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Title: Remote Sensing of Earth's Atmosphere and Surface using a Digital Array Scanned Interferometer—A New Type of Imaging Spectrometer

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We have been evaluating the capabilities of the DASI (digital array scanned interferometer) class of instruments for measuring terrestrial radiation fields over the visible to mid-infrared. DASIs are capable of high throughput, sensitivity and spectral resolution and have the potential for field-of-view spatial discrimination (an imaging spectrometer). The simplicity of design and operation of DASIs make them particularly suitable for field and airborne platform based remote sensing. Our long term objective is to produce a versatile field instrument which may be applied toward a variety of atmospheric and surface studies.

The basic principle behind the operation of the DASI is similar to that for conventional scanned interferometers. The detected signal results from two-beam interference. The wavelength spectrum of the incident radiation is obtained by Fourier transforming this recorded interferogram. However, unlike a conventional interferometer, the DASI operates with its mirrors fixed in position. The range of path differences between the recombined beams is achieved by means of the configuration of the optical components so that fringes of equal inclination are formed at the image plane. This comprises the interferogram which can be resolved spatially by a detector array. Fig. 1 shows a particular DASI configuration using a tilted grating to obtain a variable range of path differences across the detector [1].

The advantages of DASIs may best be described by comparison with other commonly used spectrometers. In general Fourier transform spectrometers (FTS) have several advantages over grating spectrometers [2]. These include enhanced throughput (particularly at higher spectral resolution) and superior signal linearity and dynamic range. DASIs have additional advantages over conventional Michelson interferometers [3]: 1) *Simplicity of design and operation* - interferograms are acquired with the optics stationary; 2) *Capability of Observing transient events* - the entire interferogram is measured simultaneously; 3) *Spatial imaging* - the redundant coordinate at the image plane can be used for one-dimensional imaging of the field of view; 4) *Enhanced throughput potential* - certain DASI optical configurations result in field widening, eliminating the aperture size constraint of Michelson interferometers [4]; 5) *Reduction of background radiation by cooling* - The absence of moving optical components facilitates cryogenic operation of the entire spectrometer which can greatly reduce ambient background radiation in the infrared. Although this is achievable with scanning interferometers [5,6], such instruments are complex and expensive.

There is much information which can be retrieved from spectrally as well as spatially resolved remote sensing data which would be applicable to both global and regional problems. At lower resolution (> 10 cm^{-1}), surface albedo and emissivity, and aerosol and cloud properties may be derived. For example radiative transfer theory may be applied to remote sensing measurements of clouds to retrieve microphysical properties of the constituent ice crystals [7] which is important for understanding the heat budget of the atmosphere, and measurements of infrared solar reflectance from plant canopies may be used to study biogeochemical processes [8].

Higher resolution instruments (< 0.1 cm^{-1}) can reveal molecular transition features. This permits superior discrimination, detection, and quantization of specific molecular species which may serve as tracers or indicators of important atmospheric chemical and dynamical processes. The derivation of altitude profiles of the atmosphere can be done in principle based on pressure effects on the line shapes and temperature effects on relative line intensities. The nadir viewing ER-2 based HIS (High resolution In-

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terferometer Sounder) is a Michelson interferometer developed for such purposes [9]. Two high resolution infrared Michelson Fourier spectrometers were flown on the NASA DC-8 aircraft during the polar ozone expeditions [10]. Observations of the sun were made to measure column densities of numerous atmospheric molecules. A higher sensitivity instrument capable of measuring molecular thermal emissions in the absence of sunlight (i.e. a cryogenic field widened interferometer) would be a major advancement for future polar missions.

For the reasons revealed above there is currently a vital need for a versatile instrument having high spectral resolution, sensitivity and tunability as well as imaging capabilities. DASIs show promise of meeting these criteria: they have many of the positive characteristics of conventional FTS instruments and the additional features described above. The ease of construction and operation due to the absence of actively scanning optical components provides a relatively inexpensive alternative to other interferometer designs.

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FIG 1 - DASI configuration using a tilted grating. Lens L2 images the grating onto the detector array so that the path difference varies across the array (in plane of paper). The orthogonal axis (perpendicular to plane of paper) is available for spatial imaging.