

High spatial resolution IR imaging system for Outer planetary missions

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Motivation:

There are numerous applications for instruments capable of combining high-resolution (megapixel) imaging with infrared color information, to “see through” planetary atmospheres. For example, Saturn and its moon Titan have thick, opaque atmospheres that prevent imaging of their surfaces at most visible and near-infrared wavelengths. Following the Cassini-Huygens missions, it is now known that both of these atmospheres have “windows” at specific wavelengths, where the surface is viewable (Fig. 1). High-resolution imaging system with sensitivity in these key infrared wavelengths would be a powerful technique for resolving planetary surface features beneath optically thick atmospheres. This system would also be capable of probing different depths in giant planet atmospheres, whose three dimensional atmospheric structure and dynamics could be imaged using an appropriate filter set (Fig. 2). Moreover, it could provide infrared color (i.e. composition) information on airless bodies. This imaging system has applicability to other planetary missions such as Venus.

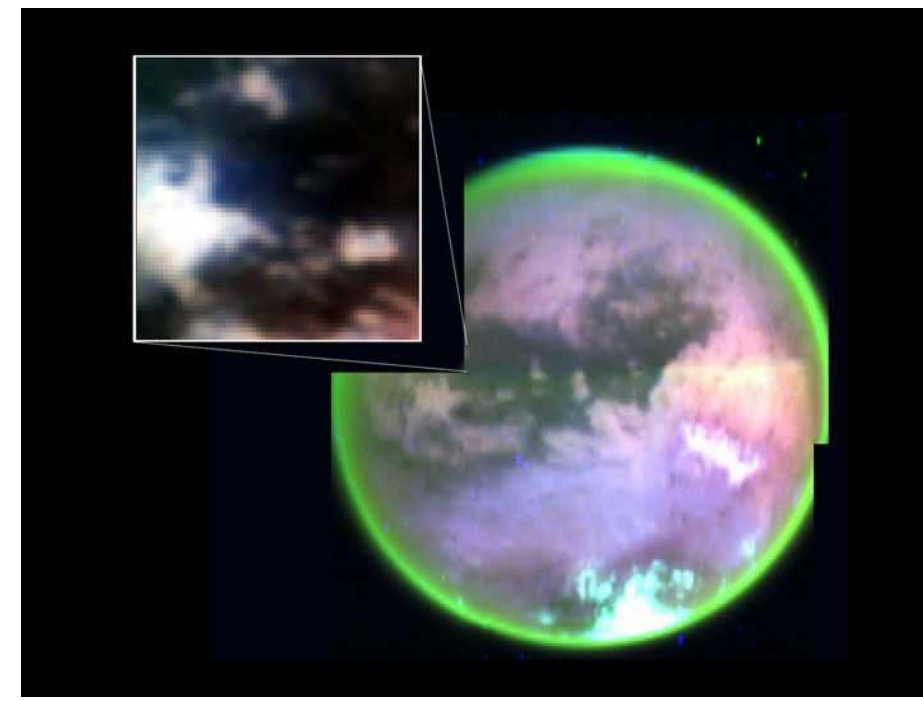


Fig. 1. Titan surface imaged by Cassini's visual and infrared mapping spectrometer (from <http://saturn.jpl.nasa.gov/photos/>).

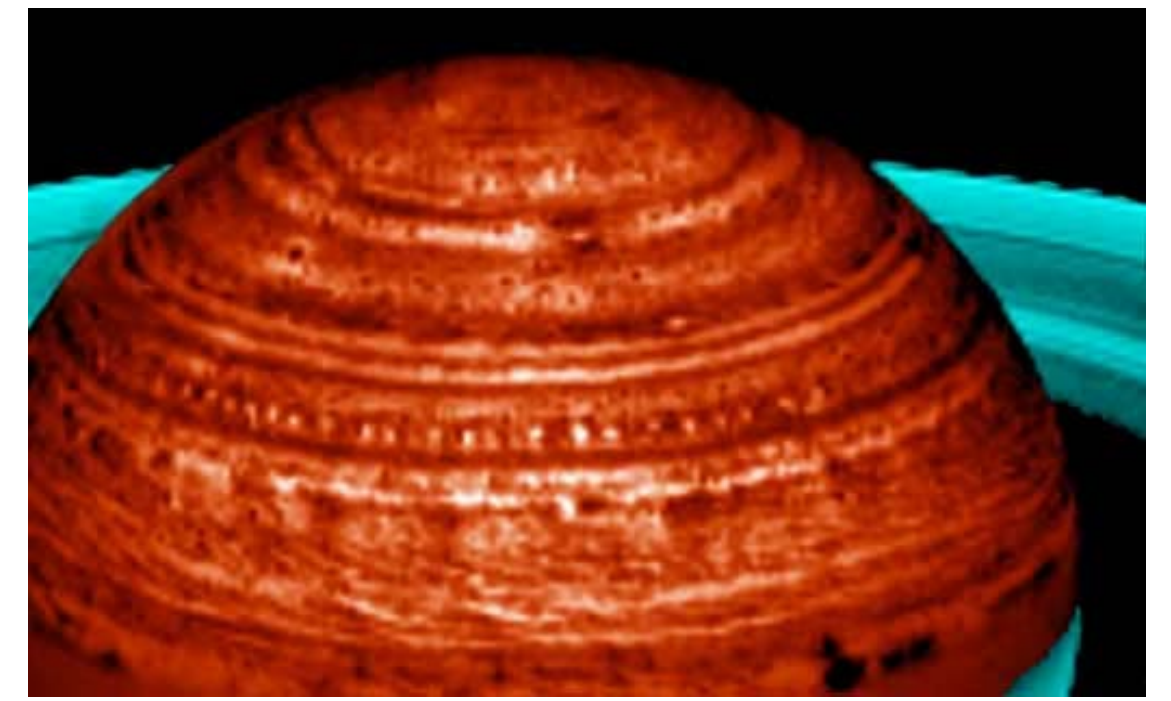


Fig. 2. Saturn's deep cloud system imaged by Cassini's VIMS.
Credits: NASA/JPL/University of Arizona

IR Imager:

This system is designed to take advantages of several technical breakthroughs in sensor technology to advance state-of-the-art of multispectral infrared imagers.

- Focal Plane Arrays (FPAs) based on Barrier Infrared Detector (BIRD) technology that can operate at higher temperatures.
- Low noise Digital Read-out Integrated Circuits (DROICs)
- Passive coolers.

The imager concept is shown in Fig. 3. The IR light is reflected by a rotating scanning mirror to the telescope. The collected light passes through an optical relay to the focal plane. The focal plane array and optical relay are cooled by a passive cooler.

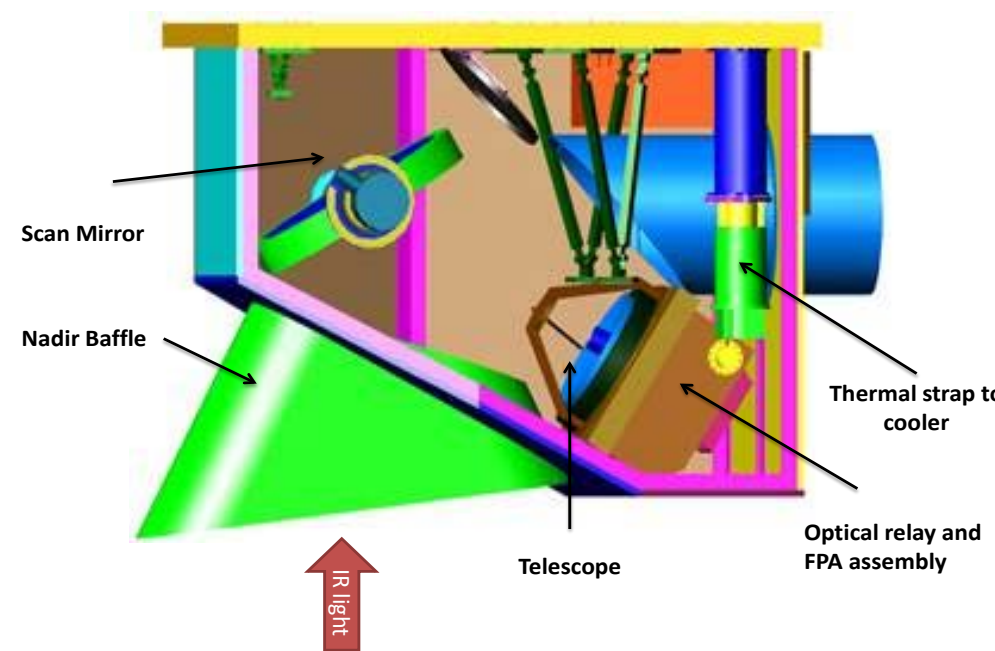


Figure 3: Schematic view of the imager

Digital Read-out Integrated Circuits (DROICs):

The IR imaging system uses digital CTIA ROICs, in which signal digitization takes place in the DROIC rather than performed by external electronics as in analog ROICs. This has several distinct advantages:

- High-speed data output
- Simple data handling since the FPA puts out digital data directly
- Low-noise data output
- Immunity to external noise sources for NUC stability
- Lower on-chip power on larger format arrays.
- Much lower power for warm electronics
- Virtually no crosstalk.
- Better uniformity and linearity than analog FPAs.
- Extremely sharp turn-on and turn-off to integration time allows true sub-microsecond integration

* Specifications are available upon request (ITAR restrictions apply)



Fig. 4. IR image of Pasadena City Hall taken with a JPL BIRD FPA.

Barrier Infrared Detector (BIRD) : The key to BIRD's success is that it can suppress dark current (noise) without impeding the flow of photocurrent (signal). The increased signal-to-noise ratio enables it to operate with higher sensitivity than a conventional p-n junction photodiode. Alternatively, for the same dark current level, the BIRD detector can operate at a higher temperature than the conventional p-n junction photodiode. Figure 6a illustrates the schematic energy band diagram of a standard p-n junction photodiode. Incident photons excite electrons thus creating photocurrent. Similarly, thermal processes can also generate electrons and holes, which, when collected at the contacts, constitute dark current. The energy band diagram of a BIRD is shown in Fig. 6b. The barrier is designed so it does not block the flow of photocurrent. The BIRD structure is designed to suppress generation-recombination dark current that is a dominant dark current mechanism. Moreover, surface leakage currents can also be suppressed in the BIRD structure by fabricating BIRD detectors in such a way that only the wide band gap barrier is exposed by shallow etching.

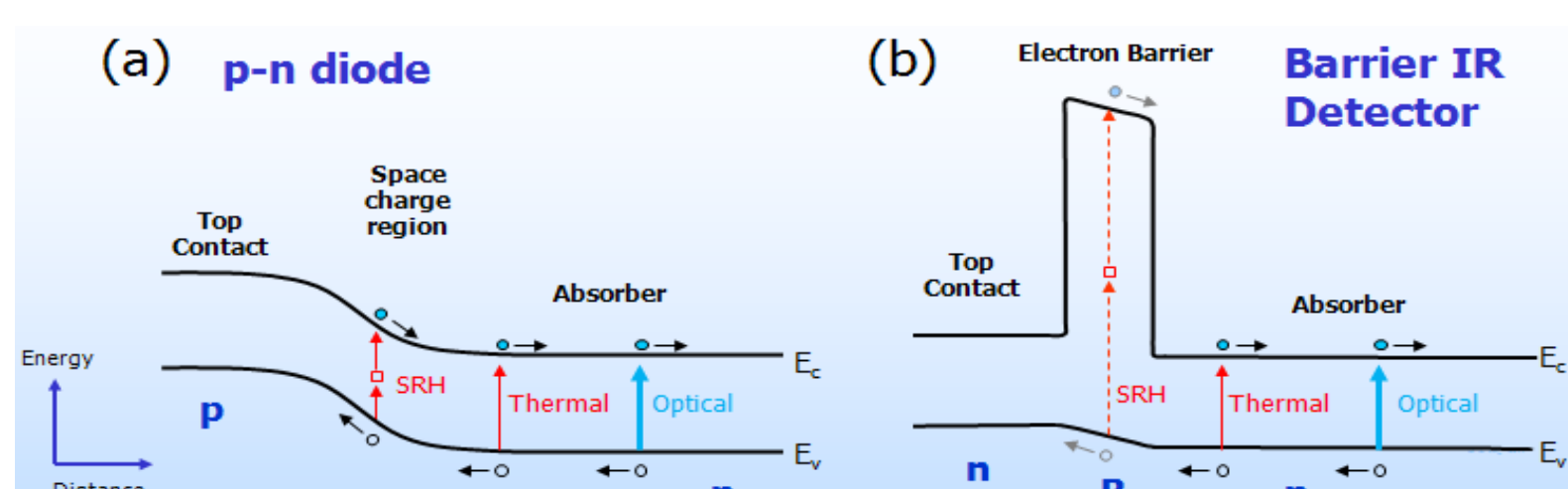


Figure 6. Schematic energy band diagram showing the conduction and valence band edges (E_c and E_v) of (a) a p-n junction photodiode, and (b) BIRD detector.

Barrier Infrared Detector (BIRD) FPA:

The Focal Plane Array (FPA) is a central part of an IR imager that typically defines the instrument performance.

The recently invented JPL BIRD technology offers a breakthrough solution for the realization of low-cost, high-performance FPAs with excellent uniformity and operability. BIRD detectors have the potential to outperform MWIR InSb or MCT devices. BIRD detectors offer numerous potential advantages over existing detector technology including

- Low dark current
- Broad spectral coverage
- High quantum efficiency
- Low $1/f$ noise (i.e., stability)

In particular, the very low $1/f$ noise and high temporal stability of BIRD detectors enable long integration times and eliminate frequent calibration. Also, BIRD FPAs can potentially operate at 15-20 C higher temperatures for the same performance as equivalent MCT devices, enabling passive rather than active cooling, or at lower temperatures with improved SNR and lower dark current. BIRD technology also offers robust manufacturability (both higher yield and uniformity) and lower development cost. The recent progress in the BIRD technology, including demonstration of large format, small pixel pitch MWIR and LWIR FPAs, clearly demonstrates that this technology has reached the maturity level required for infusion into planetary instruments (Fig 4, 5).

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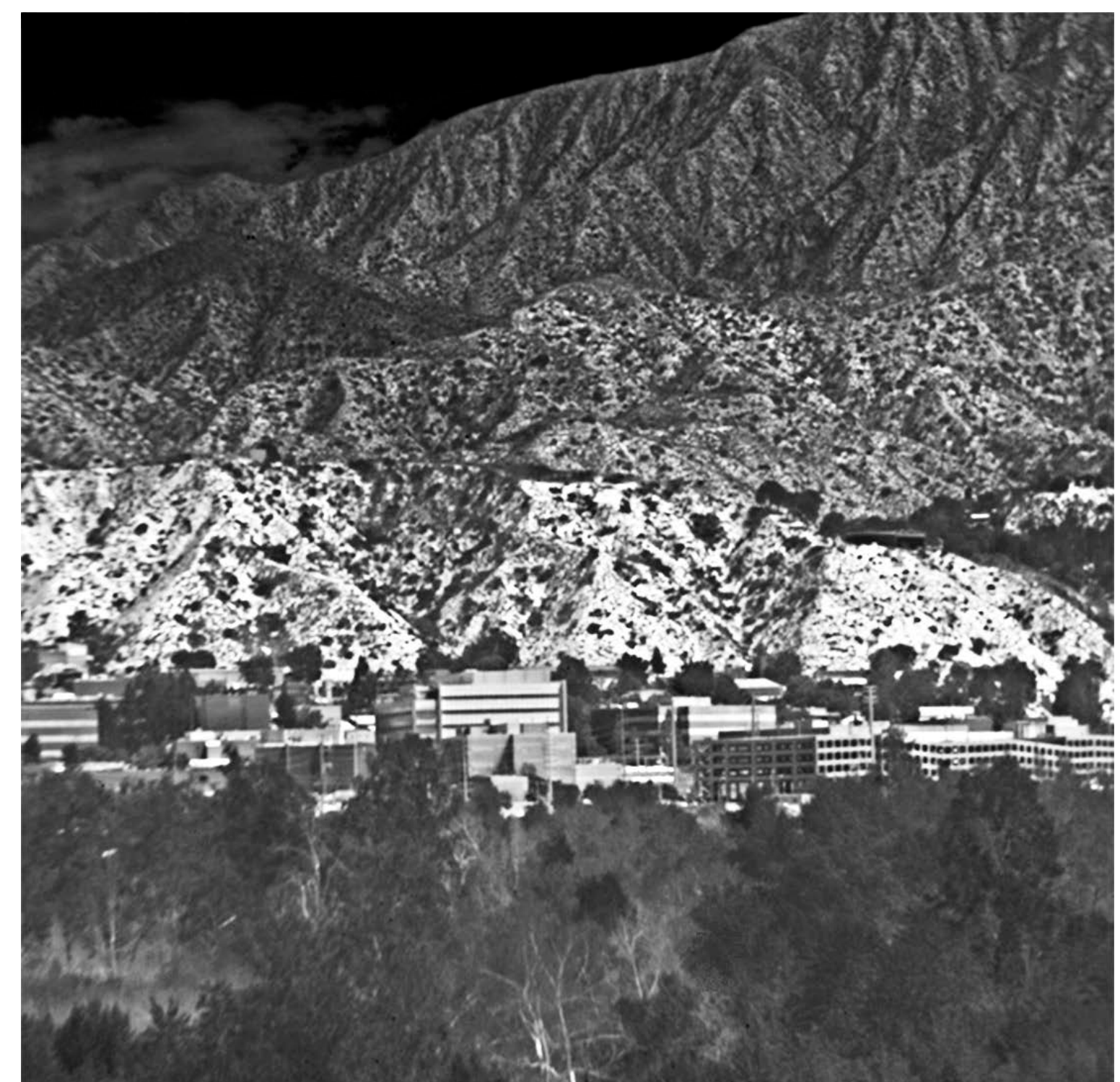


Fig. 5. IR image of JPL and San Gabriel mountains taken with a JPL BIRD FPA