Design of a 5:1 Zoom Lens for a Mid-format Infrared Focal Plane Array

K. Venkata Ravi
Research Centre Imarat, Vignyana Kancha, Hyderabad, 500069

Abstract

A long wave Infrared Zoom lens with a zoom ratio of 5: 1 for an infrared camera has been designed. The moving groups in this zoom lens are two. The loci of zoom are relatively simple. This allows for simpler opto-mechanical/electromechanical design.

Keywords: Optics Design, Zoom, Infrared

1. Introduction:

The applications of infrared cameras have increased and diversified in recent years. The functionalities, range of field of view and compactness are being demanded. However due to the difficulties in fulfilling those demands simultaneously, usage of zoom cameras has been limited. The focus shifts and losses in imaging capabilities due to temperature changes is very well known in the Infrared community. This is a major problem in the infrared optics design. Several methods have been reported to overcome this problem. We needed to develop an infrared camera in our application where the optical performance is maintained at all temperatures.

The starting point for the design of an Infrared optical system can be any of the following.

1. Commercially available zoom system
2. Zoom lenses described in patents or other reference literature
3. Thin lens solution

Selection of the starting point is very important decision to be made by the optical designer. This will strongly influence the direction of the design activity and the likelihood of the desired solution. Since designing zoom lenses is more complicated and time consuming than fixed focus lenses, selection of the best starting point is more crucial.

In most cases the starting point is patent literature or the lens prescriptions given in lens/optics design text books. There are two types of zoom lenses: Optically compensated and mechanically compensated. For any practical system, optically compensated zoom lenses are not used as the image plane is not one position. There is large excursion of the image plane which makes the systems very difficult to realize.

2. Design and Analysis

2.1 Design configuration

The zoom lens is designed for Sofradir’s 320X256 staring Focal Plane Array (FPA). The main specifications of the detector are given in table 1. The desired optical characteristics for the zoom lens for the FPA are given in table 2.

Table 1

Array Features

Pixel pitch	30 µmx30 µm
Aperture	F/2
Material spectral response	0.8 µm – 9.5 µm or 0.8 µm – 11.0 µm
Detector spectral response	7.7 µm to 9.5 µm
FPA Operating Temperature	77K for 9.5 µm

The zoom lens can be functionally divided into focusing part, zooming part and imaging part. In this design we have used re-imaging type of system. This is chosen in such a way to minimize the objective lens diameter while maintaining 100% cold shield efficiency. In infrared systems 100% cold shield efficiency is essential part of the design. Without 100% cold shield efficiency, the detector will receive parasitic flux. This will degrade the image. Basically the detector will see the hot body of the optics, which is nearby, along with the scene radiation.

Table 2

Optics Specifications

Operating wavelength range	7.7 µm to 9.5 µm
Aperture (F Number)	F/2
Zoom Ratio	5:1
Field of View (vertical)	1.6 Degree, NFOV
	8.0 Degree, WFOV
Front Lens Optical Diameter	140 mm

A continuous, mechanically compensated zoom with a zoom ratio of 5:1 is designed. The focal length varies from 54mm to 270mm.

In design process, enough care was taken to ensure that there are no deep curvatures or small thicknesses. These will be difficult to manufacture. Deep curvatures will result in very tight tolerances on the radius of curvature. The glasses are chosen such that there is a good chromatic correction over the complete zoom range. The number of glass types chosen is also minimized.

2.2 Design Results

The final design schematic is shown in Figure 1. This lens comprises of Objective, zooming part which comprises of 3 lenses in two groups, focusing group and re-imaging group. The zooming part is simple configuration. The zooming lenses move nonlinearly. This helps in reducing the total track of the system. There is no cross over or negative thicknesses in the whole zooming range. The distances at extreme zoom positions are have been kept at some reasonable values so that the lenses are mechanically separated. The power distribution of these groups are +, -, +, +. The groups 2 and 3 are the mechanically compensated moving groups. The group 2 consists of two lenses and group 3 consists of one lens. There are 4 conic surfaces in the re-imaging group. This help in balancing the aberration over the complete zooming range. The overall length of the complete system is restricted to 310mm.

The materials used in the design are Germanium and Zinc Selenide. Both the materials have good transmission in the infrared and can be fabricated easily. Germanium has very low dispersion in the LWIR region and is widely used material for lenses. Zinc Selenide is used as the colour correcting element for the complete zoom range.

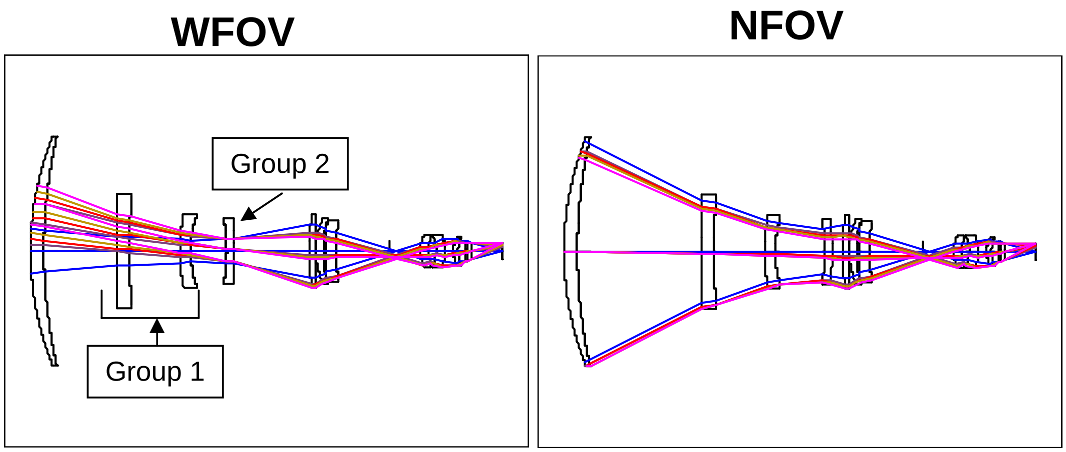

Figure 1: Schematic of Zoom Lens

2.3 Performance Analysis

Modulation Transfer function (MTF) was used as the principal method for quantifying the performance of the optical system. Figure 2 shows the polychromatic MTF of the designed zoom system. These curves are shown for the 2 extreme zoom positions. Spatial Frequency vs Modulation are plotted in these diagrams. These plots show that the system essentially gives a near diffraction limited performance for these positions. The performance for other zoom positions is similar.

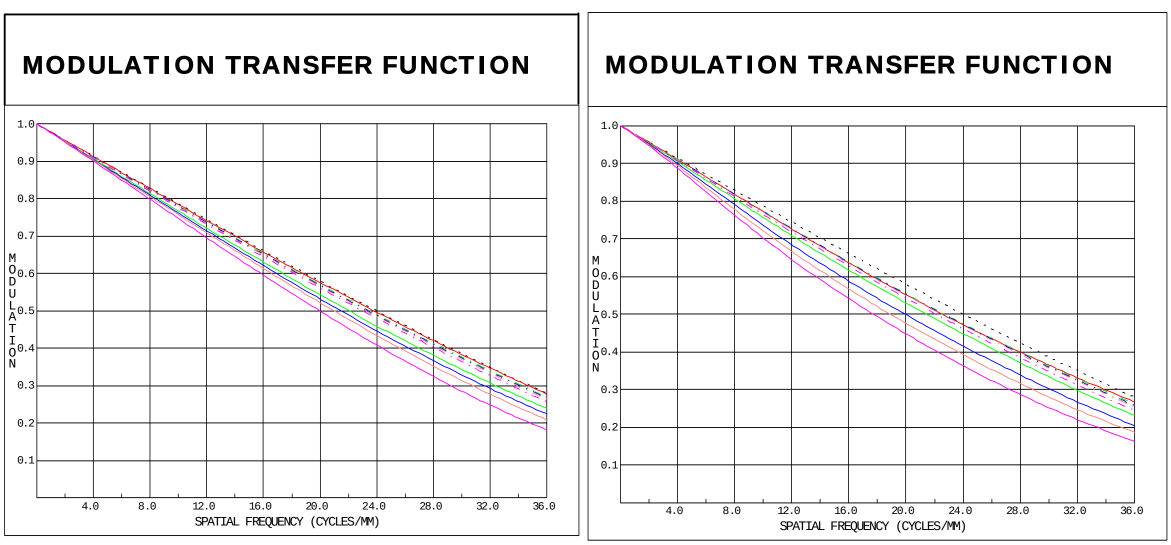

Figure 2: Design performance

The distortion for the system is less than 1% for WFOV and less than 3% for the NFOV.

3. Conclusions

The design of a mechanically compensated zoom lens has been presented. This zoom lens can provide a zoom ratio of 5:1. The design performance is near diffraction limited. The lens can give possibilities for various applications such as surveillance, tracking and target acquisition.

4. References

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