SPATIAL INTERFEROMETERS FOR REMOTE SENSING AND IN SITU ANALYSIS. P. G. Lucey[1], R. Wright[1], C. Honniball[1], S.T. Crites[2], J. Cahill[3], B.T. Greenhagen[3], T. Glotch[4], [1]Hawai'i Institute of Geophysics and Planetology, University of Hawai'i at Mānoa, 1680 East-West Road, Honolulu, HI 96822, USA (lucey@higp.hawaii.edu), [2]Japan Aerospace Exploration Agency, Institute of Space and Astronautical Science, Kanagawa, Japan, [3]Applied Physical Laboratory, Johns Hopkins University, Laurel MD, [4] Geosciences Department, Stony Brook University, Stony Brook, NY

Introduction: Interferometers have been used as spectrometers in planetary exploration for decades, from Mariner 9 IRIS to MRO TES and MER miniTES, to CIRS on Cassini through IIM on Chang E' 1. Spectral interferometry has characteristics that are distinct from other spectral measurement techniques and broaden the design space for spectrometer applications. Among these characteristics are 1) an intrinsically broad spectral range, typically limited only by the sensitivity of the detector and transmission characteristics of the beamsplitter that is the heart of many such instruments; and when using detectors that are not limited by photon noise but by the inherent noise of the detector, interferometers enjoy a signal to noise advantage over other methods that is approximately equal to the number of bands collected.

While all but one planetary spectral interferometers have been based on the Michelson Interferometer, the IIM on the Change E' 1 lunar orbiter mission used a different approach interferometric approach to collect spectral information [1]. In the Michelson interferometer, the essential interference pattern from which the spectrum is derived is collected as a function of time; the IIM is a variety of so-called spatial interferometers where the interference pattern is collected by a detector array. As a class spatial interferometers have useful features compared to Michelson interferometers, chief among them being a lack of moving parts. The Michelson requires a precise mirror scanning mechanism as well as a fringe counting auxiliary laser system to measure the position of the mirror. With no moving parts, the spatial interferometer requires only a one-time wavelength calibration that can be done on the ground and checked using flight data.

While IIM collected data with a Si CCD, spatial interferometry is well-suited to the collection of data in the infrared portion of the spectrum. Large, low power array detectors are available in the form of microbolometers and thermopile arrays, both of which have rich flight heritage with filter based instruments (MRO THEMIS, LCROSS and LRO Diviner) and Michelson interferometers (Cassini CIRS). The spatial interferometer offers the designer an alternative to filter designs for multispectral or hyperspectral data collection with superior signal to noise ratios when band counts exceed about 10.

Experience with infrared spatial interferometers: Since 1990 the University of Hawaii has been experimenting with infrared imaging spectrometers based on spatial interferometry. Most of these interferometers were, like IIM, of the Sagnac variety but it appears that any interferometer can be used as a spatial interferometer.

We have produced imaging interferometer spectrometers in the 1-2.5 [2], 3-5 [2,3] and 8-14 micron regions [4], with both cooled and uncooled detectors, and used these for airborne hyperspectral imaging, in ground to ground field applications, and as spectral microscopes. Development has been supported by NASA PIDDP and IIP (Earth Sciences Instrument Incubator Program) and DARPA.

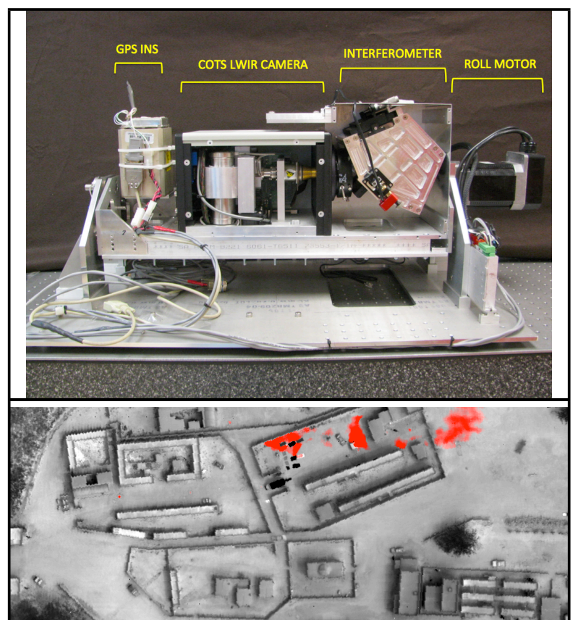

Figure 1. Top: Infrared airborne Sagnac interferometer using a cooled HgCdTe detector array. Bottom, in red, plumes of acetone evaporating from open pans.

Airborne Applications: We have flown three types of Sagnac interferometers for airborne applications: one cryogenic instrument operating from 1-5 microns, an uncooled spectrometer using a microbolometer array, and a version with a cooled detector array and uncooled interferometer. The latter instrument was developed under PIDDP funding and has the advantage of collecting high quality spectral data at high rates, while not requiring cooling of the interferometer. Figure 1 shows an example of data collected with that instrument detecting acetone vapor.

Figure 2. Backpack Sagnac spectrometer using microbolometer detector. Bottom, color composite of Mojave desert road, 9, 10, and 11 microns.

Ground to ground applications: We have developed several portable instruments for field operations, in this case all Sagnac interferometers using low power microbolometer detectors for imaging data collection from 8-14 microns. Signal to noise ratios of these instrument are very high, with peak response over 1500.

Microsocope Applications: We have implemented an IR hyperspectral microscope using a Sagnac interferometer and have used it to scan lunar soils at 30 micron resolution. Figure 3 shows a variety of minerals detected using this system, including rare quartz and phosphate grains.

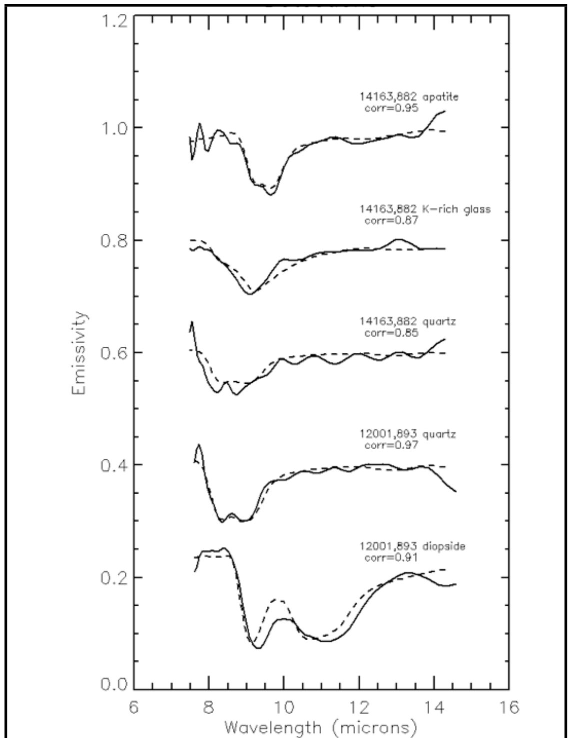

Figure 3. Lunar minerals detected with Sagnac interferometer used as a hyperspectral microscope.

Potential planetary applications: There are three niches we are pursuing with this technology: Spectral imaging from 5-200 microns for outer solar system applications; very high spatial resolution orbital imaging spectroscopy for inner solar system applications; and infrared hyperspectral microscopy for planetary landers.

Conclusions: The spatial interferometer occupies a unique niche for collection of hyperspectral data in the infrared with no moving parts and low power consumption. We have produced more than ten spatial interferometers of various designs and used all of them in field or airborne applications, demonstrating the ability of this technology to collect high quality spectral information. The low power and cooling requirements of this technology makes it ideal for planetary applications.

References: [1] Qiu, Y.H., Wen, D.S., Zhao, B.C., Chen, Z., Qiao, W.D., Acta Photonica Sin 38, 484-488, 2009, [2] Lucey P.G., Williams T., Horton K., Hinck K., Budney C., Rafert J.B., and Rusk T.B., Proc. of the Int. Symposium on Spectral Sensing Research, Gomez R.B. and McKim H., 1992. [3] Honniball CI, Wright R, Lucey PG, Crites ST, SPIE Defense Security 2016 [4]Lucey, P.G., Horton, K.A., Williams, T., Applied Optics, 47(28), F107-F113 (2008).