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Multiband, infrared imager for study of high temperature volcanism on Io

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Abstract

We are developing a multiband imager that obtains simultaneous two-dimensional imaging at short-, mid- and long-infrared wavelengths. Moreover, this instrument will deliver non-saturating, wide dynamic range images of transient, rapidly-changing events. These capabilities enable a new range of previously unobtainable high science value planetary observations. In particular, this imager will enable study of high temperature volcanism on Io, Earth, and possibly Venus.

1. Introduction

Io's extraordinary volcanism presents unique observational challenges [1]. Thermal emission radiance from Io's volcanoes spans more than six orders of magnitude and volcano behavior is highly unpredictable. Based on past experiences with *Galileo* instruments, two criteria must be met to measure the eruption temperature of Io's dominant silicate lavas (likely between 1400 K and 1900 K). The first criterion is obtaining unsaturated, multi-wavelength data of the hottest (>1400 K) exposed areas present [2]. The second is obtaining these multi-wavelength data simultaneously and quickly, overcoming uncertainty introduced into temperature measurements caused by rapid cooling between observations.

2. Current state of the technology

In the ideal application scenario, infrared imagers and spectrometers would provide high-resolution images containing spectral and temporal information with high signal-to-noise ratio and infinite dynamic range. The currently existing technologies are capable of providing only two out of three types of information (Fig. 1). For example, the currently deployed imaging spectrometers only acquire one-dimensional spatial imaging and utilize scanning to obtain a two dimensional image. This results in a time delay between obtaining data at different wavelengths for different points in the image, which is highly undesirable when a target event (e.g. a volcanic eruption) is changing on a time scale faster than the data acquisition time. Also, these instruments can be saturated if the signal is higher than anticipated. With volcanic eruptions for example, the strength of the thermal emission is impossible to predict.

3. Simultaneous multiband, infrared imager

We are currently developing a simultaneous multiband, infrared imager capable of observing a rapidly-changing transient events of unknown magnitude of thermal emission and areal extent without saturating the imager. This imager utilizes two new technologies: (1) a faceted mirror design of infrared imager (2) a digital focal plane array.

The faceted mirror design enables transient-event spectral imaging by simultaneously capturing a scene's spatial and spectral information in every frame. This design enables a multi-wavelength simultaneous data acquisition by incorporating a faceted, all reflective mirror system at near the stop plane of an Offner optical relay system [3]. Each facet imparts a phase term which diverts the beam to focus an image at a spatially shifted location on the focal plane. Once the light reaches the focal plane, each image is filtered using a "color" filter to obtain images in the selected spectral bands (Fig. 2).

The digital focal plane array enable non-saturating, very high dynamic range (>100dB) infrared imaging at high operating temperature with excellent spatial uniformity and long term stability. This advance in the digital focal plane array performance are achieved by use of two recent technological breakthroughs: digital read-outs circuits (DROICs) with internal counter and high operating temperature barrier infrared detector.

The recently invented high operating temperature (HOT) barrier infrared detectors (BIRD) are based on III-V compound semiconductors [4]. These offer an innovative solution for the realization of high-performance, large-format focal plane arrays (FPAs). The long wavelength infrared HOT BIRD FPAs cover 1 - 10µm spectral band with high sensitivity and operate at T = 70K with excellent pixel-to-pixel uniformity and pixel operability. Moreover, they do not suffer from 1/f noise, thus offering high temporal stability.

The novel DROICs used in this imager were developed by MIT Lincoln Laboratory [5]. These DROICs do not saturate due to the pixel-level analog-to-digital conversion and a digital counter integrated into each pixel. These digital counters do not saturate if their maximum count number is exceeded. Instead, they “roll over” and begin counting again from zero. The number of “roll overs” is stored so the true count number can be recovered using real-time processing. The result is a non-saturating detector with very high dynamic range.

4. Figures

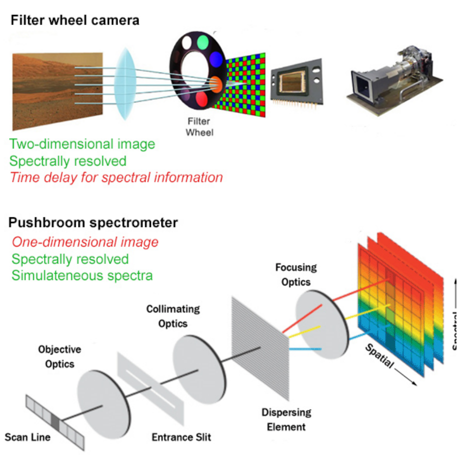

Figure 1: Two most commonly used approaches to acquire spectrally resolved images. (Top) The filter wheel camera that can obtain two dimensional images but has a time delay between images acquired in different spectral windows. (Bottom) Pushbroom spectrometer that only acquires a one-dimensional spatial image and utilizes scanning to obtain a two dimensional image.

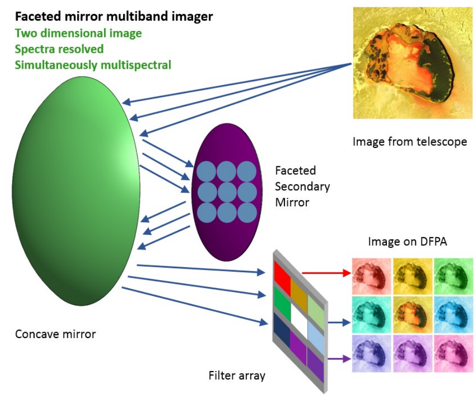

Figure 2: Illustration of a faceted mirror multiband imager. The faceted secondary mirror creates multiple images at the focal plane. Each image except for central one is filtered by a bandpass filters in a filter array mounted above the digital focal plane array.

5. Summary and Conclusions

We present our progress on development of non-saturating, simultaneous multiband, infrared imager that will enable investigation of Io’s extraordinary volcanism.

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