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# COTS Lens and Detector Characterization for Low Cost, Miniature SAL Seekers

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# Abstract


- In the spirit of lower cost, weight, and volume, a simple aspheric refractor lens is characterized with a square detector for Semi-Active Laser (SAL) seeker applications.
- Experimental results show an angular error of 0.176˚ over an az/el range of ±6˚ and an error of 0.097˚ over an az/el range of ±4˚. (detector linear region)
- In the final 10 seconds of a typical SAL engagement, the slant range is ~2500m, corresponding to a Target Location Error (TLE) of 7.7m (former) and 4.2m (latter).
- These initial results are very encouraging as the experimental research continues.

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# Motivation

- More demanding requirements
  - Yet same incremental design approach
  - Gimbals and additional optical elements
- Analog to digital
  - Yet unrealized improvement in system performance
- Problem compounded by multiple modes
- Previous (performance) requirements led to
  - Large volume, large mass
- Current (cost, size) requirements lead to
  - Small volume, small mass

- TAKE A SYSTEMS APPROACH INSTEAD!

# Systems Requirements Summary

| Seeker Attributes | Previous | Desired |
|---|---|---|
| Volume ($cm^3$) | >10,000 | <100 |
| Weight (kg) | >50 | <1 |
| Outer mold line | Seeker-defined | Airframe-defined |
| Guidance loops | Simple, linear, analog | Complex, non-linear, discrete |
| Countermeasure | Limited | Robust |
| Flight time (sec) | >60 | <10 |
| Accuracy (collateral damage) | Limited | Critical |
| Performance vs Cost | Performance more important than cost | Cost more important than performance |

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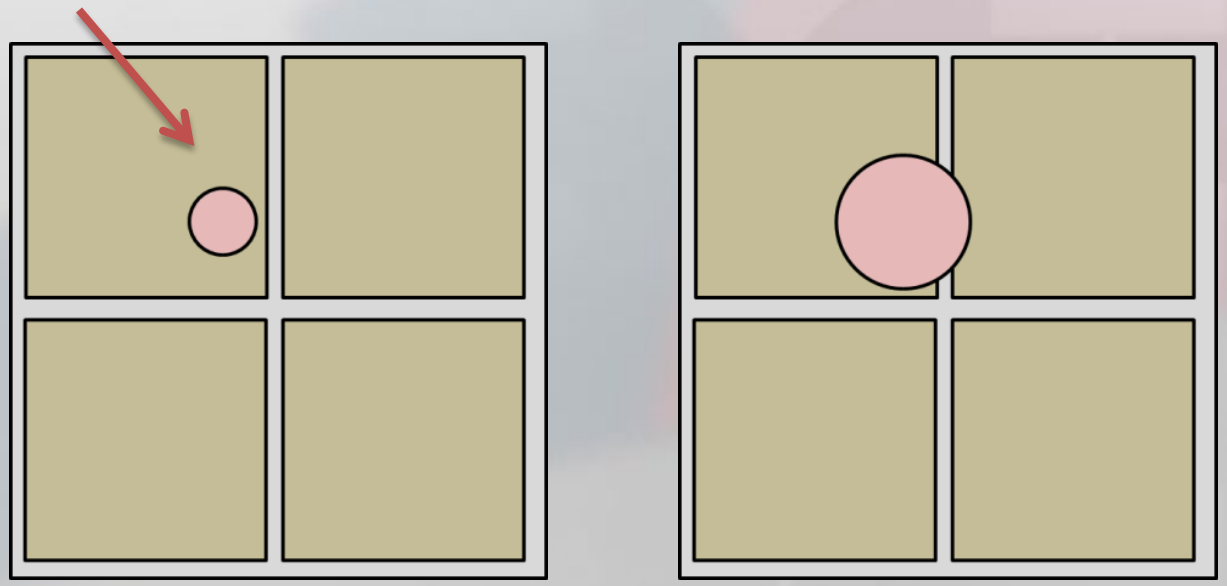
# Spot Focus

- Negative effect
  - Focused laser energy anywhere in QII
  - Relatively large control signal down and to the right to center the laser spot, which results in **more** demand on the control system



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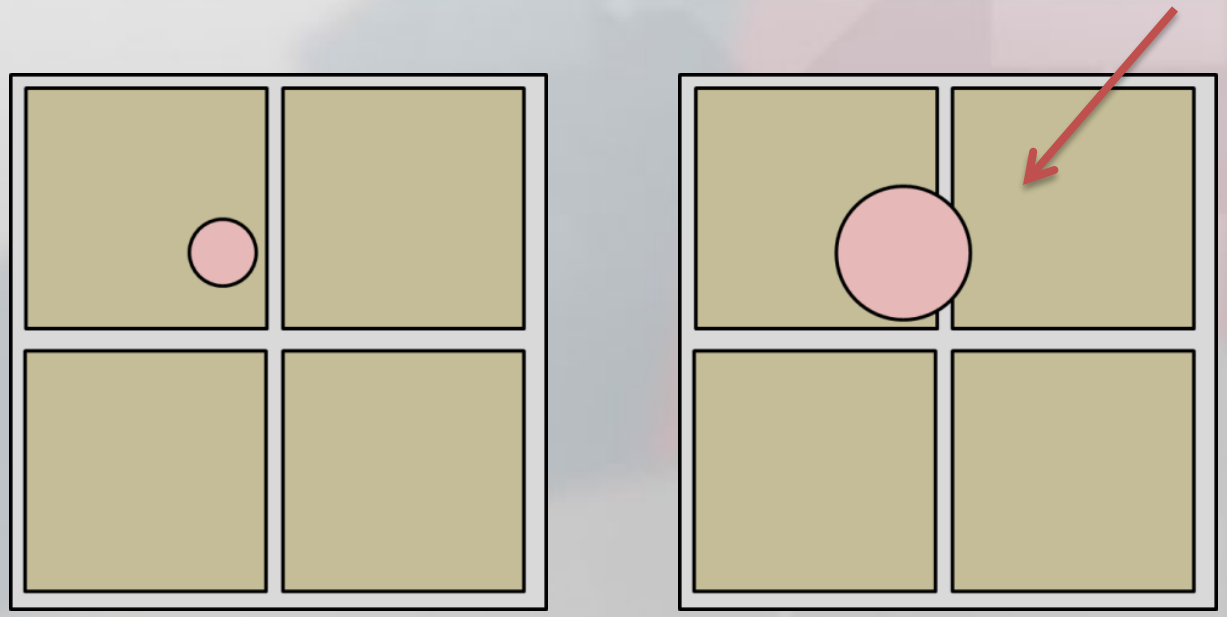
# Spot Defocus

- Positive effect
  - Defocused laser energy spread into QI
  - Relatively small control signal down and slightly right required to center the laser spot, which results in **less** demand on the control system



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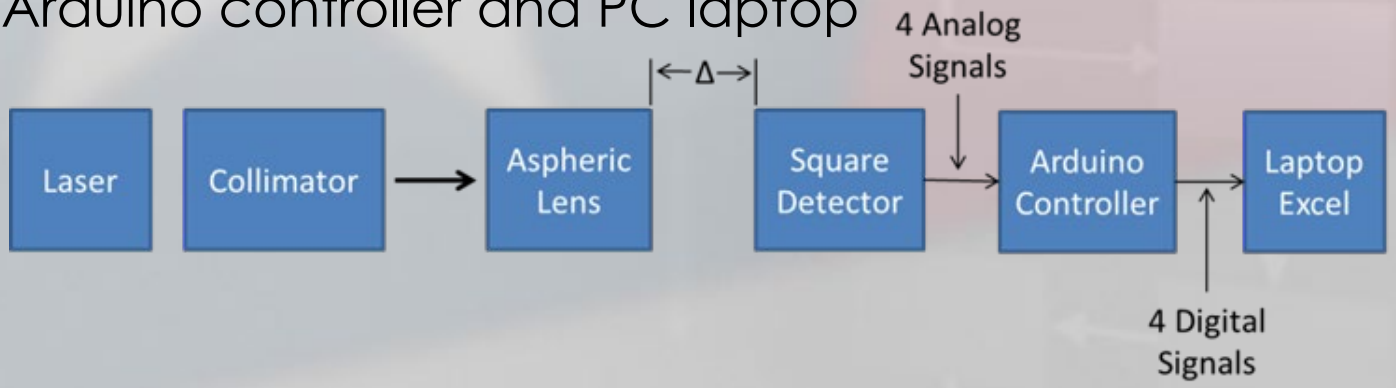
# Challenge the Assumption

- A large defocused spot is a traditional means to implement a seeker intended for pursuit guidance with "bang-bang" actuator systems.
- This experiment seeks to explore the performance of such a simple design with modern signal processing instead of expensive hardware components.
- A commonly held view among seeker designers has been to believe it was not possible to have a large region of linear angular response (needed for more than simple pursuit guidance) unless there was a large, complex optical system.

- WE SOUGHT TO CHALLENGE THAT ASSUMPTION!

# Test Components

- Coherent lasers: green and IR
  - No chromatic aberration
- Collimated 1" diameter, parallel rays
- Edmund 27mm X 13FL aspheric lens
  - No spherical aberration
- Δ to investigate defocusing effects
  - 3mm increments from focal plane to 9mm in front of focal plane
- 20mm X 20mm square detector
- Arduino controller and PC laptop



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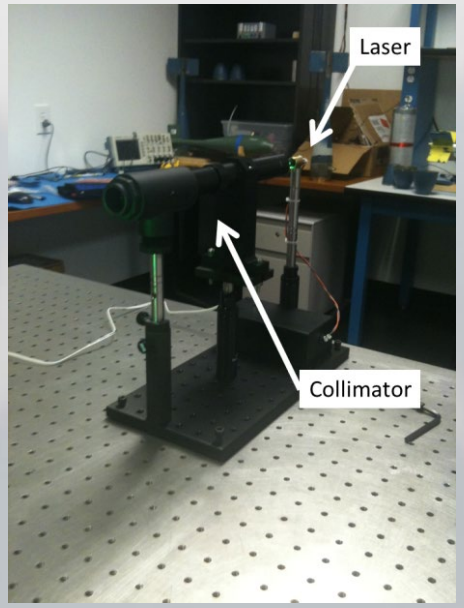
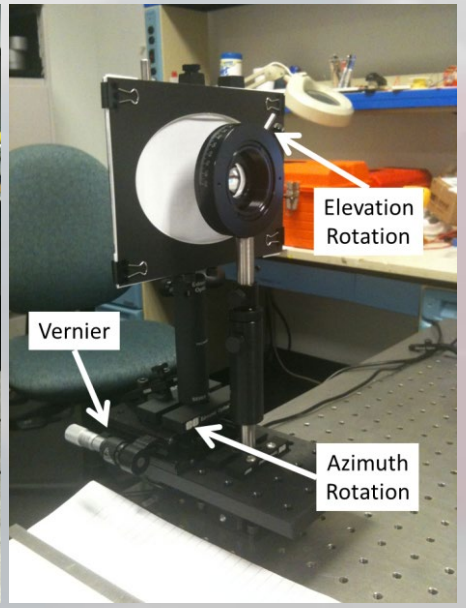
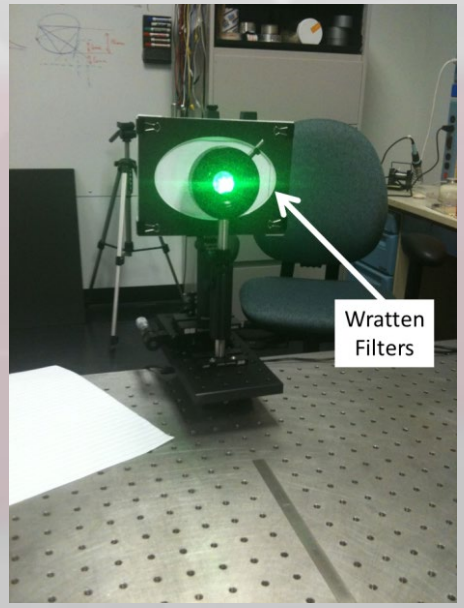
# Testing Procedure

- Rotate lens from -90˚ to +90˚ elevation in 15˚ increments
- Rotate lens from -30˚ to +30˚ azimuth in 1˚ increments
- Laser on, read data, laser off, write data, rotate

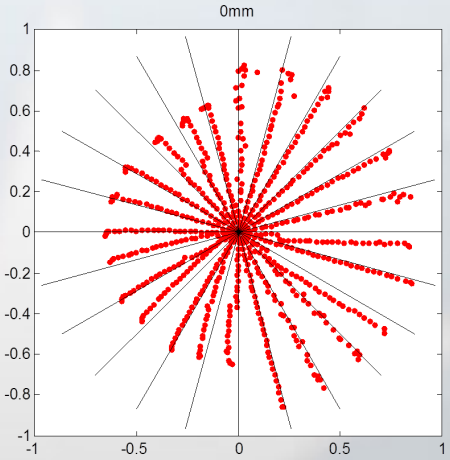


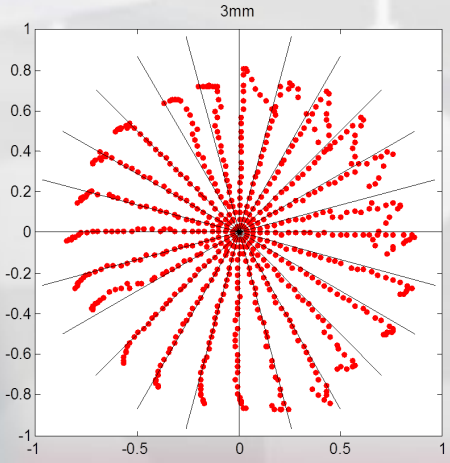



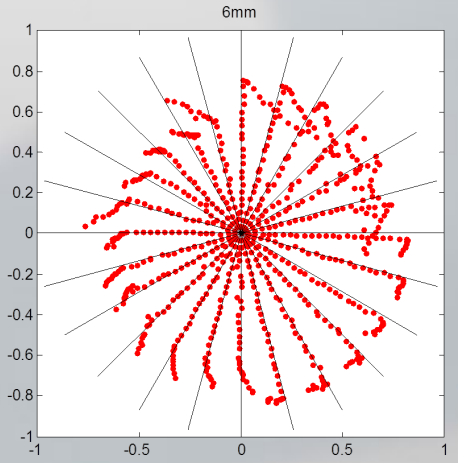



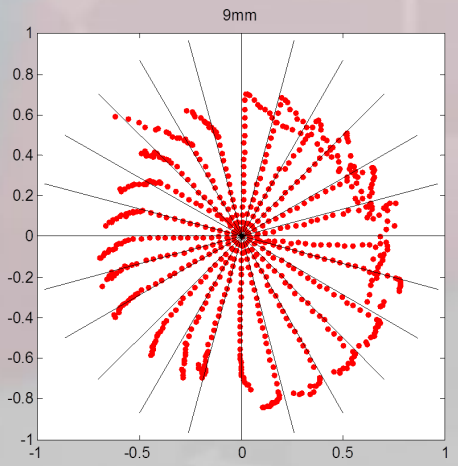
# Results (Green Laser)

**Focal Plane measurements**



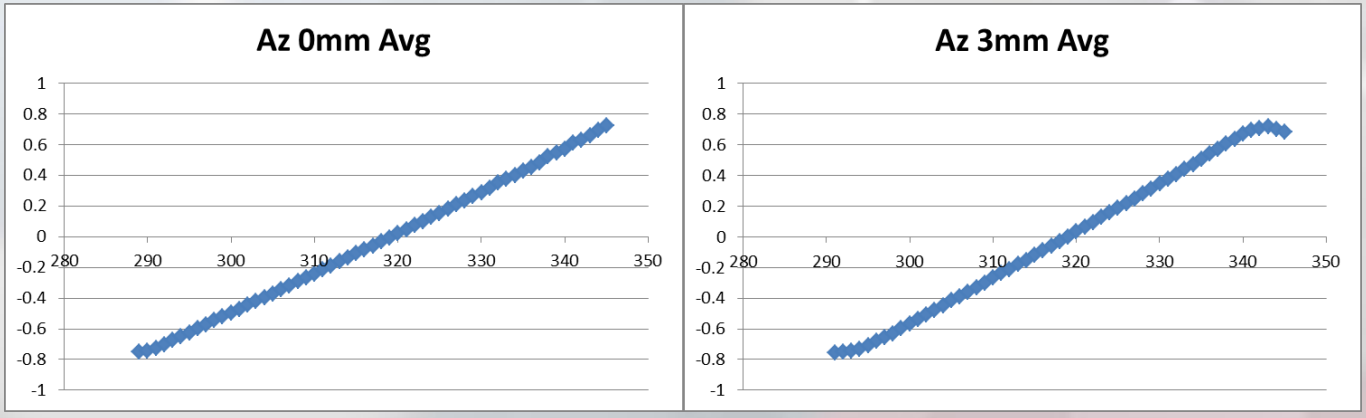




**Each red dot represents a measurement**

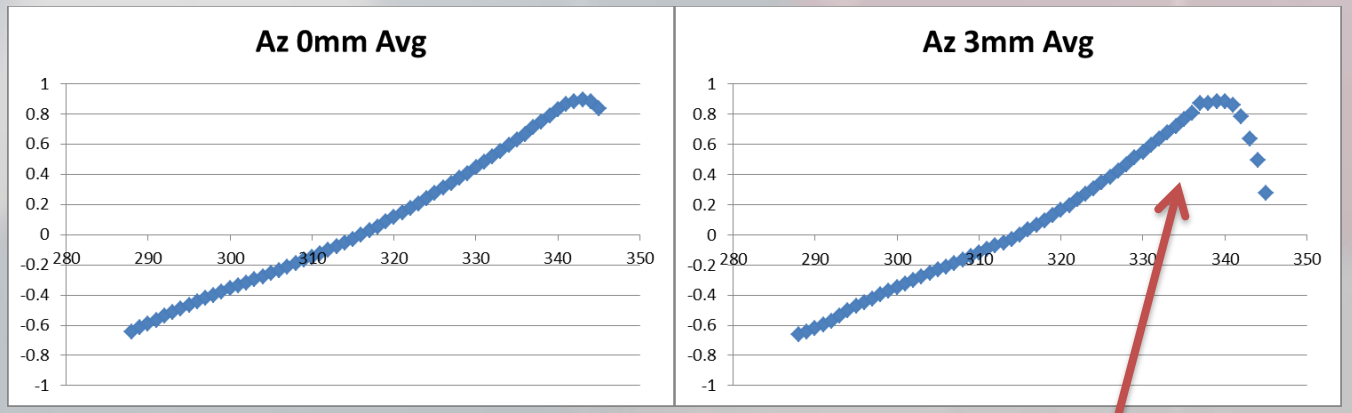
# Results (Green Laser)

## Azimuth error (deg) vs Azimuth (deg)



# Results (IR Laser)

- Switched from green to IR laser
- Data plotted at 0mm and 3mm only
- Maximum linear region is still ±25˚
  - Same as the green laser

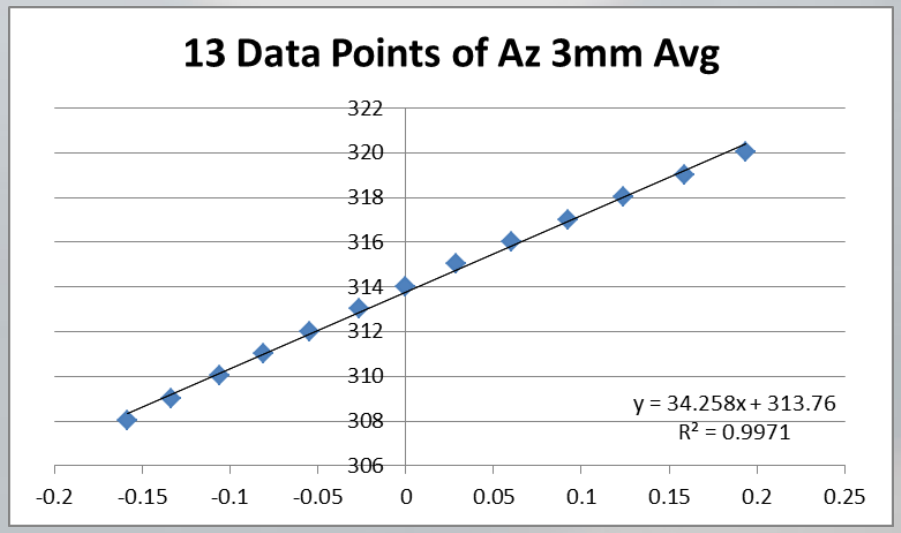


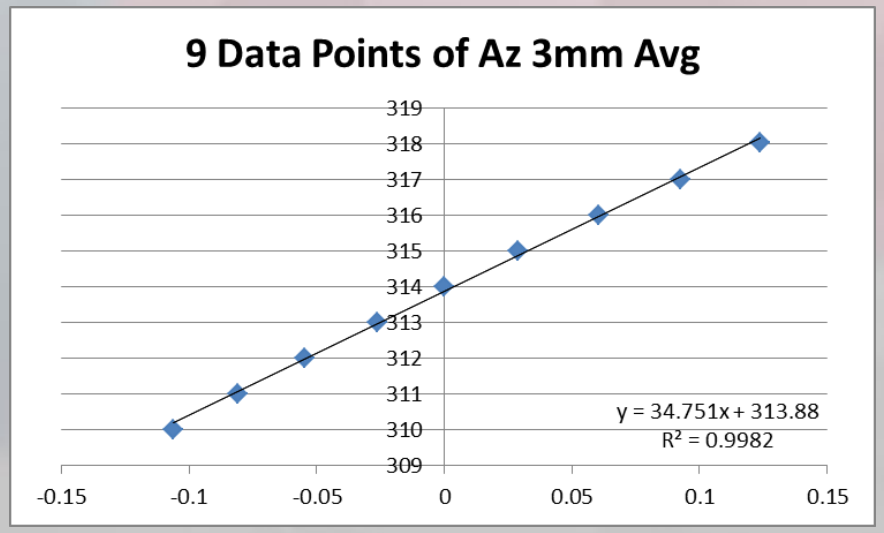

**Saturation, linear region shortened**

# Results (IR Laser)

- Detailed analysis of azimuth errors with 3mm defocused data
- Azimuth ranges of ±6˚ and ±4˚

**Azimuth (deg) vs Azimuth error (deg)**



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# Results (IR Laser)

- Using a COTS lens/square detector, accurate angular sensing is achieved over a linear region of the detector which is useful in many guidance applications

| Azimuth Range (degrees) | Azimuth Error (degrees) |
|---|---|
| ±6 | 0.176 |
| ±4 | 0.097 |

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# Conclusions

- This work shows a low cost COTS configuration yields a feasible light-weight, small-volume SAL seeker.
- With Patent Pending signal processing, the low cost seeker supports nearly any type of guidance law.

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# Conclusions

- A typical SAL end-game engagement begins about 10 seconds before impact with slant ranges ~2500m; even with no further guidance corrections, the results presented here would yield a target location error (TLE) of about 4m.
- These results challenge high performance and expensive seekers in production today.

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# Future Work

- Replace square detector with a quad cell detector
- Replace analog amps with log amps
- Other areas to explore
  - Sensitivity
  - Pulse characteristics
  - Dynamic range
  - Optical filtering bandwidth