Broadband Achromatic Telecentric Lens

Lens works with a matched spectrometer for applications covering the entire solar-reflected spectrum.

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A new type of lens design features broadband achromatic performance as well as telecentricity, using a minimum number of spherical elements. With appropriate modifications, the lens design form can be tailored to cover the range of response of the focal-plane array, from Si (400–1,000 nm) to InGaAs (400–1,700 or 2,100 nm) or InSb/HgCdTe reaching to 2,500 nm. For reference, lenses typically are achromatized over the visible wavelength range of 480–650 nm.

In remote sensing applications, there is a need for broadband achromatic telescopes, normally satisfied with mirror-
based systems. However, mirror systems are not always feasible due to size or geometry restrictions. They also require expensive aspheric surfaces. Non-obscured mirror systems can be difficult to align and have a limited (essentially one-dimensional) field of view. Centrally obscured types have a two-dimensional but very limited field in addition to the obscuration. Telecentricity is a highly desirable property for matching typical spectrometer types, as well as for reducing the variation of the angle of incidence and cross-talk on the detector for simple camera types.

This rotationally symmetric telescope with no obscuration and using spherical surfaces and selected glass types fills a need in the range of short focal lengths. It can be used as a compact front unit for a matched spectrometer, as an ultra-broadband camera objective lens, or as the optics of an integrated camera/spectrometer system. This kind of camera and spectrometer system can find applications in remote sensing, as well as in-situ applications for geologic mapping and characterization of minerals, ecological studies, and target detection and identification through spectral signatures. Commercially, the lens can be used in quality-control applications via spectral analysis.

The lens design is based on the rear landscape lens with the aperture stop in front of all elements. This allows sufficient room for telecentricity in addition to making the stop easily accessible. The crucial design features are the use of a doublet with an ultra-low dispersion glass (fluorite or SFPL53), and the use of a strong negative element, which enables flat field and telecentricity in conjunction with the last (field lens) element. The field lens also can be designed to be in contact with the array, a feature that is desirable in some applications.

The lens has a 20° field of view, for a 50-mm focal length, and is corrected over the range of wavelengths of 450–2,300 nm. Transverse color, which is the most pernicious aberration for spectroscopic work, is controlled at the level of 1 μm or below at 0.7 μm field and 5 μm at full field. The maximum chief ray angle is less than 1.7°, providing good telecentricity. An additional feature of this lens is that it is made exclusively with glasses that provide good transmission up to 2,300 nm and even some transmission to 2,500 nm; thus, the lens can be used in applications that cover the entire solar-reflected spectrum. Alternative realizations are possible that provide enhanced resolution and even less transverse color over a narrower wavelength range.

This work was done by Pantazis Mouroulis of Caltech for NASA’s Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1).

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