MSc Physics Sem – IV Experiential Laboratory: Project Proposal – II

1. Project Title: "Design and Optimization of a Lens-Based Diffraction-Limited Earth-Observing Telescope for Low Earth Orbit(LEO) Applications by Zemax OpticStudio Simulations"

2. Students Details:

- Names, Enrollment Numbers & Email Addresses:
  (i) ANJNI L. GORSIYA (23-PPH-035) 23pph035@sxca.edu.in

  (ii) RUSHIKESH M. KAVA (23-PPH-006) 23pph006@sxca.edu.in

3. Project Type:
Purely Simulation

4. Objective:
The primary objective of this project is to design and optimize a lens-based Earth-observing telescope for Low Earth Orbit (LEO) applications at an altitude of 500 km. The telescope aims to resolve fixed ground distances of 5m or 10m with high precision while operating in the visible spectrum (400–700 nm). The goal is to achieve diffraction-limited imaging and validate its performance using Zemax OpticStudio with a focus on critical parameters such as GSD (Ground Sampling Distance), aperture size, f-number, MTF (Modulation Transfer Function), wavefront error (WFE) and swath width will be analysed and optimized.

5. Description:
This project focuses on the optical design, simulation & performance optimization of a lens-based telescope system for Earth observation from LEO. The physics concept centres around the principles of geometric and wave optics, including diffraction, image formation, and aberration control. The telescope is designed to achieve high-resolution imaging by ensuring diffraction-limited performance. Ground Sampling Distance (GSD) is a key parameter, directly relating to the optical system's focal length, aperture size and the detector's

pixel size. The project explores the use of Zemax OpticStudio to simulate, analyse and optimize the system for high image quality while balancing parameters such as aperture size, focal length and field of view.

6. Methodology:

The following steps will be carried out to achieve our project goals:

1. System Requirements Definition:
    - Set altitude (500 km), desired GSD (5m or 10m) and operating wavelength range is visible wavelength range (400–700 nm).
    - Define the detector specifications, including pixel pitch and resolution.
2. Optical System Design:
    - Use Zemax OpticStudio to design a lens-based telescope system.
    - Select appropriate lens materials for visible wavelength operation.
    - Define and optimize aperture size, focal length and f-number to meet resolution requirements.
3. Optimization and Aberration Control:
    - Minimize optical aberrations (e.g., chromatic aberration, spherical aberration) to achieve diffraction-limited performance.
    - Use ray tracing and optimization tools in Zemax to refine the optical design.
4. Performance Analysis:
    - Evaluate image quality using Modulation Transfer Function (MTF) analysis.
    - Analyse spot diagrams and ensure proper Nyquist sampling for the given detector pixel pitch.
    - Calculate the swath width and field of view for efficient ground coverage.
5. Validation:
    - Simulate the system’s performance for resolving ground features at 5m and 10m resolution.

7. Expected Outcomes:

- A fully optimized lens-based telescope design capable of resolving ground details of 5m or 10m from an altitude of 500 km.
- As possible as Simulation results showcasing high-resolution image quality and efficient ground coverage.

- Calculation of key optical parameters: GSD, aperture size, f-number, swath width, detector pixel pitch and Nyquist sampling.
- A practical understanding of optical lens-based telescope design principles and optimization for Earth observation applications.
- Validation of diffraction-limited imaging performance using Zemax tools, including MTF analysis and spot diagrams to ensure image quality.

8. Timeline:

- Try to done all the calculation part upto 2nd week of January.
- Try to done Simulation & optimization part Zemax upto 2nd week of February.
- Try to done all the result analysis part upto end of February.

9. Collaboration Details:

Anjni: All Calculation and Result Analysis part

Rushikesh: Simulate & optimization of system in Zemax

10. Resource Requirements:
High Quality Laptop

11. Challenges/Concerns:
The main challenge in this project is minimize system optical aberration. & also challenging task is Evaluate image quality using Modulation Transfer Function (MTF) and spot diagram analysis.

Try give our best expertise to understand and solve properly this challenge.

12. Signature(s):

- Students: Anjni L. Gorsiya
  Rushikesh M. Kava
- Date of Submission: 22/12/2024