Laser-Radar to Detect and Classify Insects and Drones

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Research Intent

Precision agriculture technology is used to make farms more efficient and sustainable by optimizing resource consumption, pest management, and ecological monitoring. In this project, we participated in the development of a new laser-radar system that can be used to detect and classify insects. This laser-radar system targets an airborne object's moving airfoil (e.g. an insect wing) with rays of laser radiation. Different insects have different wingbeat frequencies, facilitating identification through analysis of the backscattered laser radiation. With a drone as our object, we used a two-lens set up as a tunable lens system to maximize backscattered laser radiation and maximize the signal captured by a photodetector.

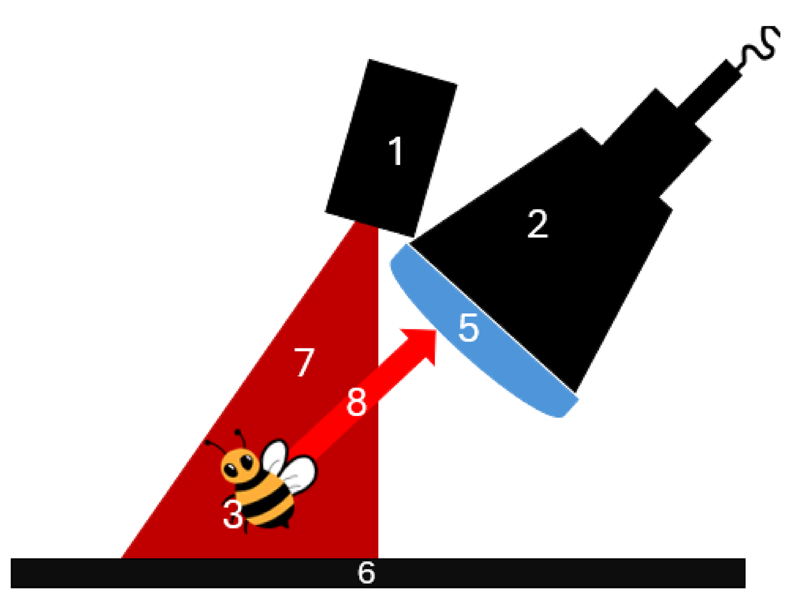


Figure 1A. Laser-Radar System Without a Tunable Lens System

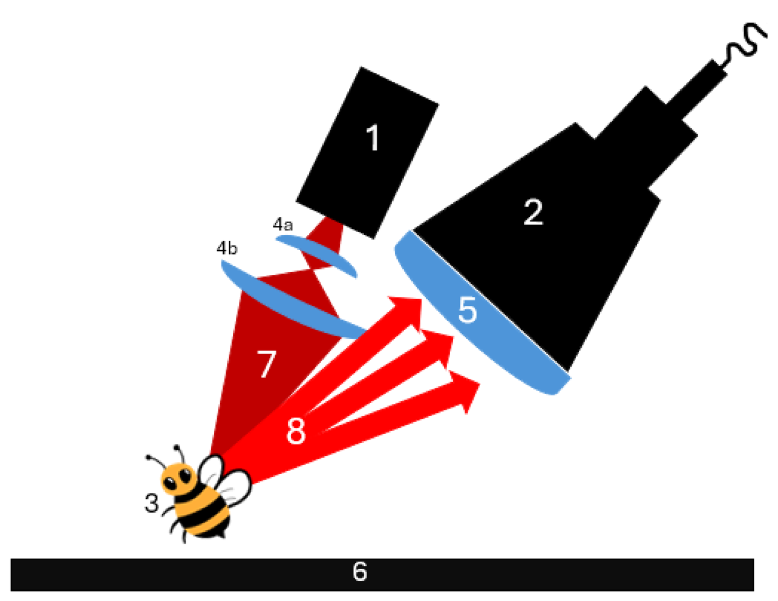


Figure 1B. Laser-Radar System With a Tunable Lens System

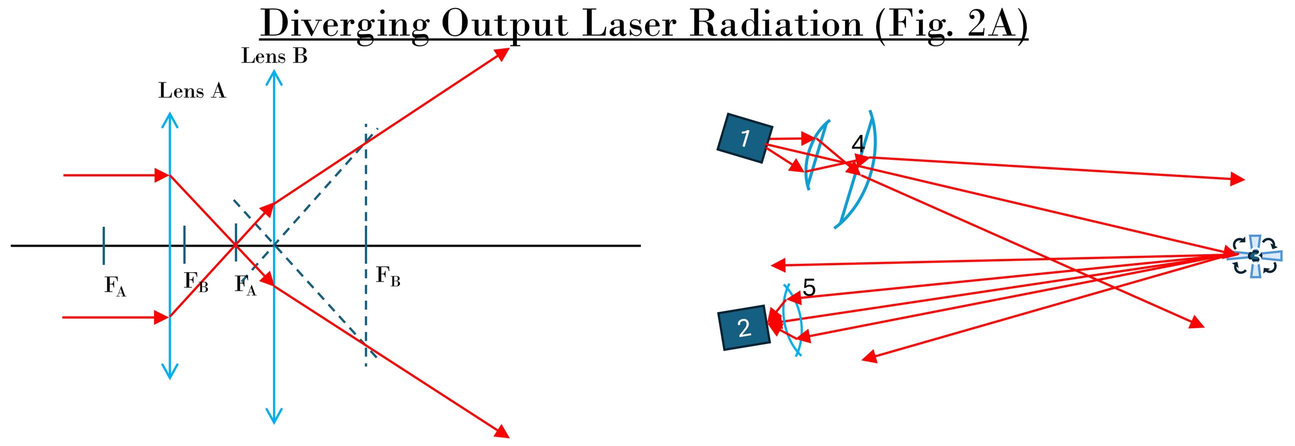
1. 655nm Laser
2. Photo Detector
3. Object

4a. 110mm Convex Lens
4b. 220mm Convex Lens
5. Convex Lens

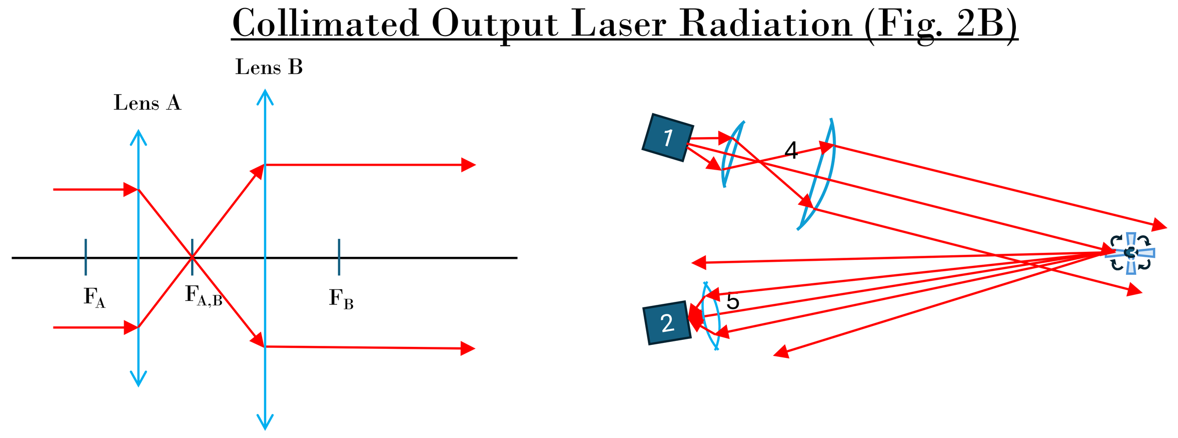
6. Flat Ground
7. Laser Radiation
8. Backscattered Radiation

Optical Diagrams

Diverging Output Laser Radiation (Fig. 2A)



Collimated Output Laser Radiation (Fig. 2B)



Converging Output Laser Radiation (Fig. 2C)

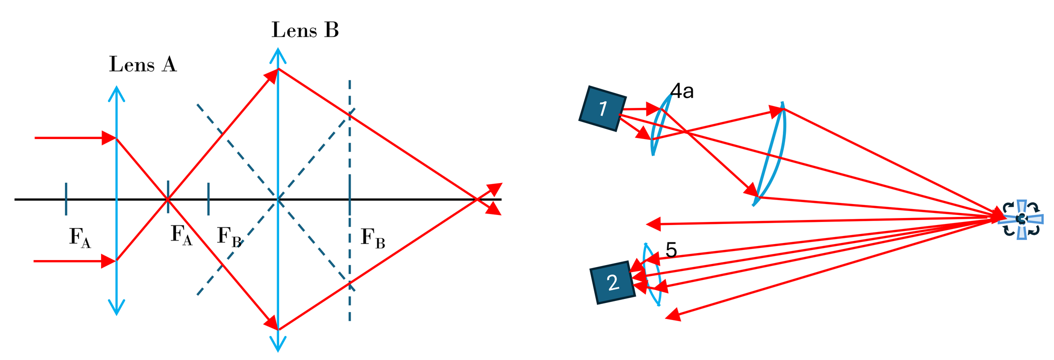


Fig 2A. Propagation of paraxial rays through two convex lenses: focal distances of the two lenses overlap.

Fig 2B. Propagation of paraxial rays through two convex lenses: the lenses are separated by their two focal distances.

Fig 2C. Propagation of paraxial rays through two lenses: the lenses are separated by a distance greater than their two focal distances.

Computer Simulation

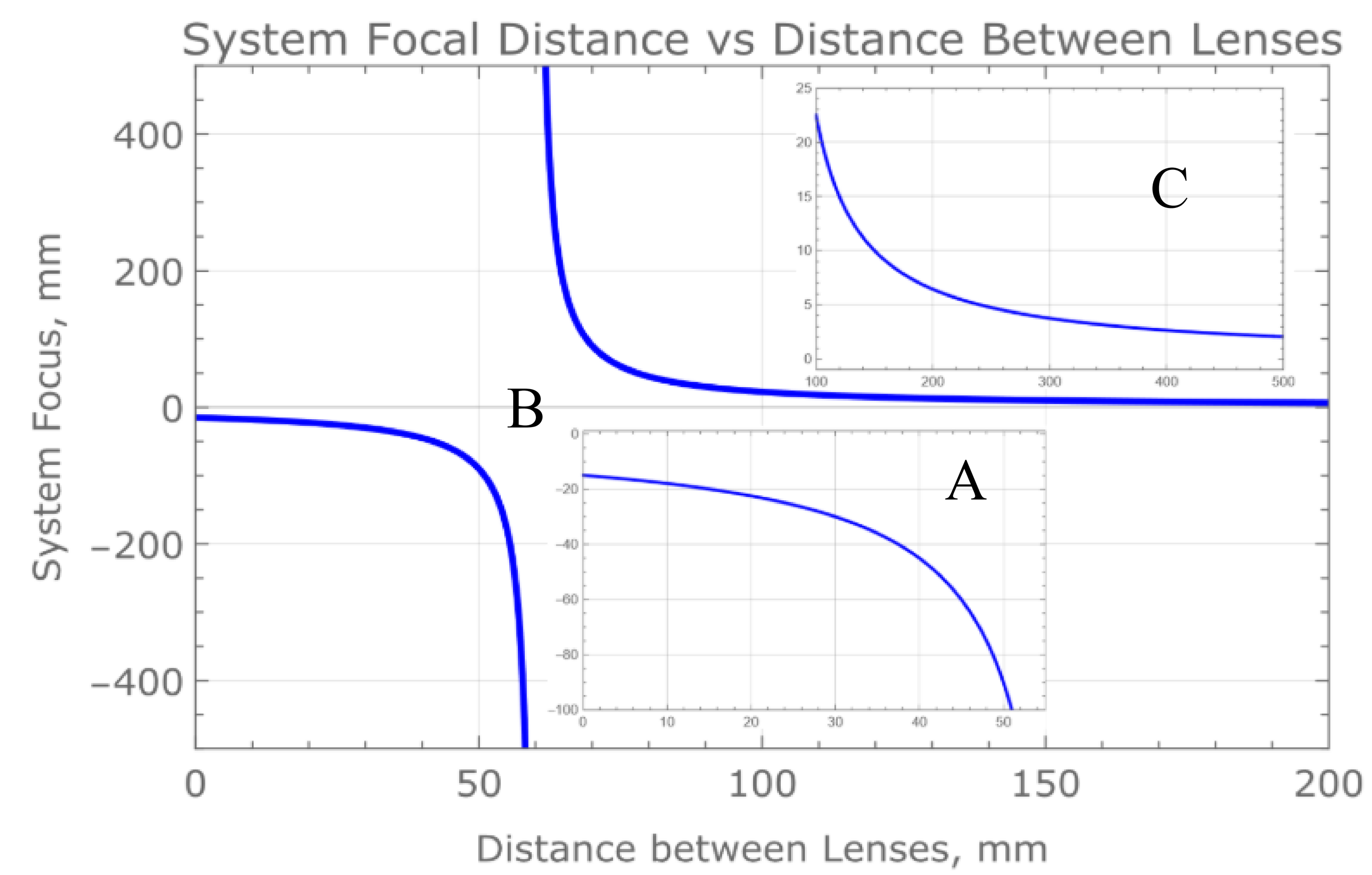
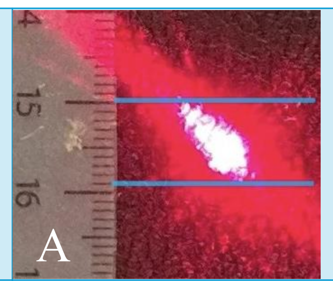
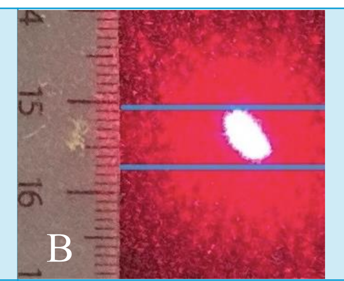
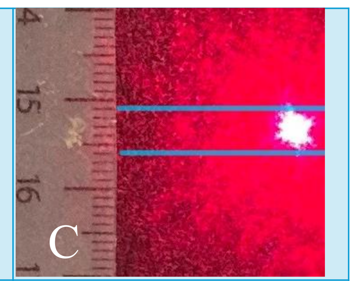


Fig. 3. Computer simulations of an effective focal distance of two lens setup performed by using an approach of matrix optics.

A. The negative effective focal length producing the divergent laser radiation depicted in Fig. 2A.
B. The infinite focal length of collimated laser radiation depicted in Fig. 2B.
C. The positive effective focal length producing the converging radiation depicted in Fig. 2C.

Experiment

Photos of Laser Spots (A. and B. Unfocused, C. Focused)			
Distance between two Lenses (mm)	353	373	393
Intensity (mW/mm^2)	1.05	3.21	3.80

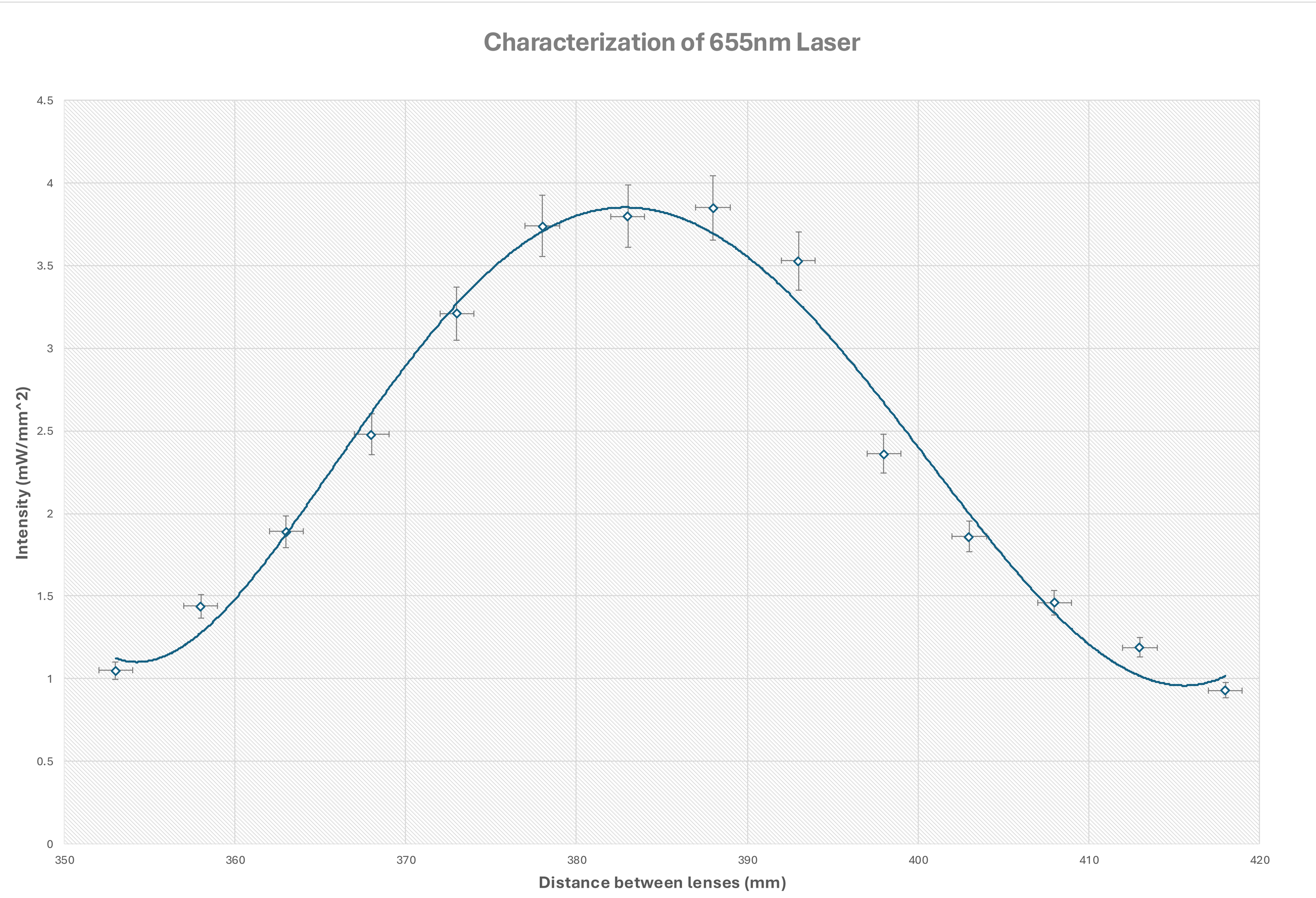


Fig 4. The dependance of laser radiation on the object versus the distance between the two lenses.

Data Acquisition

The data was collected by connecting the photodetector to an oscilloscope and computer processor to view and analyze the backscattered radiation from the drone's propeller. The data was first collected without using any lenses at the output of the laser, producing the signal in Fig. 5A. Then, data was collected with the lens setup demonstrated in Fig. 1B and 2C, producing the signal in Fig. 5B.

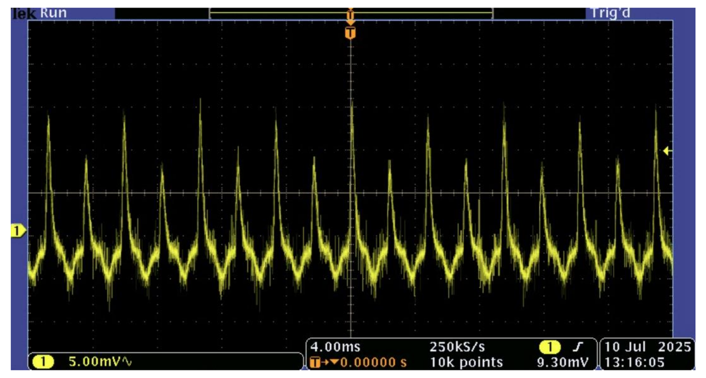


Fig. 5A. Oscilloscope Signal with no lenses

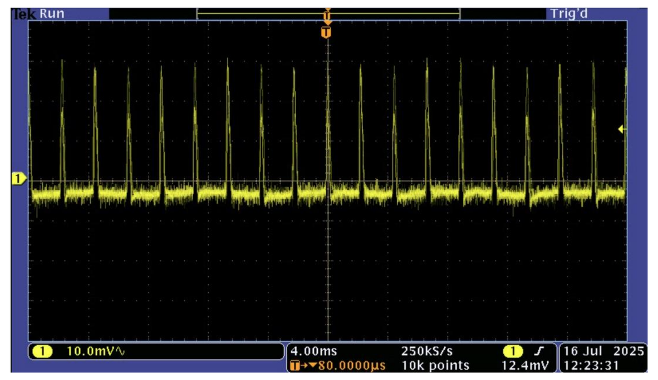


Fig. 5B. Oscilloscope Signal with lenses

The setup with no lenses produced a weaker signal with more noise (Fig. 5A) than the setup with lenses (Fig. 5B). The noise signal in the no-lens system is greater than the noise signal in the lens system.

Data Processing

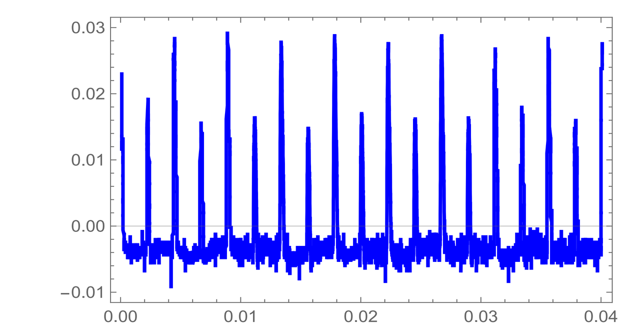


Fig. 6A: Plot of raw data collected from the photodetector: Current of photodetector versus time.

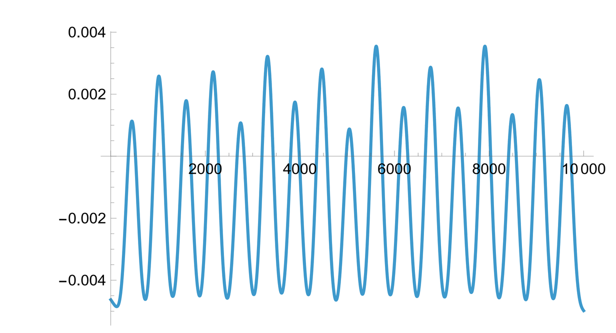


Fig. 6B. Plot of data filtered for noise using Lowpass Filter: Current of photodetector versus time.

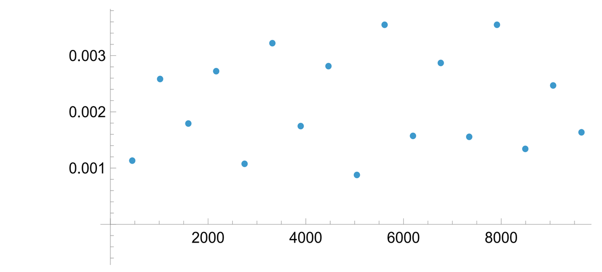


Fig. 6C. Plot of signal peaks used to calculate an average period: peaks versus time.

$$f = \frac{1}{T}$$

$$f = 435.02 \pm 4.92\ Hz$$

Conclusions

The tunable lens system increased the intensity of backscattered laser radiation. It provided greater signals and reduced the impact of noise on measurements and calculations needed to find the frequency of the drone propellor.

Future work can improve the lens setup for the photo-detector, which will also improve the data acquisition from backscattered laser radiation.

Acknowledgements

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