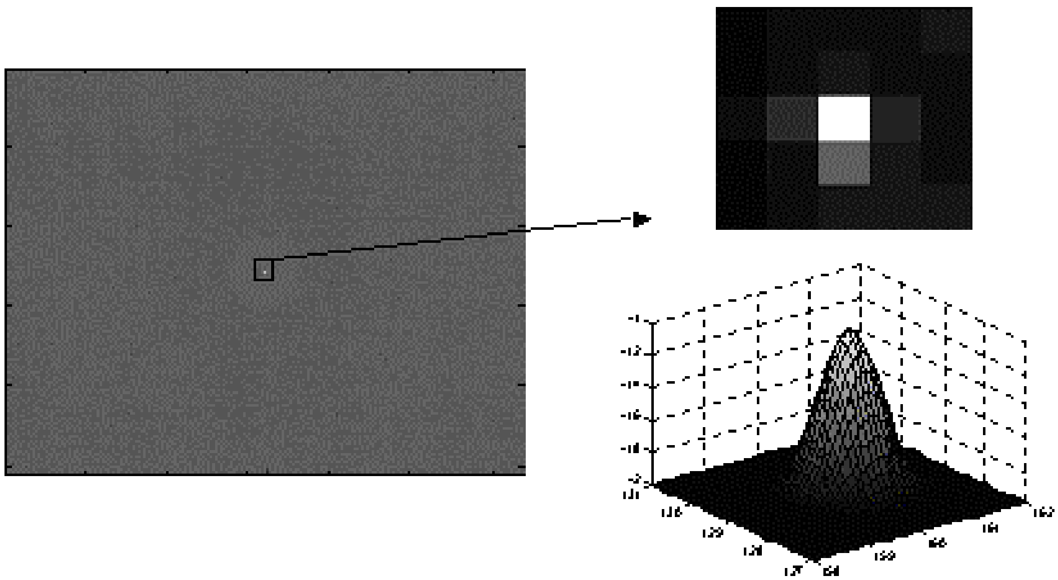


Fig. 1. Measured optical blur for a collimated source in the center of the FPA

4. Radiometric Performance

The sensor has been designed to give state-of-the-art performance. Every little details were considered and shot-noise limited performance was the target. The étendue of the system is maximized along with the transmittance. Both, the field stop and the aperture stop are cold and located in the FPA dewar.

NESR (Noise Equivalent Spectral Radiance) is the sensor noise in the same units as the scene spectral radiance. Figure 2 shows the NESR measurement of a single pixel made for 10 seconds of observation time of a 300 K scene. The bin spacing on the spectral axis for this measurement is set to 1.3 cm^{-1} (spectral resolution of 1.6 cm^{-1} FWHM) The NESR is in the order of 8×10^{-4} W/m^2 sr cm^{-1}.

In addition to the noise performance, we also measured the radiometric accuracy of the sensor. By using the two internal blackbodies as the calibration sources, we calibrate the measurement of an external blackbody and calculate the deviation from the theoretical radiance of this blackbody using the Planck function. The radiometric accuracy is better than 2% for this sensor.

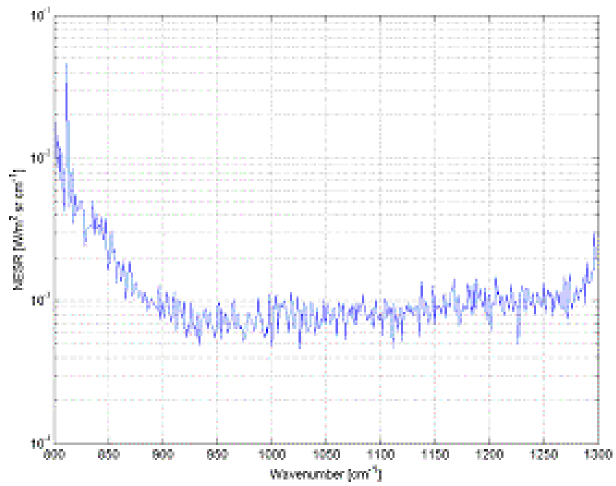


Fig. 2. Measured NESR for a single pixel

5. Conclusion

Telops' FIRST is an outstanding spectral imaging sensor. It provides imaging capability in the 8-12 µm LWIR region with 320×256 pixels and 350 µrad IFOV. The spectral resolution is user' selectable and can be as low as 0.25 cm^{-1}. The single-pixel NESR is in the order of 8×10^{-4} W/m^2 sr cm^{-1} and is expected to be reduced by a factor of 3. Additional functionalities such as real time FFT will be integrated in the sensor in the near future.