Collimator Design for Dynamic IR Scene Projection

PRECISION-OPTICAL ENGINEERING

OSE 004

Application Note

Introduction

HardWare-In-The-Loop testing (HWIL) is a way of assessing the effectiveness of missile seekers in acquiring and tracking their targets without carrying out a live firing. HWIL testing has three main hardware requirements: the target simulator device which generates the thermal scenes; a collimator which projects the target and the means of driving the target simulator and seeker. This technical datasheet describes a collimator, designed by the Optical Systems Engineering team at P-OE which is used in the long wave region of the infra-red spectrum, 8-12 microns. The target simulator is a 256 x 256 pixel resistor array located on a 61.44 x 61.44 mm substrate developed by the British Aerospace Sowerby Research Centre. The Unit Under Test (UUT), collimator and resistor array are mounted on a 5-axis flight motion simulator, or flight table, where the entrance pupil of the UUT lies at or near the centre of rotation of the 5 main moving structures. The UUT can undergo three movements: roll, where the UUT can be rotated about a longitudinal axis; pitch and yaw. The thermal picture projection movement can be controlled in pitch and yaw to maintain alignment between the UUT and the projected scene.

General Optical Layout

A general schematic layout of the collimator is shown in Figure 1, illustrating the main factors which influence the overall collimator structure.

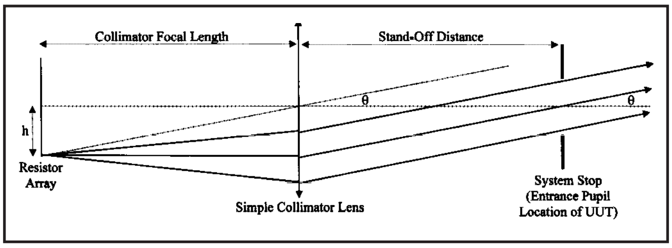

Figure 1. General optical scheme for collimator

The system is designed as if the resistor array is the image (detector) rather than the object (source). The semi-field angle needs to be compatible with the range of UUTs. The area of the array to be projected then determines the focal length according to

$$EFL = h/\tan\theta$$

The entrance pupil of the UUT acts as the system stop of the collimator. Unusually, the stop is a long way outside the system and the separation of the stop directly influences the size of the optical components. The distance between the aperture stop and the front lens of the collimator is known as the stand-off distance. The diameter of the front lens is a function of stop size, field angle and stand-off distance, where

the minimum clear aperture of the front lens = (2 x stand-off distance x tan(θ)) + stop diameter

Collimator Design

The general collimator layout is shown in Figure 2. The overall output lens clear diameter is 140 mm and the focal length is 908 mm. The collimator operates in the 8-12 micron thermal waveband, so germanium is used for all optical components except lens 3. This is made from

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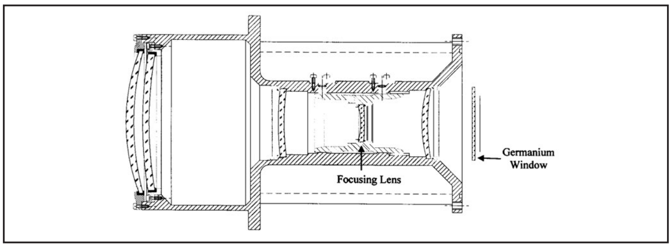

Figure 2. Collimator layout

zinc selenide for chromatic correction. Lens 4 is held in a separate barrel to provide focus adjustment for initial setting up and athermalisation. The overall length from the UUT entrance pupil to the resistor array plane is 1253.0 mm. The resistor array has the 61.44 x 61.44 mm format described above. The level of resolution is consistent with the pixel size.

The collimator is designed to be telecentric with all principal rays controlled to well under 1.0 degrees.

Athermalisation

The collimator has been designed to work under laboratory conditions, within a temperature range of 10 to 30 deg C. Even over this relatively small temperature range, the change in refractive index of germanium with temperature (the thermo optical coefficient) is of significance. This means that it is necessary to refocus to compensate for temperature change despite the very low relative aperture. The mechanical construction of the collimator allows lens 4 to be moved manually, with graduated positions according to temperature.

Mechanical construction

The collimator body is made from high strength aluminium alloy and is attached to the flight table by a 9 mm thick interface plate. This gives sufficient rigidity to control dynamic boresight error to less than half a pixel. The focusing and athermalisation mechanism consists of a sleeve containing lens 4 which can be manually rotated. The structure is sufficiently robust to withstand forces of up to 3 g that are experienced during normal flight table operation and of over 5 g should a flight table arm hit an end stop for any reason.

Recent developments

The collimator described above has been successfully used for several years, and the experience gained has allowed P-OE to add to its range of IR Scene Projection Collimators. Systems have been designed to take advantage of the higher resolution 512 x 512 arrays currently available and the 1024 x 1024 arrays under development.

A number of the new systems are used in the 3-5 micron waveband and incorporate additional ports for the injection of two or more sources. IRSP collimators can be designed to customer requirements according to the waveband of operation, the architecture of the hardware in the loop test bed and the characteristics of the unit under test (primarily entrance pupil diameter and field of view).

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