

Dual Aperture Optical System for Infra-red Camera

Conventional infra-red optical systems with high magnification and switchable FOVs (field of view) suffer from strong unwanted Narcissus effect (a form of thermal noise). This is mainly caused by retro-reflections from the objective lens back to the detector plane. In this project, a new dual aperture optical configuration has been developed to reduce substantially the Narcissus effect while maintaining good optical performance.

A design example is presented in this paper. The relative Narcissus Induced Temperature (NIT) is reduced from about 1.4°C to about 0.1°C, thus enhancing the detection range of the infrared system.

1. Conventional Optics Design

Conventional infrared optical systems with multi-FOV are normally designed with one fixed objective lens and a few lens groups arranged in a rotational structure to achieve different FOVS. An example of this type of optical system with 3 switchable FOVs is shown in Fig 1.

2. Narcissus Effect in Wide FOV

As shown in Fig 1, the conventional design approach uses one common objective lens which is shared by all different FOVS.

Based on this approach, when the system requires a high magnification between the narrow and wide FOVS, the effective aperture required for the wide FOV at the objective lens will be much smaller compared to narrow FOV (assume same F/# for all FOVS). As a result, strong unwanted Narcissus appears in the wide FOV, which is mainly caused by retro-reflection from the objective lens back to the detector plane.

To demonstrate the Narcissus effect in the wide FOV, Fig 2 shows the ray trace of retro-reflections at the objective lens. It can be seen that Narcissus is mainly caused by the objective lens.

Generally, Narcissus effect can be quantified by the Narcissus Induced Temperature (NIT) analysis. Fig 3 shows a plot of NIT vs detector plane in the wide FOV, based on the example shown in Fig 1. The relative NIT (difference between the peak response and the background) in this system is about 1.4°C. This value is not acceptable, because it is much higher than the system noise equivalent temperature (NET), normally less than 0.1°C. The MTF performance in the wide FOV is shown in Fig 4.

3. Dual Aperture Design

The idea of this new design is to make a separate optical path for the wide FOV, thus reducing the Narcissus effect, since no ray is going through the objective lens. An example of this design approach is demonstrated in Fig 5. This design is modified and improved from a conventional design (see Fig 1). Basically, the design for the narrow and medium FOV remains unchanged. As for the wide FOV, one meniscus lens and two reflective mirrors are added in the optical path. The NIT and MTF performance of the wide FOV are shown in Fig 6 and Fig 7 respectively. The relative NIT of this design is greatly reduced to about 0.1°C.

Conclusions

The use of Dual Aperture optical design to reduce the Narcissus effect in a multi-FOV infrared optical system is demonstrated. The design concept can be implemented in many advanced infrared camera systems with switchable FOVS. Based on this idea, a long range multi-FOV infrared optical system, with no Narcissus effect and good optical performance has been developed.

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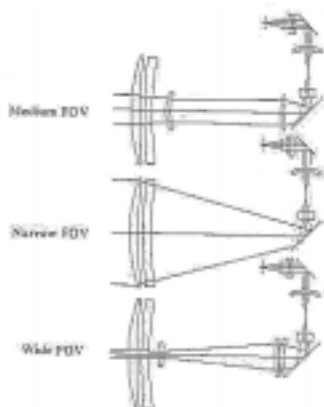


Figure 1 : Conventional Optical Design

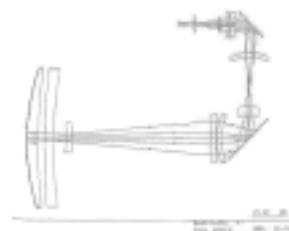


Figure 2 : Ray Trace in the wide FOV

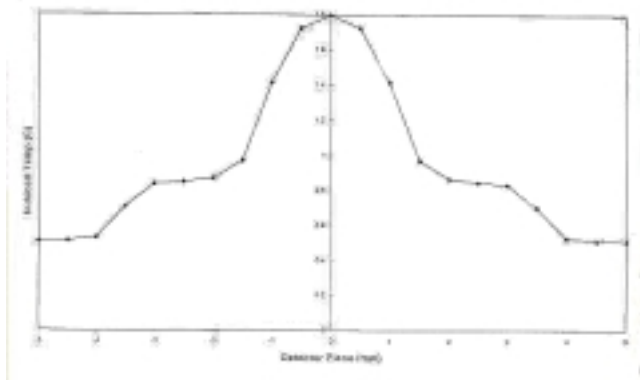


Figure 3 : Narcissus in the wide FOV (old design)

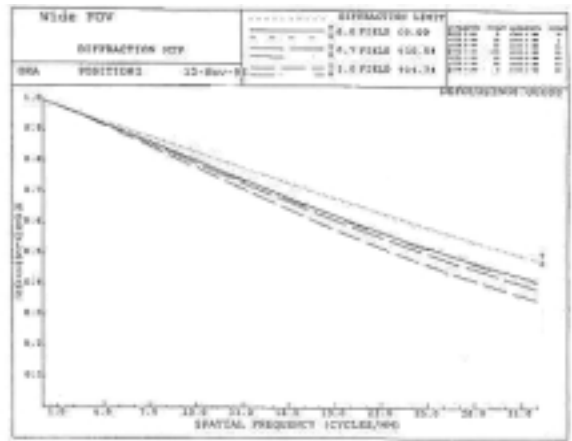


Figure 4 : MTF of wide FOV (old design)

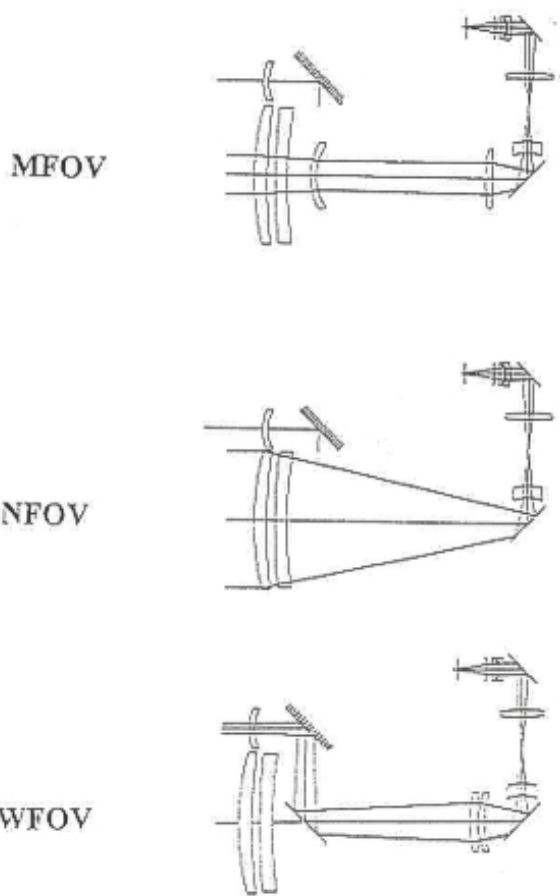


Figure 5 : Dual Aperture Optical Design

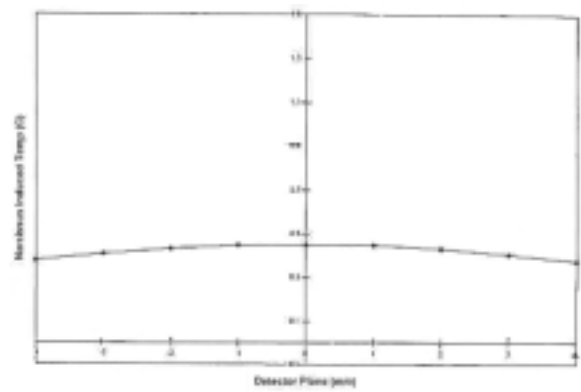


Figure 6 : Narcissus in the wide FOV (new design)

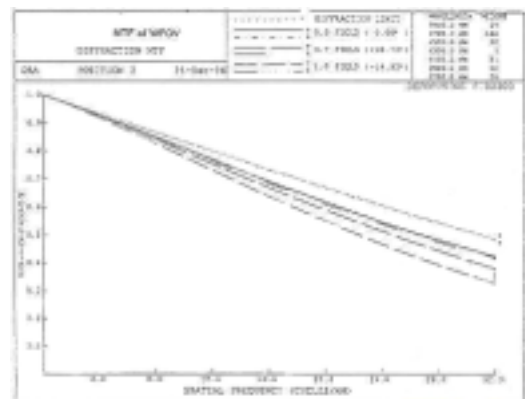


Figure 7 : WTF in the wide FOV (old design)