OPTICS FOR LASER SEEKER

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Abstract: This paper presents the optics design of laser seeker for semi-active homing of precision, guided munitions. The designed optical system has a field of view of 25º, EPD of 40mm and the working wavelength is 1064 nm. The design constraints/criticality of the system is discussed. The performance evaluation curves are also presented.

Keywords: Precision guided munitions, Laser Seeker, Optics design

1. INTRODUCTION

Seeker is used for automatic homing of precision, guided munitions. There are two types of seekers; imaging seekers and non-imaging seekers. Imaging seekers are passive in nature, operate at IR wavelengths and match target signature. Laser seeker is a non-imaging type of seeker. This is an active device. For automatic, self-controlled homing of the aerial platform at the terminal guidance stage, the target is illuminated by a laser designator. The laser designator may be located on a ground-based or air-borne platform. The laser beam used to designate a particular target is usually encoded so that a friendly target is not engaged. The laser light reflected from the target is collected by an optical system onboard which focuses the light on a quadrant detector. The departure of the target from the line of sight of the seeker optics module is determined by the ratio of energy falling on different quadrants of the detector, which is then fed to the guidance system of the aerial platform to steer it towards the designated target. The guidance system works on proportional navigation principle. Naturally, for proper generation of the error signal from the quadrant detector, the light spot falling on it needs to be perfectly circular in shape, uniform in intensity in all fields of view as well as big enough (of the order of $1/4^{th}$ to half of the diameter of the detector) to cover major portions of all the four quadrants simultaneously. Correction of asymmetric aberrations is required while spherical aberration and defocus needs to be deliberately introduced in the optical system to achieve the stated nature of the light spot. Wider the field of view of the optical system, greater is the probability to detect light reflected from a misaligned target. The designed optical system has a field of view of 25º. To increase the field of view further, the optics may be mounted on a gimbal and wider area can be scanned for target detection (field of regard). In addition to it, the system needs to be light weight as well as small in size. Narrow band filters are used in front of the optics in order to suppress undesired wavelengths from reaching the detector; thus enhancing the signal-to-noise ratio. The entire module is placed inside a separate optical dome to provide a protective cover as well as for aerodynamic design.

In the following sections, we present the design methodology and the layout of the optics for laser seeker. The design constraints/criticality of the system is discussed. The performance evaluation curves like spot diagram, factor of encircled energy, uniformity of energy distribution on the sensor plane of the detector are also presented.

2. THE OPTICAL DESIGN & LAYOUT

A silicon quadrant detector has been used in our system, the diameter of the active sensor area being 11.3mm. The required optimum size of the light spot is 5.5mm in diameter (almost half the diameter of the detector). The proportional field of view of the system is required to be 12.2º. The detector has peak spectral response at around 1µm. Naturally, the designation is done with Nd:YAG laser (1.064 µm). The range at which a target can be detected depends on the amount of light energy collected and in order to get a desired range, EPD of the optical system has been taken to be 40mm. Once the detector size and the FOV of the system are specified, the effective focal length of the optical system also gets fixed. In our case, the effective focal length of the lens system is 25.4mm and F# is 0.64. As perfectly circular as well uniform light spot should be formed on the quadrant detector in all FOVs for proper functioning of the seeker, automated optimization process could not be used in this case since computerized optimization only reduces the RMS spot size and does not lead to a uniform energy distribution. By manual adjustment of various design parameters, circular as well as uniform spot of diameter 5.5mm was obtained at an in-focus plane. The designed system consists of two spherical lens elements, both made of SF14 glass (figure-1). Since the field of view is high and the required f-number of the system is less than 1, use of high index glass is inevitable. Moreover, mechanical constraints were there on the size of the two lenses as well as the distance of the detector from the last lens of the optical system. All these constraints together made the design critical. The distance of the sensor plane from the vertex of the last lens is 5.3mm, the effective focal length of the lens system being 25.4mm. It may be mentioned in this connection that the paraxial image plane or the best focus plane of this optical system is further away as uniform distribution is obtained in an in-focus plane. The vertex of the front lens to detector distance is only 33mm and the weight of the designed optics is around 55g only.

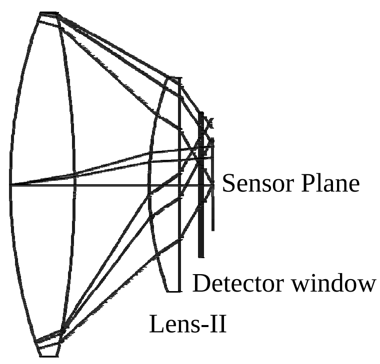

Figure-1: Optical Layout

3. PERFORMANCE OF THE OPTICAL SYSTEM

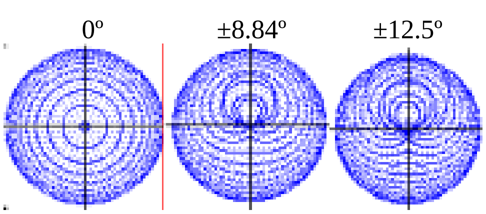

Figure-2: Nature of the spot formed on the Quadrant Detector for various FOV

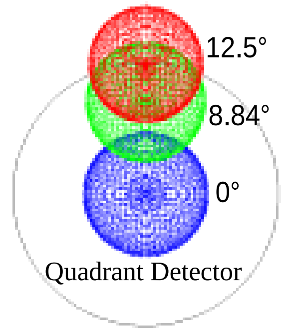

Figure-3: Location of the spots on the quadrant detector for various FOV

Figure-2 and figure-3 show the nature and location of the spot formed on the quadrant detector for various fields of view. From the nature of the spots it is clear that as off-axis aberrations like coma could not be made negligible the uniformity of the spots are slightly affected for off-axis field points. These spots are not formed on the paraxial image plane or the best focus plane. Defocus has been deliberately introduced to get the best possible uniform energy distribution on the sensor plane of the detector. Figure-4 depicts the factor of encircled energy for various FOV. The diameter of each spot is around 5.5mm as required. In fact, the spot formed by the axial beam is marginally bigger than that formed by off-axis beams. Figure-5 depicts the normalized energy versus area plot for various FOV. The dotted line is for ideally uniform energy distribution across a spot of diameter 5.5mm. It is obvious that the concentration of energy suddenly rises towards the edges as compared to the ideal curve and the diameter of the spots is slightly lower than 5.5mm (please note that $[5.5mm/2]^2 = 7.5625mm^2$).

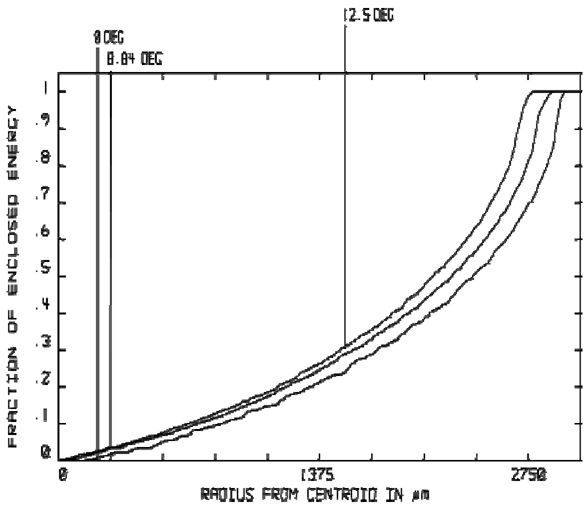

Figure-4: Factor of encircled energy for various FOV

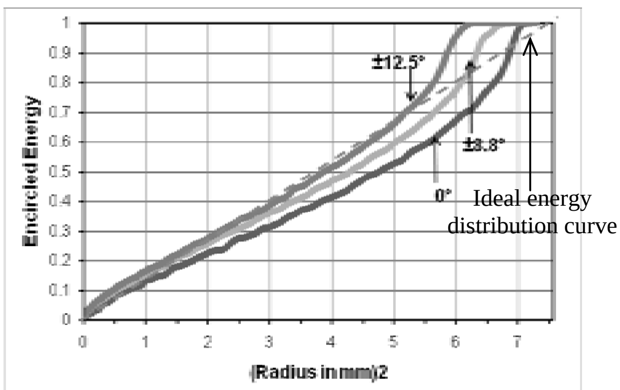

Figure-5: Energy vs. area plot for various FOV

4. CONCLUSION

This paper describes the optics design of laser seeker for semi-active homing of precision, guided munitions. The designed optical system has a field of view of 25º, EPD of 40mm, focal length of 25.4mm, F# 0.64 and the working wavelength is 1064 nm. The proportional field of view of the system is 12.2º and a circular as well as uniform spot has been obtained at an in-focus plane. The design constraints/criticality of the system was discussed. The performance evaluation curves were also presented.

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