Abstract: Laser Seekers are used for the detection of the reflected laser pulses from a target and for tracking the target location. The seeker optics plays a pivotal role in gathering the information from the target and focusing on to the detector. The critical design aspects of Laser Seeker optics and electronics are discussed. The circular spot uniformity and the energy distribution inside the spot are also analyzed. A brief overview of the work carried out in the realization of hardware and the generation of error signals for a seeker is presented in this article.

1. INTRODUCTION

There has been large scale proliferation of Lasers and Optoelectronic devices and systems for application like range finding, Target acquisition, Target tracking and designating. The unique characteristics of lasers offer significant improvements in the detection limits up to several kilometers. Highly divergent beam can give pinpoint accuracy in the detection of target of interest from very long distances. This paper gives an overview of the work carried out on the design of a optoelectronic device. Laser seeker system is a semi active spot tracker used for guiding the munition for its precise deployment on to the designated target. Guided munition launched from an aircraft may employ a self contained receiver to receive the reflection from the target illuminated by the launching aircraft.

The seeker operates as a beam rider or follows the illuminated beam to the target. This is known as the semi active homing. The seeker unit is housed in an aerodynamic stabilizer and mounted on a gimbal enabling free pitch and yaw movements. It gets aligned with the velocity vector.

2. SEEKER DESIGN

The seeker head consists of the front end optics, detector, preamplifier and post processing electronics. The block diagram of the seeker is shown in Figure 1. Since the atmospheric effects play a major role when laser beam is incident on to a distant target, the following aspects are to be considered in the design of a laser seeker.

- Designator characteristics like peak transmitted power, beam divergence etc
- Backscatter effect
- Atmospheric visibility
- Target characteristics and reflectivity
- Selection of low noise amplifier
- Receiver characteristics like FOV, collecting aperture and detector characteristics
- High frequency design techniques

2.1 Seeker Optics Design

The front end optics collects the reflected energy within its Field Of View (FOV) from the target and makes a uniform circular spot on a quadrant detector.
The optical transmission expected is more than 70% for the required collecting aperture. Total FOV required is ±15°. The operating wavelength is 1.06 micro meter. The size of the spot has to remain the same throughout the received field of view of ±15°. The constraints here are maintaining the weight and the transmission of optics. To meet all this requirement a single lens concept becomes cumbersome. A combination of lenses (ie) minimum two lenses with different glass materials is considered. To arrive at the best optimal design there is a trade off in selection of material. Optical material like Bk-7, SF-14 and SF-12 from catalogue Schott and Pilkington is chosen. The design has been optimized using Zemax software. The proportional region expected with this design is more than ±3.

2.2 Spot Uniformity

The defocused spot made on the image plane at different angles are analyzed. The variation in the spot size is from 3000 micron at (zero degree FOV) to 3200 micron (15 degree FOV). It is observed that the spot remains uniform throughout the proportional region for different target positions. The spot diagram analyzed using zemax in the linear region is shown in Figure 2.

From the encircled energy diagram shown in Figure.3 and Figure 4, it is evident that the energy distribution in the spot at zero degree FOV and 4 degree FOV is uniform. The theoretical estimates and the practical values arrived at are in accordance. Tolerance analysis for the optics has also been carried out to compute the acceptable tolerance limits during fabrication. The tolerance values for the surface tilt, thickness of the glass, radius of curvature were analyzed and found that the results are within acceptable limits.

Figure 3 ENCIRCLED ENERGY DIAGRAM

Thermal analysis at two extreme temperatures -40°C and 60°C is carried out. It was found that there is no change in the linearity curves observed. This reveals that the radius of curvature and the thickness of the glass material are as per the requirement.
2.3 Seeker Electronics

The laser Bandwidth is calculated to be 20 to 35 MHz for typical pulse duration of 13 to 21 n sec \([17 \pm 4 \text{ n sec}]\). The estimate of the received power at the detector is computed using the formula mentioned below,

\[
W_r = \frac{W_t \cdot \rho \cdot t \cdot \cos \theta \cdot \exp^\mu (R_1 + R_2) \cdot D^2}{4R_2^2}
\]

- \(W_r\) – Received power at seeker unit,
- \(W_t\) – Transmitted power from the Laser Designator
- \(\rho\) - Target reflectivity, \(t\) = optical transmission of seeker optics
- \(\theta\) - Angle between receiver line of sight and normal to the target.
- \(\mu\) – Atmospheric attenuation coefficient, \(D\) – Seeker aperture diameter.
- \(R_1\) - Distance between Laser Designator and target (designating range)
- \(R_2\) - Distance between seeker and target (seeking range).

The power is estimated at detector end for different visibility conditions using the above formula. The laser power at the seeker is affected due to Path attenuation (due to Poor, Normal and Good weather conditions)

2.4 Quadrant Detector for Tracking.

There are quite a few detectors available for the detection of the reflected laser signal. In order to obtain a linear error signal with respect to the position of the target a silicon Quadrant detector is the best suited for tracking application. The output of each detector is proportional to the power incident upon its sensitive area.

For a typical detector diameter of 12mm the FOV required is \(\pm 15\) degree. Since the input power falling on the detector estimated is of the order of micro watt the detector with low dark current must be selected. The detector has a response time of \(< 20\) nS, low noise equivalent power and high sensitivity. Detector Bandwidth is 20 MHz which matches with that of the laser input bandwidth. Detector is operated in the photoconductive mode with variable gain.

3.0 SIGNAL PROCESSOR

The light incident on the detector is converted to a equivalent voltage by using a trans impedance amplifier with different gain stages. The gain switched output from preamplifier is given to a pulse stretcher circuit using low noise operational amplifier having required bandwidth of \(> 20\) MHz. The amplified and stretched pulse is processed by a micro controller with a resolution of 10mV. It computes the algorithm for the generation of Azimuth and Elevation error signals in a serial format. Figure 5 shows the seeker unit developed in house.

![Seeker Unit](image)
placed within the line of sight so as to acquire the reflected laser pulses from the target. When the target is acquired the signal is tracked and processed.

CONCLUSION

The challenging task of reducing the size of the optics and the aperture is under study. Reduction in the aperture size reduces the power falling on detector. This can be overcome by increasing the sensitivity of the electronics.

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