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Spherical warm shield design for infrared imaging systems

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Highlights

- The detailed theory of spherical warm shield design is introduced.
- A polished spherical warm shield is designed based on the theory above.
- The stray radiation suppression performance and the alignment error are analyzed by simulation.
- Experimental results indicate that the designed spherical warm shield can suppress stray radiation sufficiently.

Abstract

The F-number matching is the primary means to suppress stray radiation for infrared imaging systems. However, it is difficult to achieve exact F-number matching, owing to the restriction from detectors, or multiple F-number design. Hence, an additional shield is required to block the certain thermal radiation. Typical shield is called flat warm shield, which is flat and operates at room temperature. For flat warm shield, it cannot suppress stray radiation while achieving F-number matching. To overcome the restriction, a spherical reflective warm shield is required. First of all, the detailed theory of spherical warm shield design is developed on basis of the principle that stray radiation cannot directly reach the infrared focal plane array. According to the theory developed above, a polished spherical warm shield, whose radius is 18mm, is designed to match an F/2 infrared detector with an F/4 infrared imaging system. Then, the performance and alignment errors of the designed spherical warm shield are analyzed by simulation. Finally, a contrast experiment between the designed spherical warm shield and two differently processed flat warm shields is performed in a chamber with controllable inside temperatures. The experimental results indicate that the designed spherical warm shield cannot only achieve F-number matching but suppress stray radiation sufficiently. Besides, it is demonstrated that the theory of spherical warm shield design developed in this paper is valid and can be employed by arbitrary infrared imaging systems.

Key words: Spherical warm shield; Infrared imaging system; Stray Radiation; Radiometric calibration

1. Introduction

Stray radiation, known as the stray light, refers to the unwanted radiation or light that reaches the infrared focal plane array (IRFPA). Stray radiation can reduce the signal to noise ratio (SNR) of images [1, 2]. There are many methods to improve the stray radiation suppression performance of an infrared imaging system. But for cryogenic infrared imaging systems, the primary means of reducing stray radiation is to take the cold stop as the aperture stop, namely the F-number matching or 100% cold shield efficiency [3, 4]. When the F-number matching is achieved, which means the F-number of optics equals to the F-number of detector, only the radiation inside the field of view (FOV) can reach the IRFPA [5, 6], as shown in Fig. 1. As a result, the stray radiation is suppressed sufficiently. However, it is difficult to achieve the accurate F-number matching in practical applications, due to the restriction from detectors or the requirement for multiple F-number design, etc. For example, the F-number of typical cryogenic infrared detectors is F/2 or F/4, which means in order to suppress stray radiation, the F-number of infrared imaging systems must be equivalent to F/2 or F/4. As a result, we cannot build infrared imaging systems with other F-number, such as F/8 or greater.