# Multispectral Imager With Improved Filter Wheel and Optics

## "Dead" time is reduced substantially, relative to prior systems of the same type.

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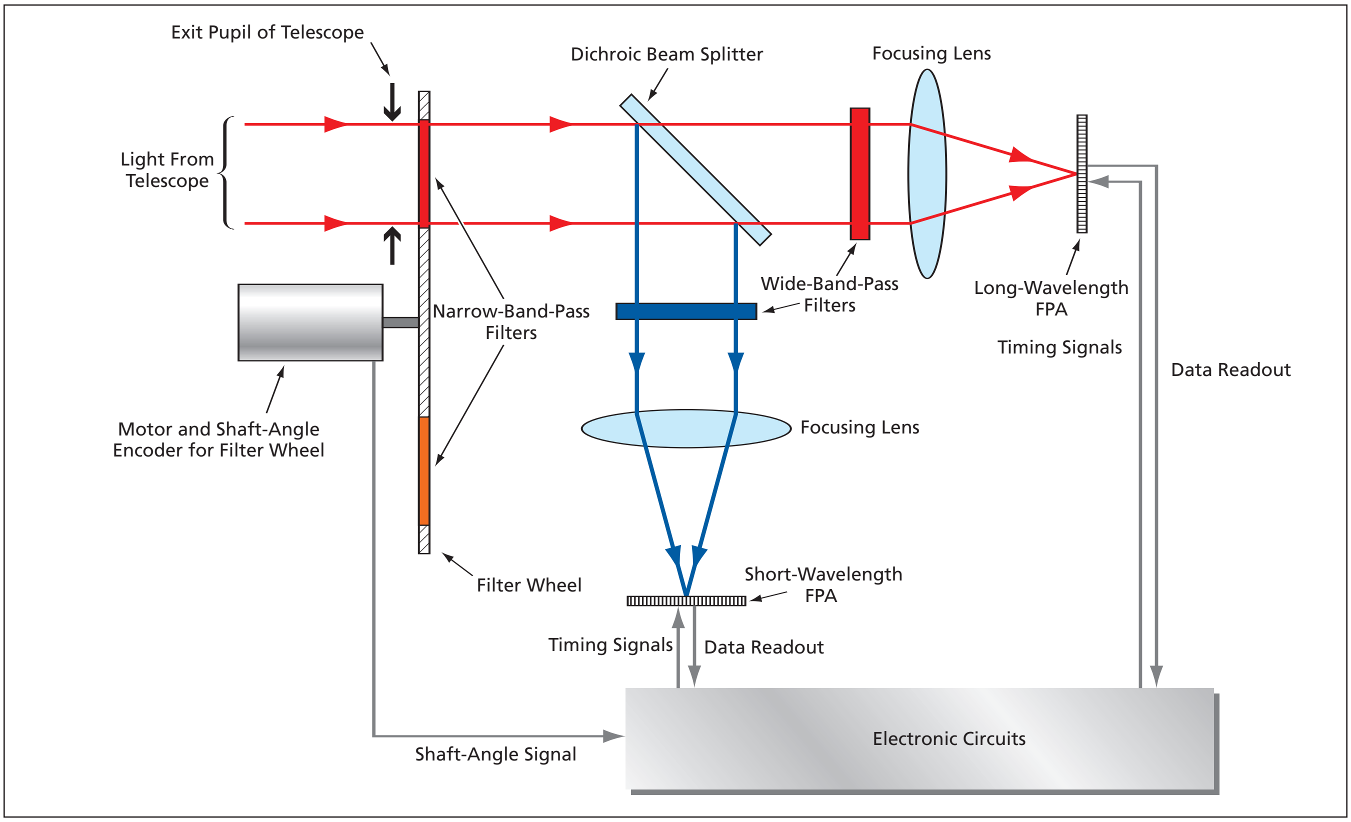


Figure 1. The **Dichroic Beam Splitter** and associated optics and electronics make it possible to utilize light from the telescope, even when the light beam straddles two adjacent narrow-band-pass filters. Light passed by one of these filters goes to one FPA; light passed by the other filter goes to the other FPA.

uFigure 1 schematically depicts an improved multispectral imaging system of the type that utilizes a filter wheel that contains multiple discrete narrow-band-pass filters and that is rotated at a constant high speed to acquire images in rapid succession in the corresponding spectral bands. The improvement, relative to prior systems of this type, consists of the measures taken to prevent the exposure of a focal-plane array (FPA) of photodetectors to light in more than one spectral band at any given time and to prevent exposure of the array to any light during readout. In prior systems, these measures have included, variously the use of mechanical shutters or the incorporation of wide opaque sectors (equivalent to mechanical shutters) into filter wheels. These measures introduce substantial "dead" times into each operating cycle — intervals during which image information cannot be collected and thus incoming light is wasted. In contrast, the present improved design does not involve shutters or wide opaque sectors, and it reduces dead times substantially.

The improved multispectral imaging system is preceded by an afocal telescope and includes a filter wheel positioned so that its rotation brings each filter, in its turn, into the exit pupil of the telescope. The filter wheel contains an even number of narrow-band-pass filters separated by narrow, spokelike opaque sectors. The geometric width of each filter exceeds the cross-sectional width of the light beam coming out of the telescope. The light transmitted by the sequence of narrow-band filters is incident on a dichroic beam splitter that reflects in a broad shorter-wavelength spectral band that contains half of the narrow bands and transmits in a broad longer-wavelength spectral band that contains the other half of the narrow spectral bands. The filters are arranged on the wheel so that if the pass band of a given filter is in the reflection band of the dichroic beam splitter, then the pass band of the adjacent filter is in the longer-wavelength transmission band of the dichroic beam splitter (see Figure 2).

Each of the two optical paths downstream of the dichroic beam splitter contains an additional broad-band-pass filter: The filter in the path of the light transmitted by the dichroic beam splitter transmits and attenuates in the same bands that are transmitted and reflected, respectively, by the beam splitter; the filter in the path of the light reflected by the dichroic beam splitter transmits and attenuates in the same bands that are reflected and transmitted, respectively, by the dichroic beam splitter. In each of these paths, the filtered light is focused onto an FPA.

As the filter wheel rotates at a constant angular speed, its shaft angle is monitored, and the shaft-angle signal is used to synchronize the exposure times of the two FPAs. When a single narrow-band-pass filter on the wheel occupies

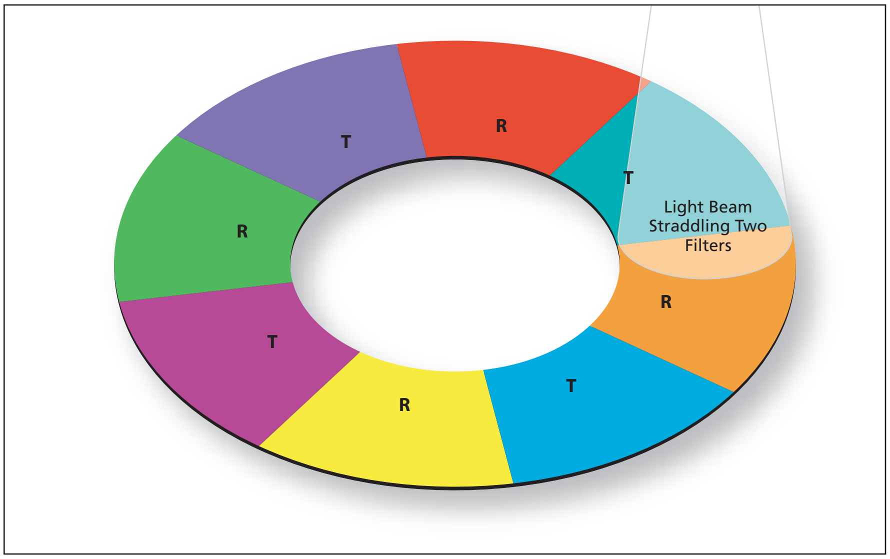


Figure 2. The **Filter Wheel** contains narrow-band-pass filters arranged so that the pass bands of adjacent filters lie, alternately, in the transmission (T) and reflection (R) spectral band of the dichroic filter.

the entire cross section of the beam of light coming out of the telescope, the spectrum of light that reaches the dichroic beam splitter lies entirely within the pass band of that filter. Therefore, the beam in its entirety is either transmitted by the dichroic beam splitter and imaged on the longer-wavelength FPA or reflected by the beam splitter and imaged onto the shorter-wavelength FPA.

When the beam straddles two narrow-band-pass filters on the wheel, the spectrum of the light incident on the dichroic beam splitter includes one component in the transmission band and one component in the reflection band. The fraction of beam power in each component at a given instant of time is approximately equal to the fraction of the cross-sectional area of the beam occupied by the corresponding narrow-band-pass filter. The out-of-band signal on each path downstream of the dichroic beam splitter is further attenuated by the broad-band-pass filter on that path. Each FPA integrates incident light during frame times synchronized with the rotation of the filter wheel. Because the dichroic filter and the broad-band-pass filter on each path block out-of-band light, each FPA can integrate a spectrally pure image, not only when the light beam is passing through a single filter, but also when it is straddling two adjacent filters.

The dichroic beam splitter and the narrow-band filters, in combination, act like a shutter for each FPA at the end of its integration period, making it possible to read out each FPA without incurring degradation of the image. The focusing lens and the FPA for each optical path downstream of the dichroic beam splitter can be optimized over a range of wavelengths spanning half the spectral bands of the system.

*This work was done by James C. Bremer of Swales Aerospace for* **Goddard Space Flight Center**. *Further information is contained in a TSP (see page 1).*
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# Integral Radiator and Storage Tank

## Weight and volume are reduced.

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A simplified, lightweight system for dissipating heat of a regenerative fuel- cell system would include a heat pipe with its evaporator end placed at the heat source and its condenser end integrated into the wall of the regenerative fuel cell system gas-storage tanks. The tank walls act as heat-radiating surfaces for cooling the regenerative fuel cell system. The system was conceived for use in outer space, where radiation is the only physical mechanism available for transferring heat to the environment. The system could also be adapted for use on propellant tanks or other large-surface-area structures to convert them to space heat-radiating structures.

Typically for a regenerative fuel cell system, the radiator is separate from the gas-storage tanks. By using each tank's surface as a heat-radiating surface, the need for a separate, potentially massive radiator structure is eliminated. In addition to the mass savings, overall volume is reduced because a more compact packaging scheme is possible. The underlying tank-wall structure provides ample support for heat pipes that help to distribute the heat over the entire tank surface.

The heat pipes are attached to the outer surface of each gas-storage tank by use of a high-thermal conductance, carbon-fiber composite-material wrap. Through proper choice of the composite layup, it is possible to exploit the high longitudinal conductivity of the carbon fibers (greater than the thermal conductivity of copper) to minimize the unevenness of the temperature distribution over the tank surface, thereby helping to maximize the overall heat-transfer efficiency.

In a prototype of the system, the heat-pipe and the composite wrap contribute an average mass of 340 g/m$^2$ of radiator area. Lightweight space radiator panels have a mass of about 3,000 g/m$^2$ of radiator area, so this technique saves almost 90 percent of the mass of separate radiator panels. In tests, the modified surface of the tank was found to have an emissivity of ≈0.85. The composite wrap remained tightly bound to the surface of the tank throughout the testing in thermal vacuum conditions.

*This work was done by Kenneth A Burke and John R. Miller of* **Glenn Research Center**, *and Ian Jakupca and Scott Sargi of Analex Corp. Further information is contained in a TSP (see page 1).*

*Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Glenn Research Center, Innovative Partnerships Office, Attn: Steve Fedor, Mail Stop 4–8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-17666-1.*