# AGILE: Axially Graded Index Lens Fabrication

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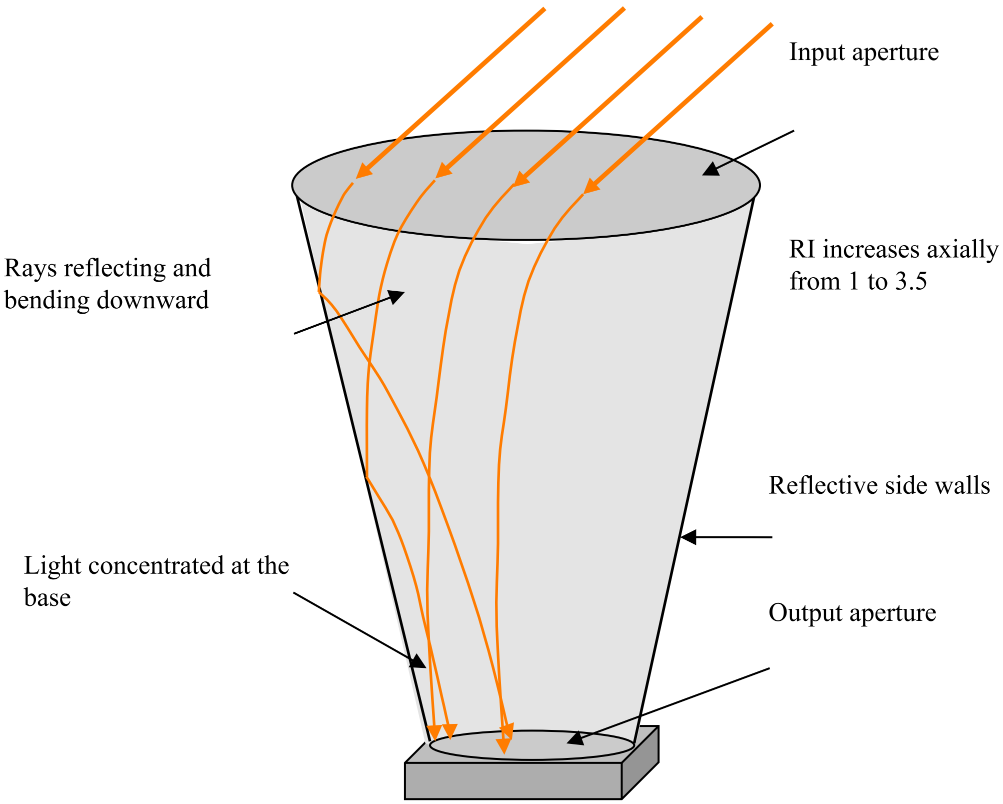
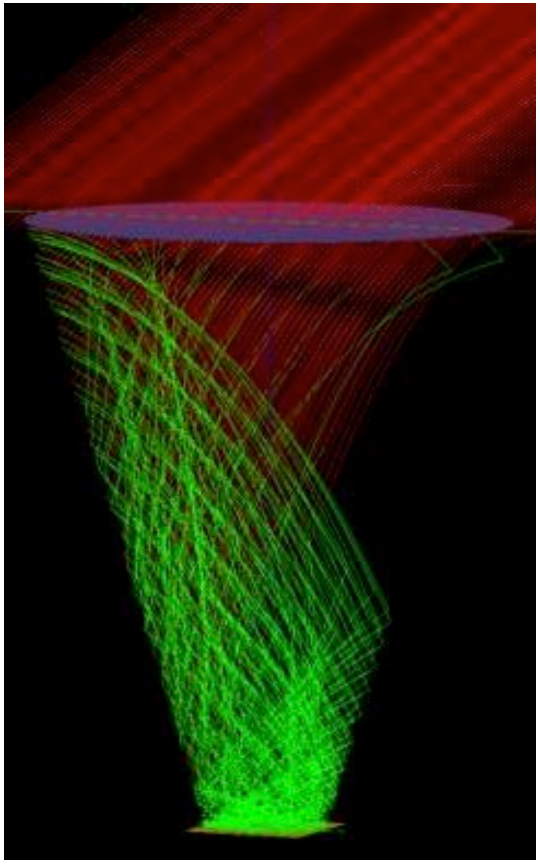
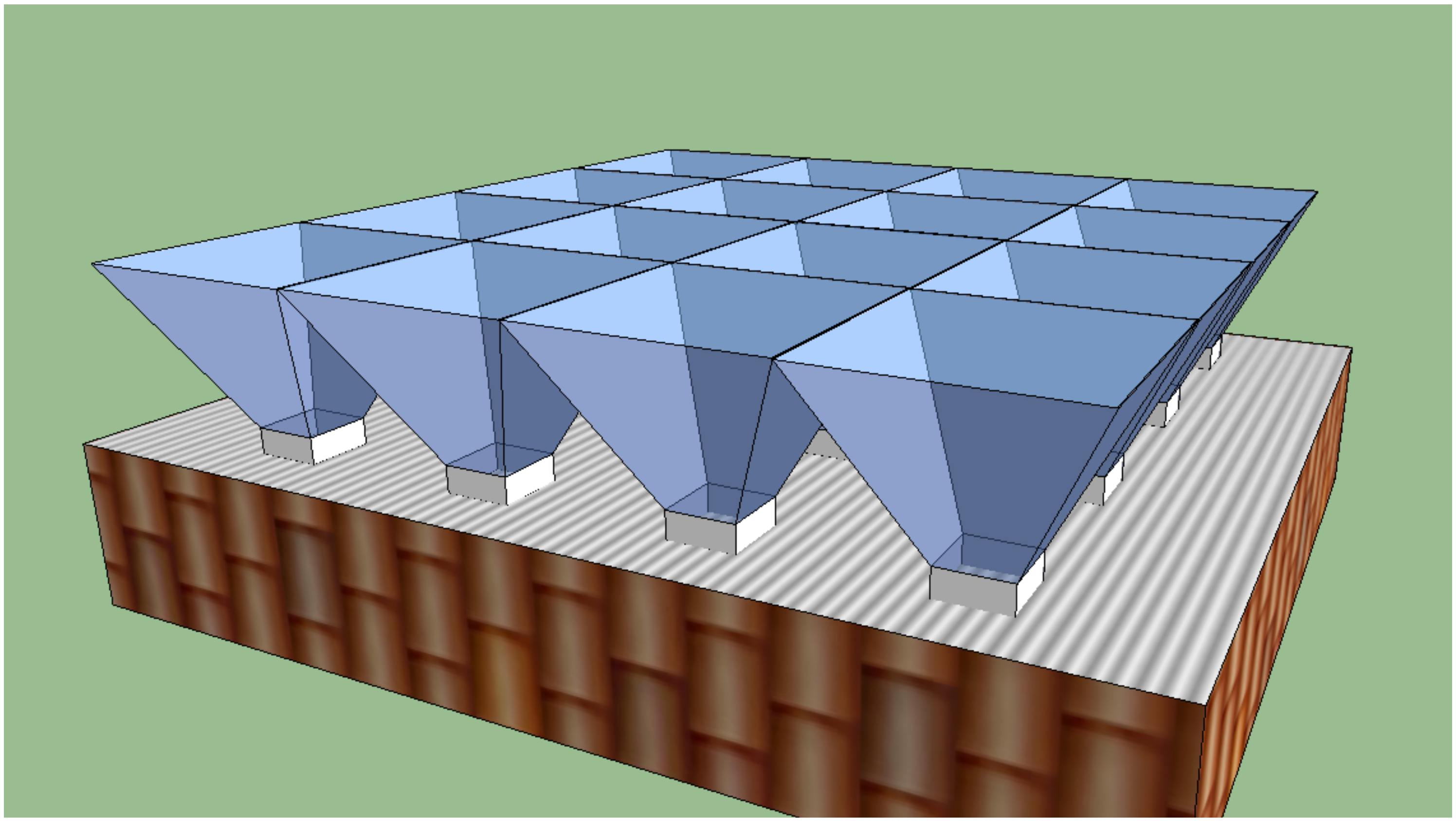
# Concept and Simulation

## FRED Results



# The AGILE System - Our Vision



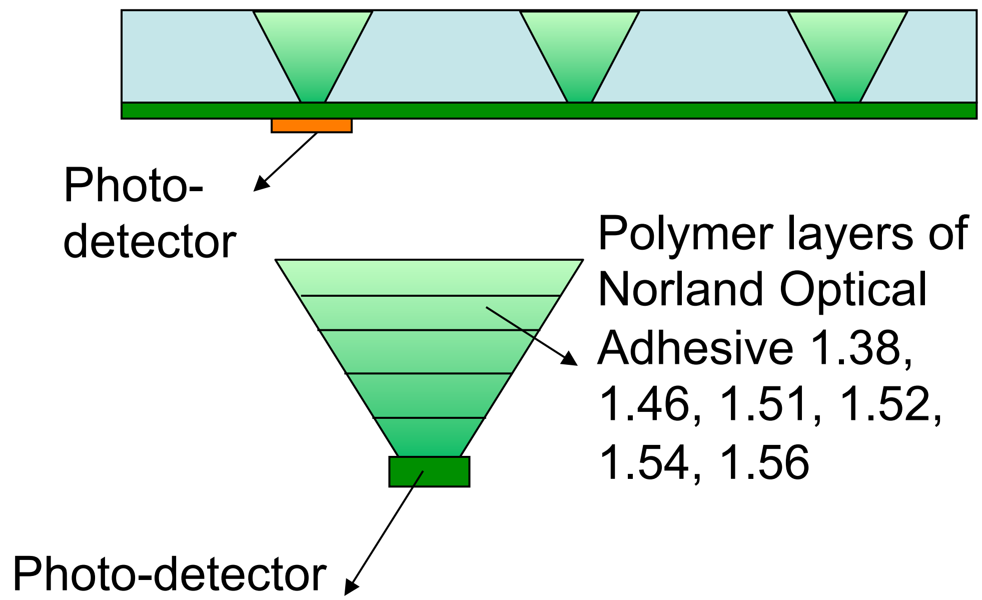
Passive AGILE roof top system

# AGILE EE412 Aims Spring Quarter 2011

- Characterize refractive index of different laminated stacks of optical materials/optical adhesives
- Summarize and fine tune a process to make graded index optical lens material
- Test the fabricated AGILEs

# AGILE Fabrication – Structure 1

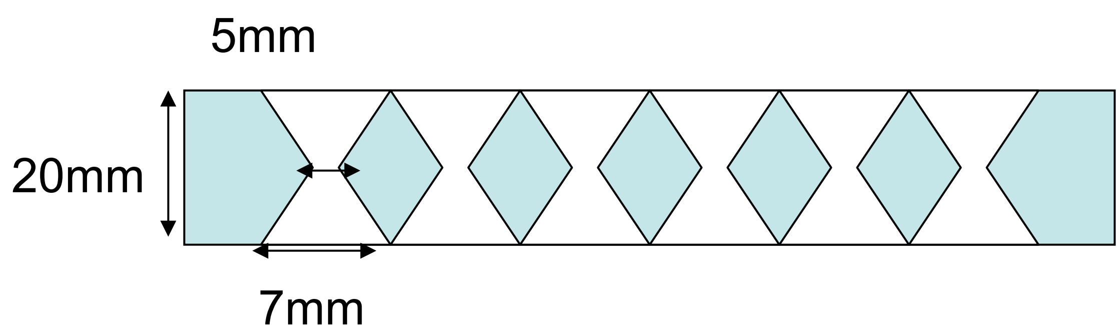
- Single sided AGILE
- Advantages:
  - Layered structure of different polymers
  - Photo-detector to measure the output power
  - N^2 ratio = 1.28, area ratio = 1.96 (7mm to 5mm and height of 10mm)



# Back-to-Back AGILE: Structure 2

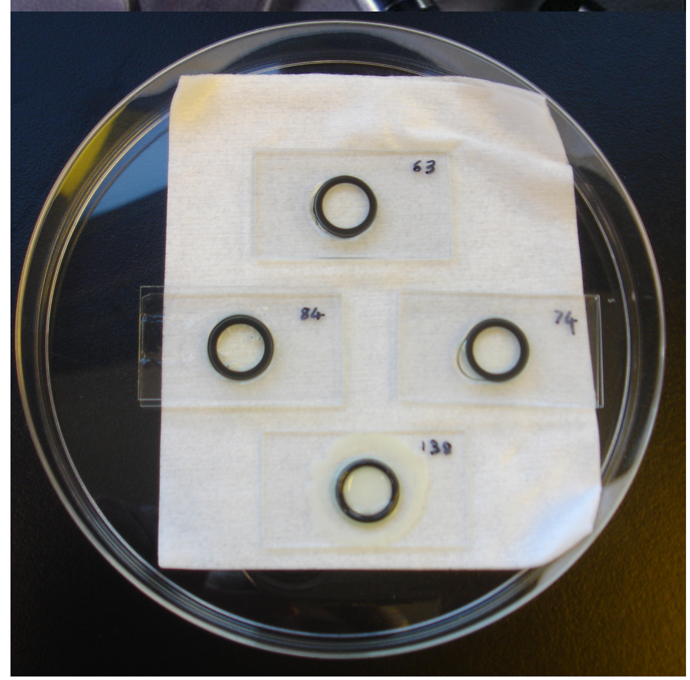
Aluminium plate with conical holes which have larger diameter of 7mm and smaller of 5mm

Advantages: Detection is easier, power goes from larger to smaller to larger aperture (less index mis-match)



# UV Optical Adhesives of Different Refractive Indices

- NOA138 (1.38)
- NOA84 (1.46)
- NOA 89 (1.51)
- NOA74 (1.52)
- NOA68 (1.54)
- NOA63 (1.56)
- These UV curable adhesives would be used to fill the AGILEs

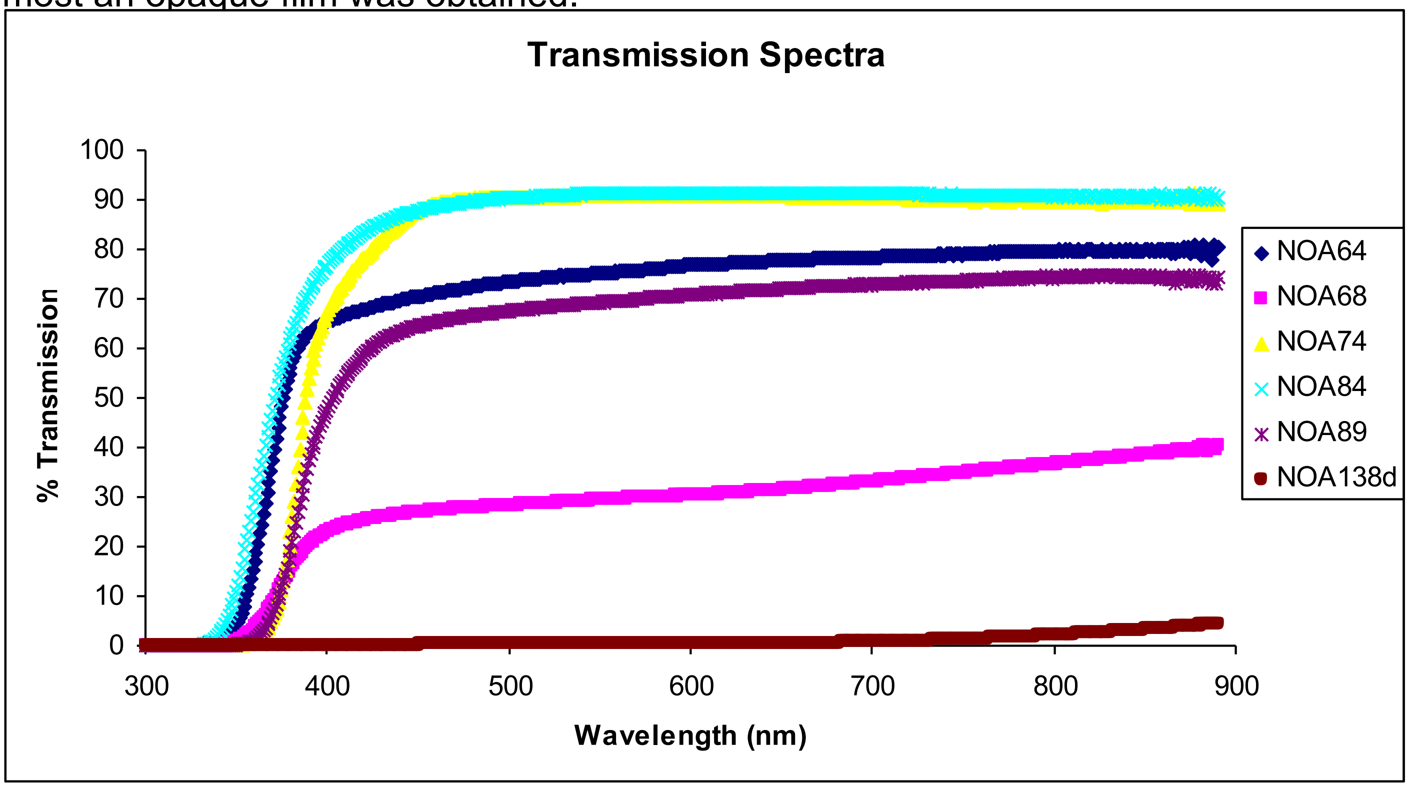
# Spectral Transmission Measurements

- Spectrophotometer measurements for different film samples to characterize the optical adhesives and the polymers was done
- Optical adhesives were put between two glass slabs with a spacer to make thin films and then this can be used a specimen for the transmission measurements for the polymers that are not characterized

# Transmission Spectra of the Different Samples

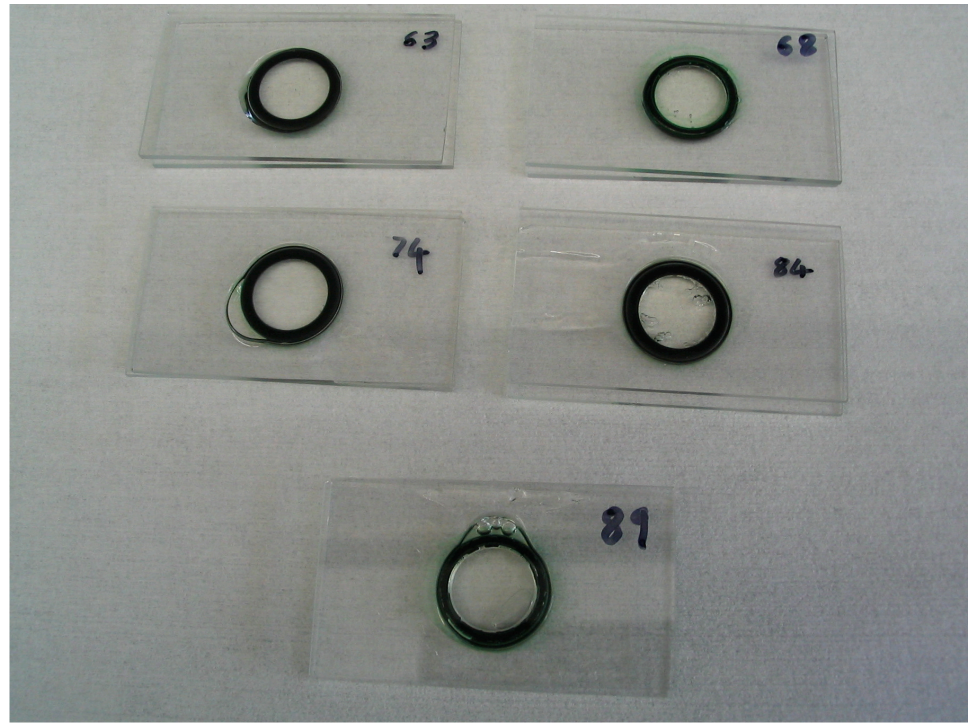
When fully cured, NOA68 has very good adhesion and solvent resistance, but it has not reached its optimum adhesion to glass. This will come with aging over a period of about 1 week in which a chemical bond will form between the glass and adhesive. This optimum adhesion can also be obtained by aging at 50° C for 12 hours. This explained the low %T of NOA68. Same was the case for NOA74

%T of NOA138 is so low as it requires inert atmosphere while curing and this sample was made in air, hence almost an opaque film was obtained.



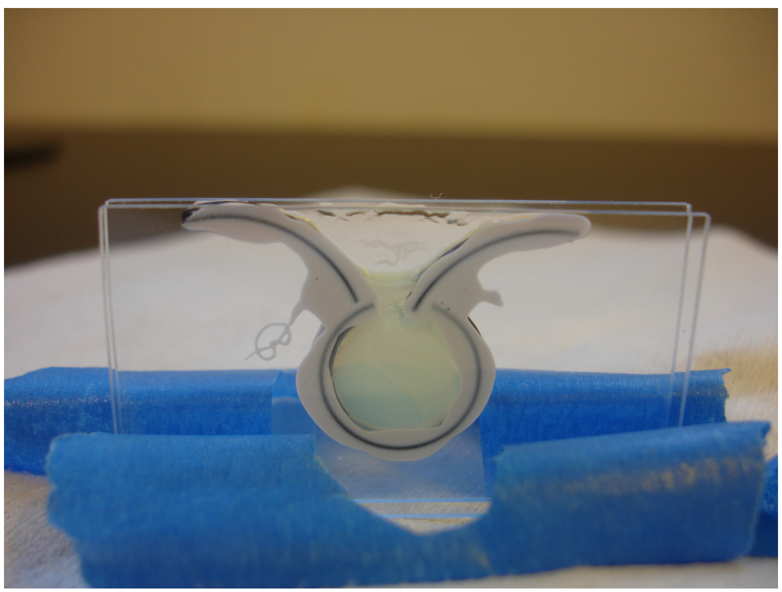
# Optical Adhesives that Worked Well

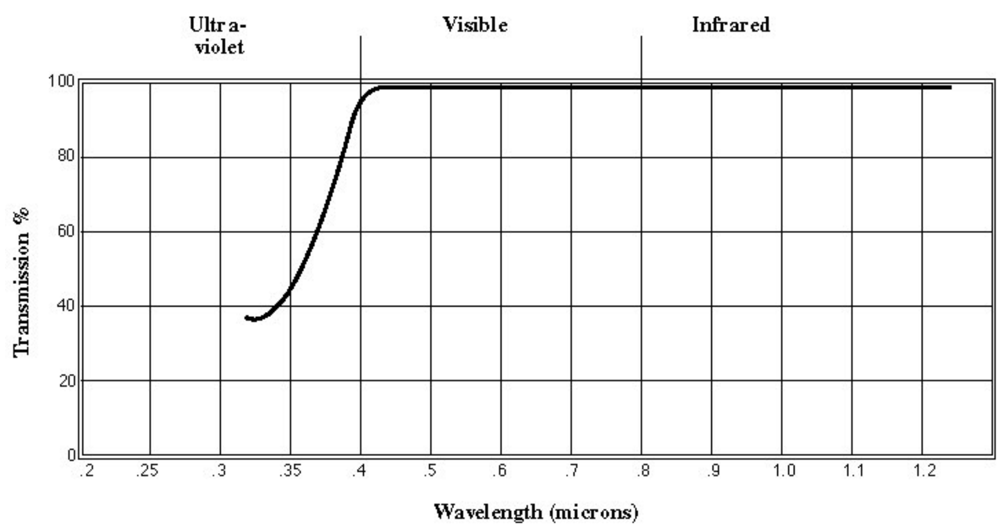
- All except NOA138 (RI of 1.38) behave well and are characterized
- The NOA84 does show a lot of shrinking which is only a problem in this closed test structure and not in agile
- NOA68 and NOA74 need aging after curing



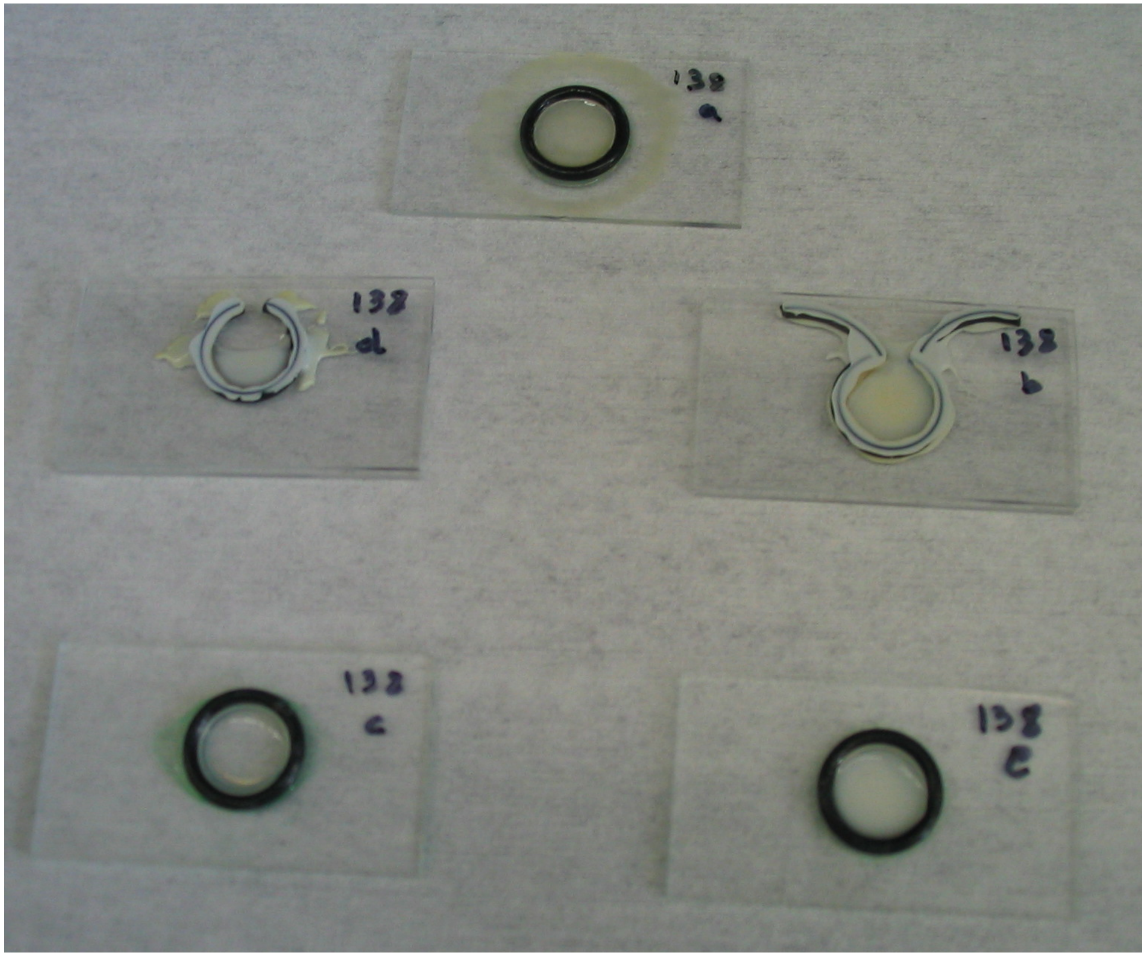
# NOA138

- Aliphatic Urethane Acrylate* * 5-20% and Acrylate Monomer * 40%-85%
- The layer becomes cloudy and yellowish after UV cure, this layer is thick of about 1mm.
- On closer inspection, the adhesive exhibits oxygen inhibition when used as a coating.  To overcome this the adhesive must be cured under an inert atmosphere, such as nitrogen.



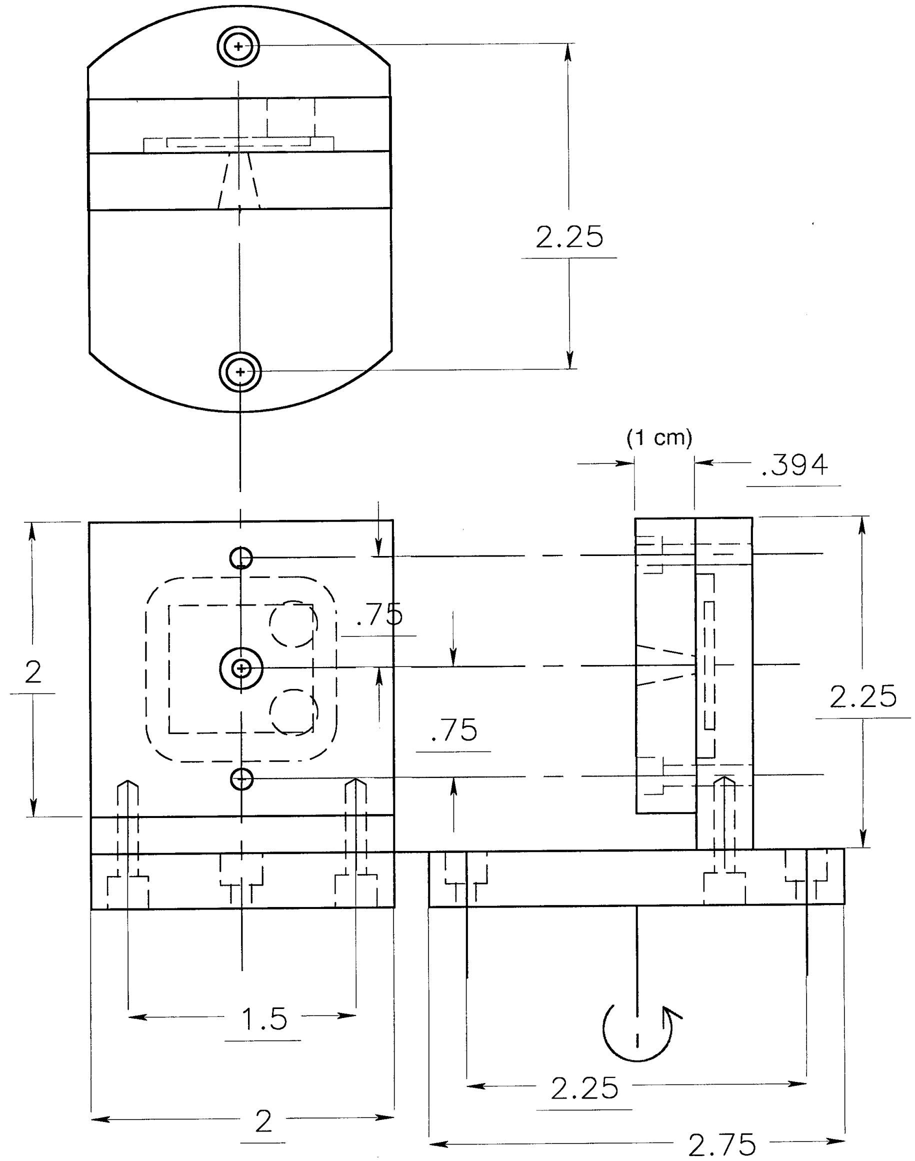


# NOA138 Needs to be Cured in Inert Atmosphere



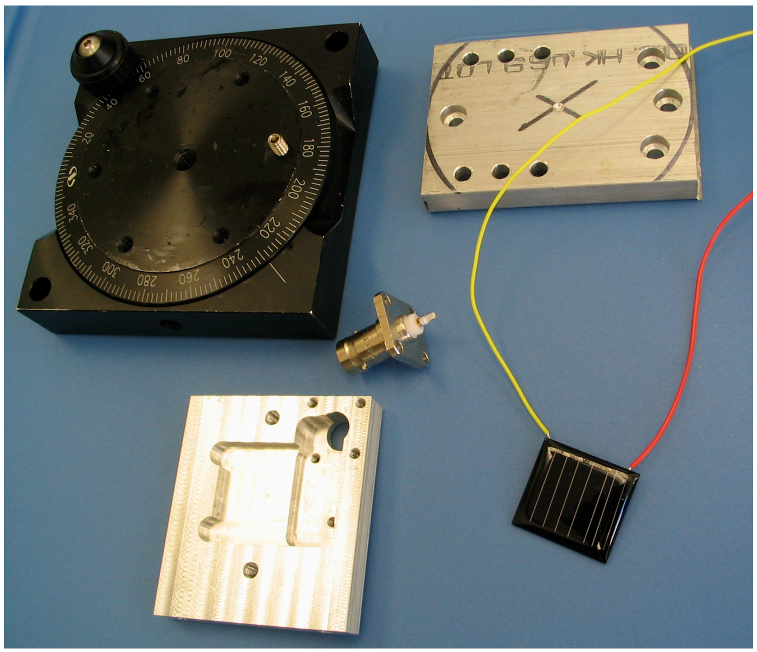

- Solution: rather than a NOA138 bottle, get smaller separate syringes (single use only in a glove box)
- Interaction between rubber and NOA138 was ruled out, because same happens just with glass or Aluminium

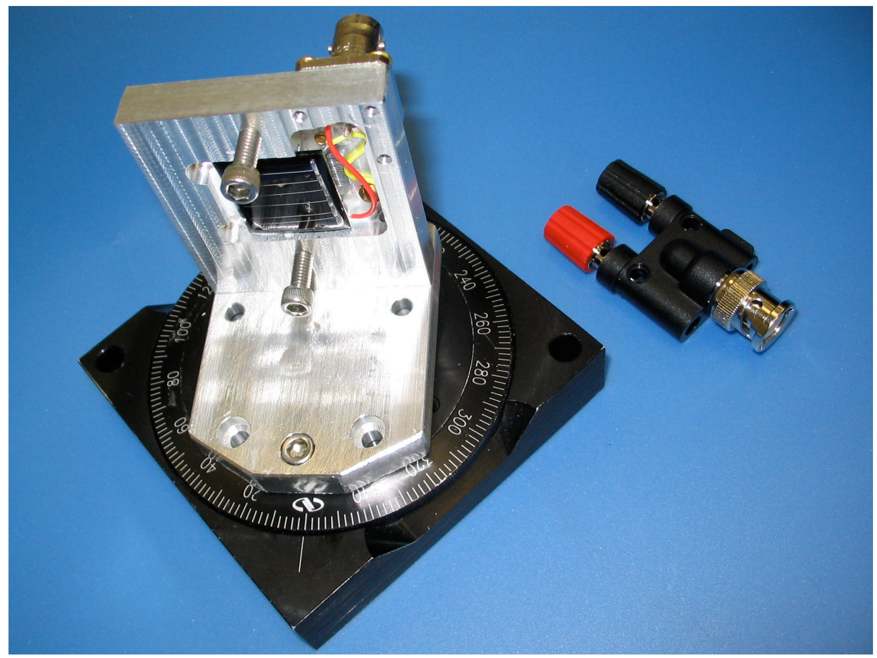
# CAD Drawing of Test Setup



# Solar Cell Detector

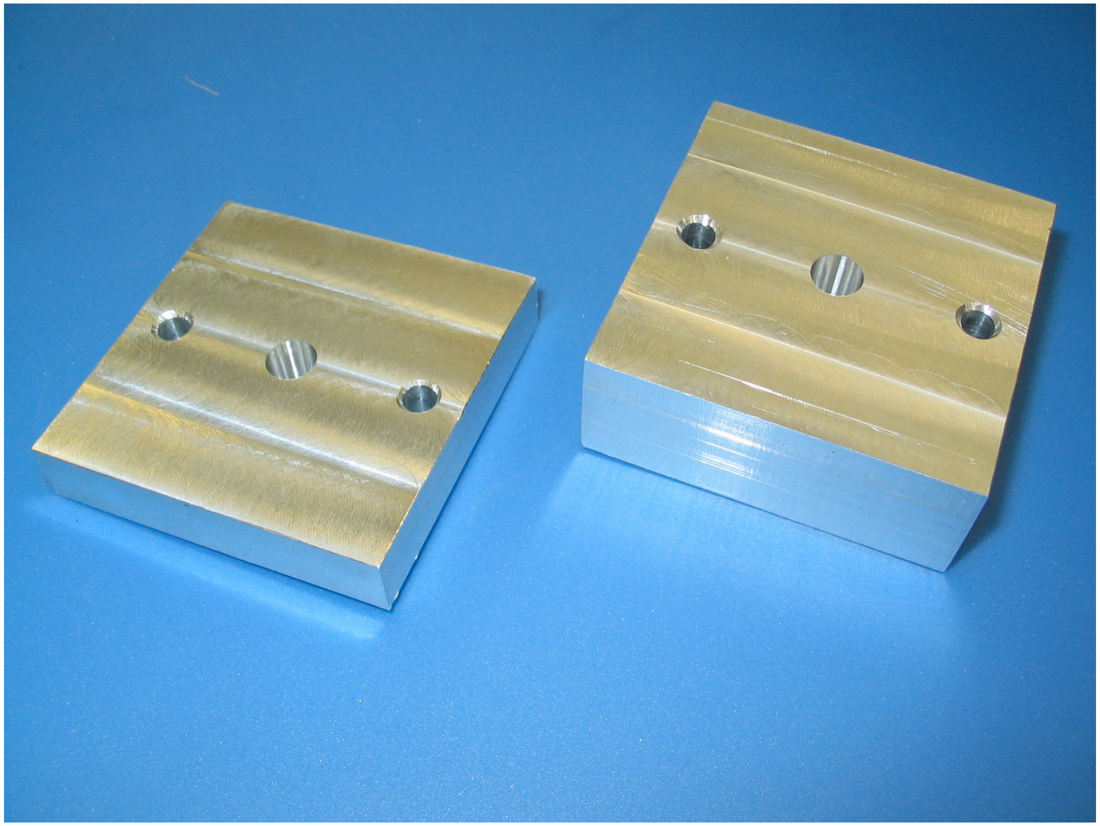
- Testing of AGILE performance





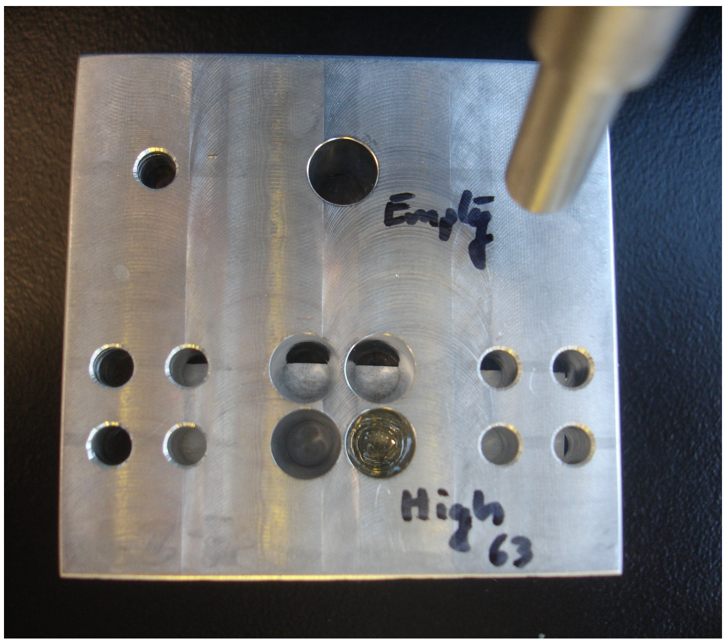
# Aluminium Stencils

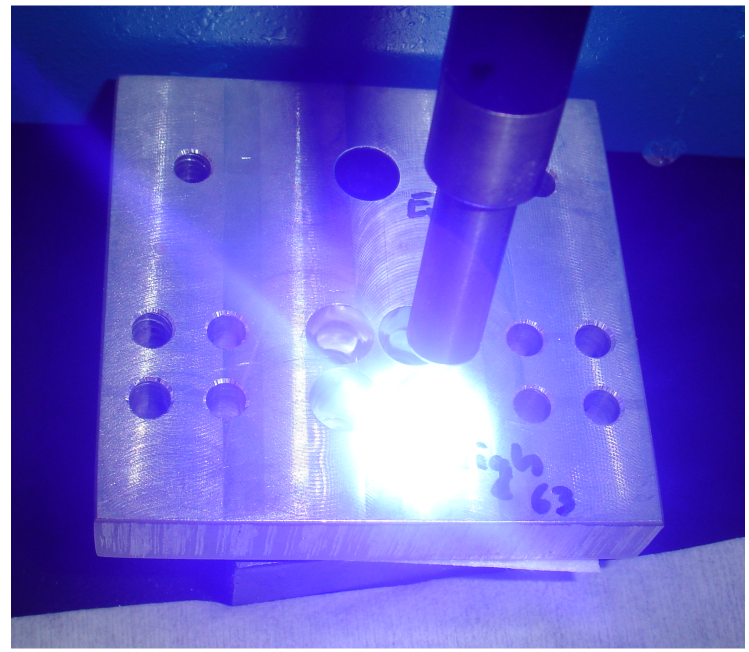
- Agile Stencils: single and back to back structures



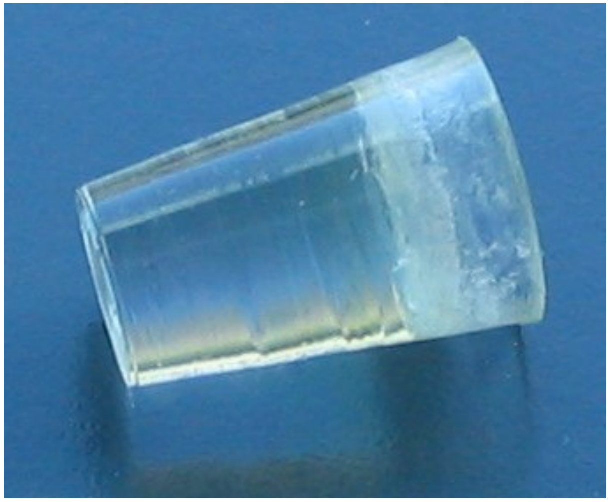
# Filling the First Arrays

- UV curing of optical adhesives

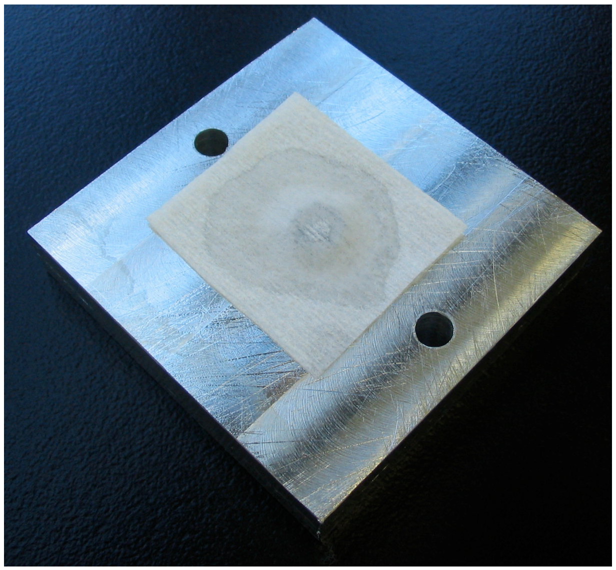


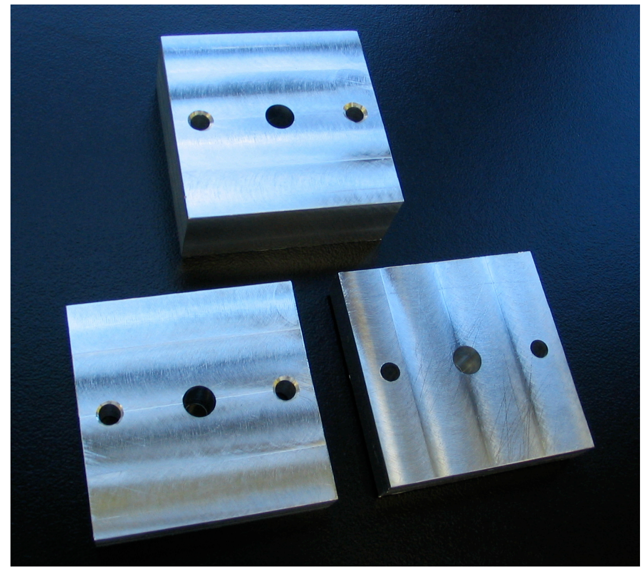


# Close Up of Extracted AGILE (made with NOA138 as top layer)



# Details and Tricks for Fabrication of the AGILEs



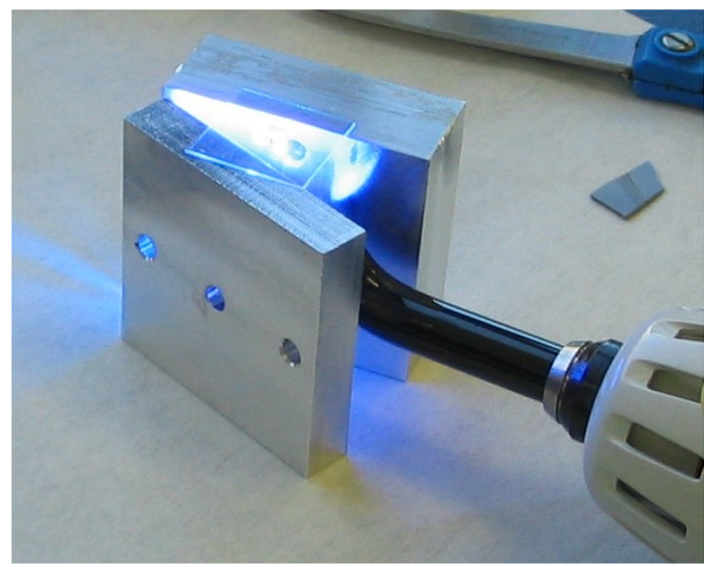


Polish (Al polish with drill and Q-tip)

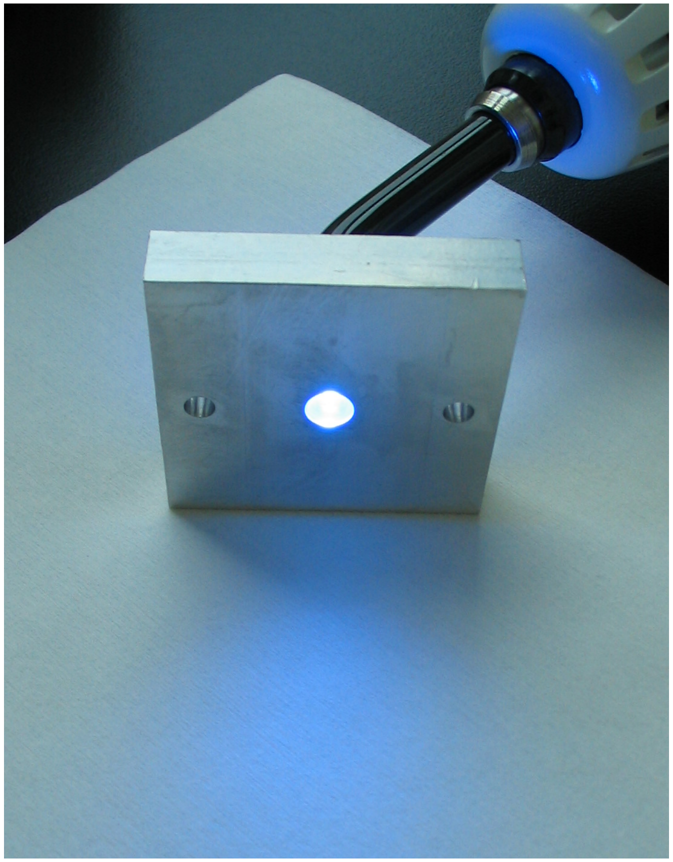
Degreasing and Cleaning

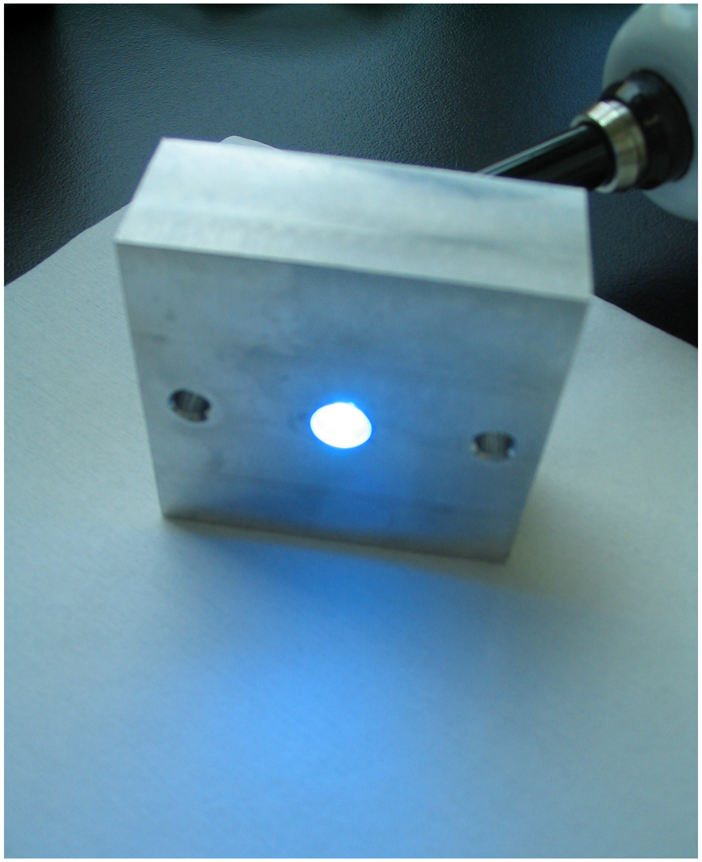
Sealing the Agile with PDMS and Elmer's glue backing (as it does not stick to the optical adhesives)

Glass and PVA backing to cure back to back structure from both sides. PVA is water soluble.

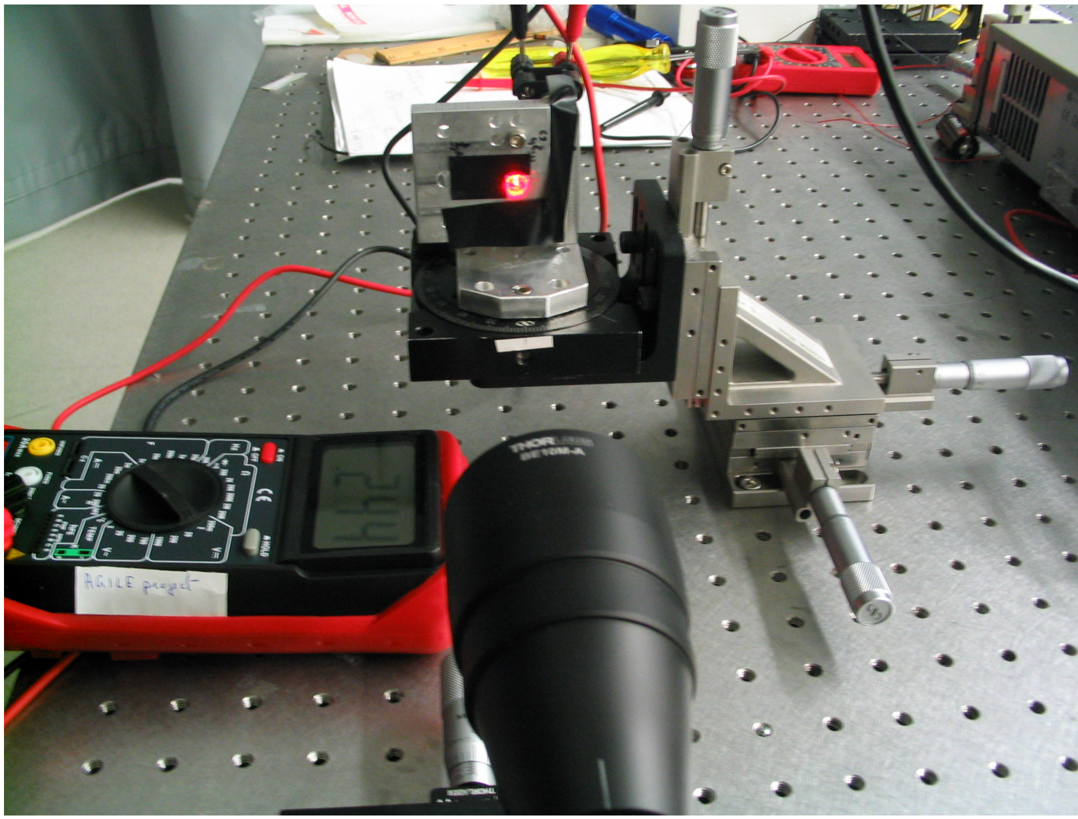


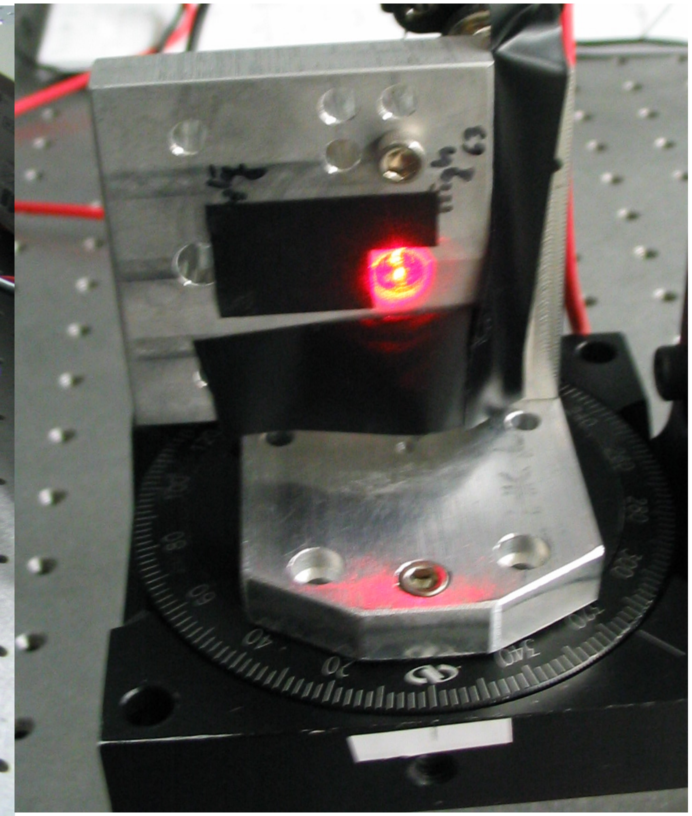
# AGILE Illumination



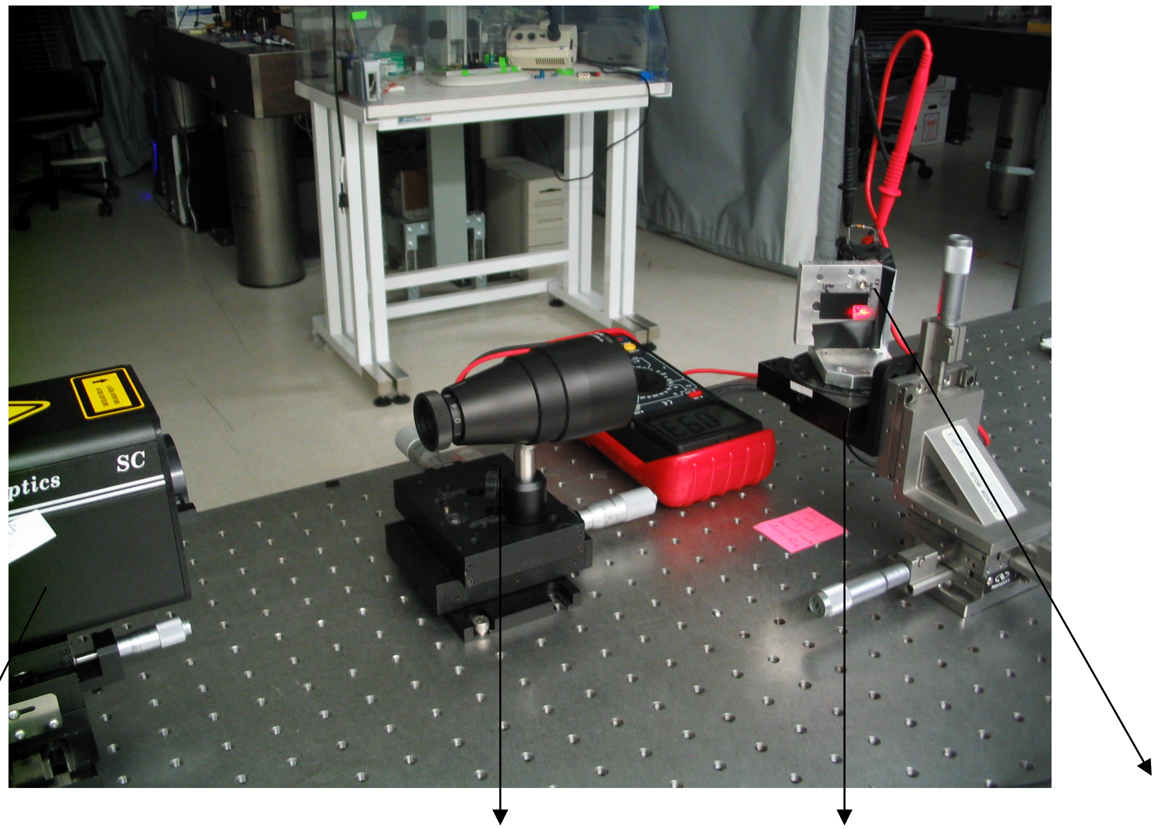


# Final Setup: Red Laser: Normal Incidence



# Final Setup: Red Laser: 60 Degrees Incidence



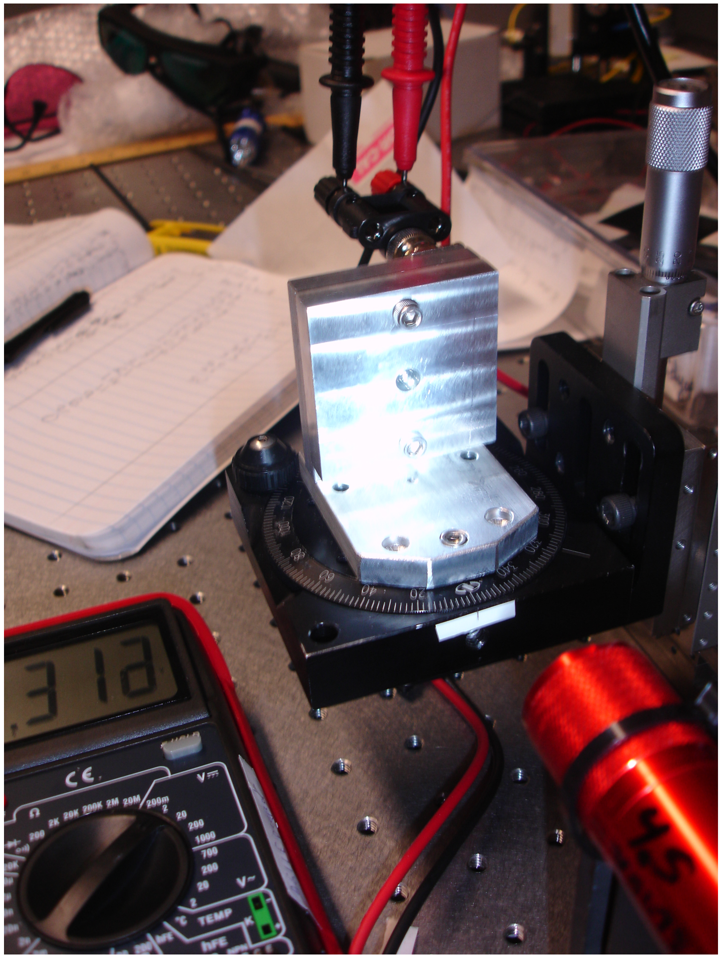

Laser

Beam Expander

Rotational Stage

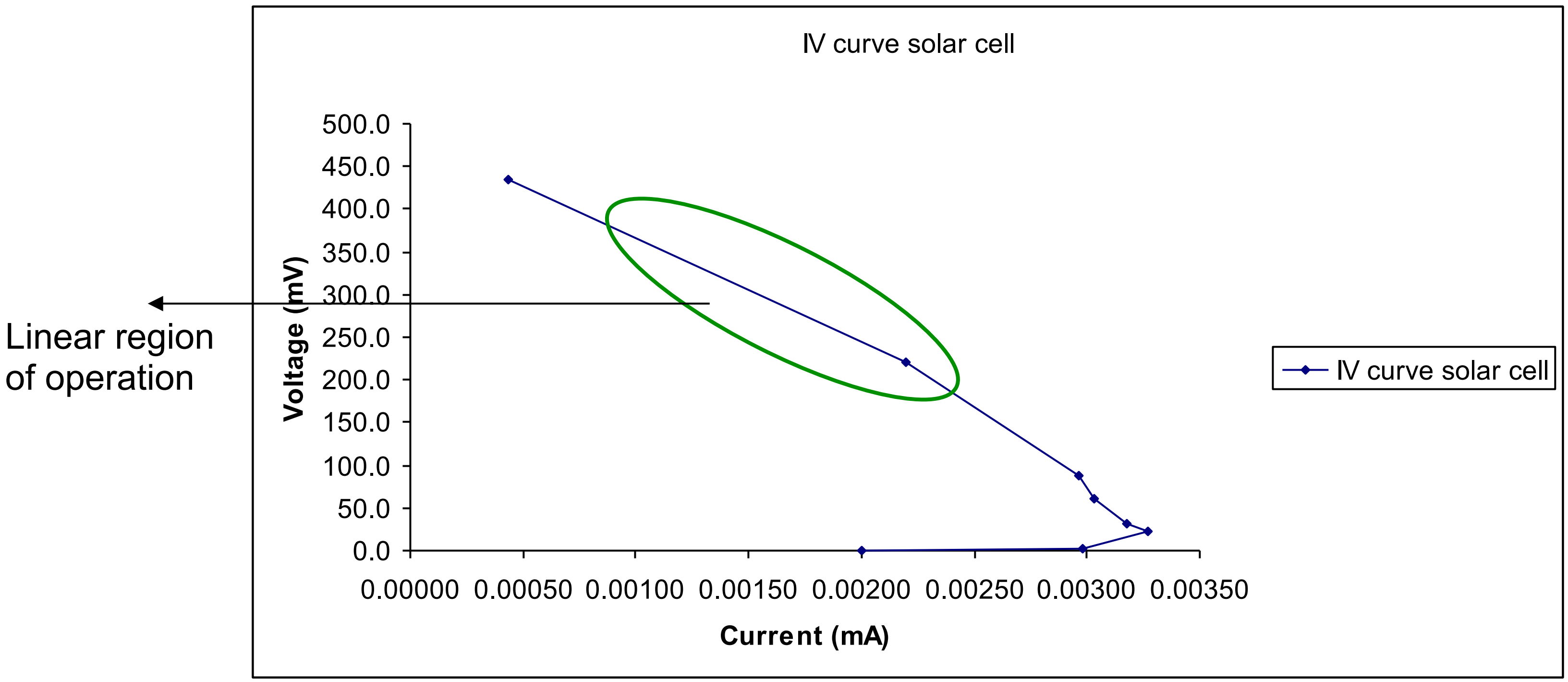
AGILE

# Final Setup: White LED: Normal Incidence



- The input face of the AGILE is located at the centre of rotation for every device
- Angular measurement test results are symmetric (clockwise and anti-clockwise)
- The measurements are done in one plane but they also have full 360 degree symmetry (important for solar applications)

# Characterizing the Photo-detector

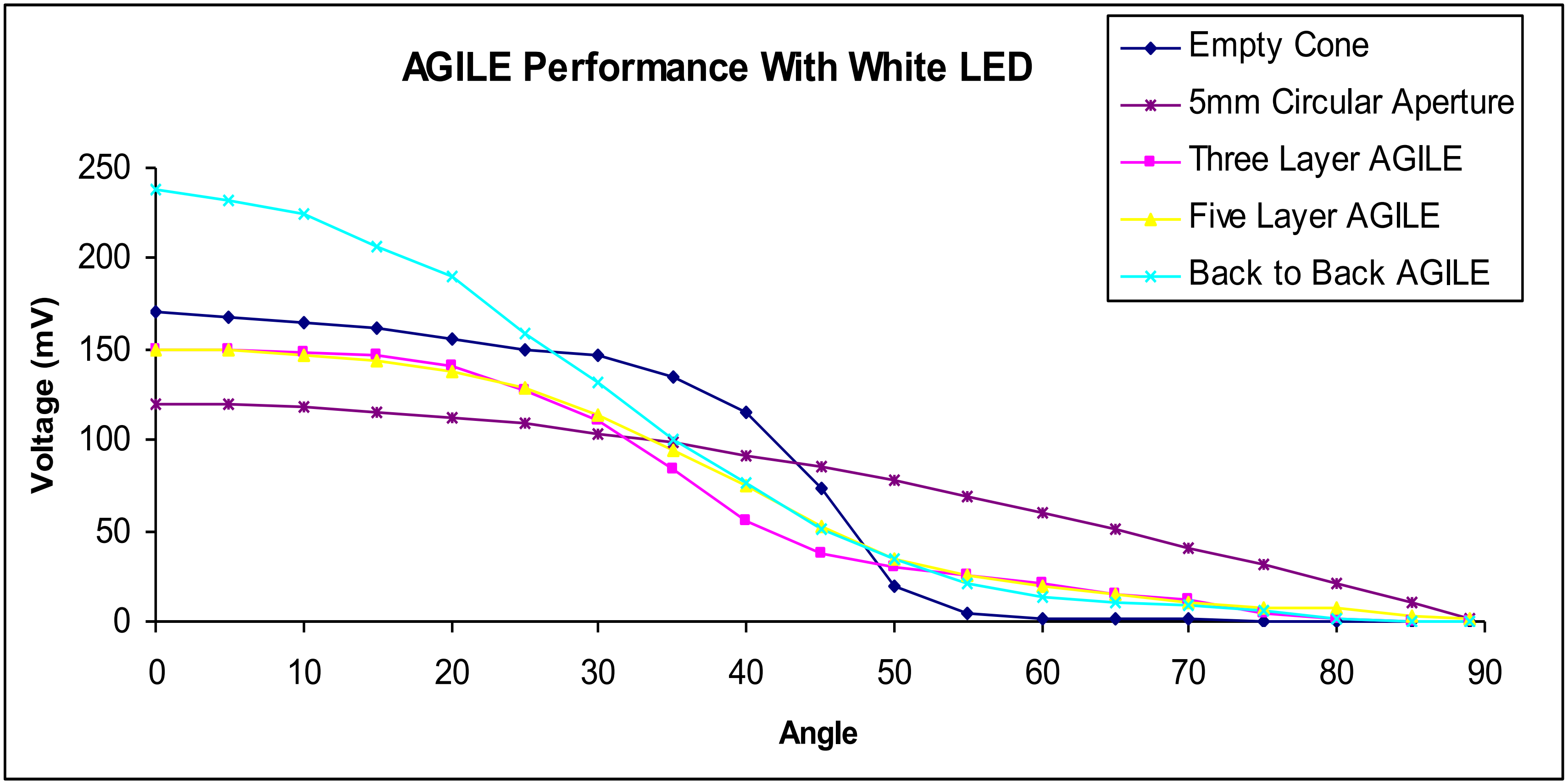



1) I-V curve for solar cell detector measured at different loads: confirms operation of 100K load (final design load) in linear region and hence we can relate voltage measured from solar cell to light energy at output

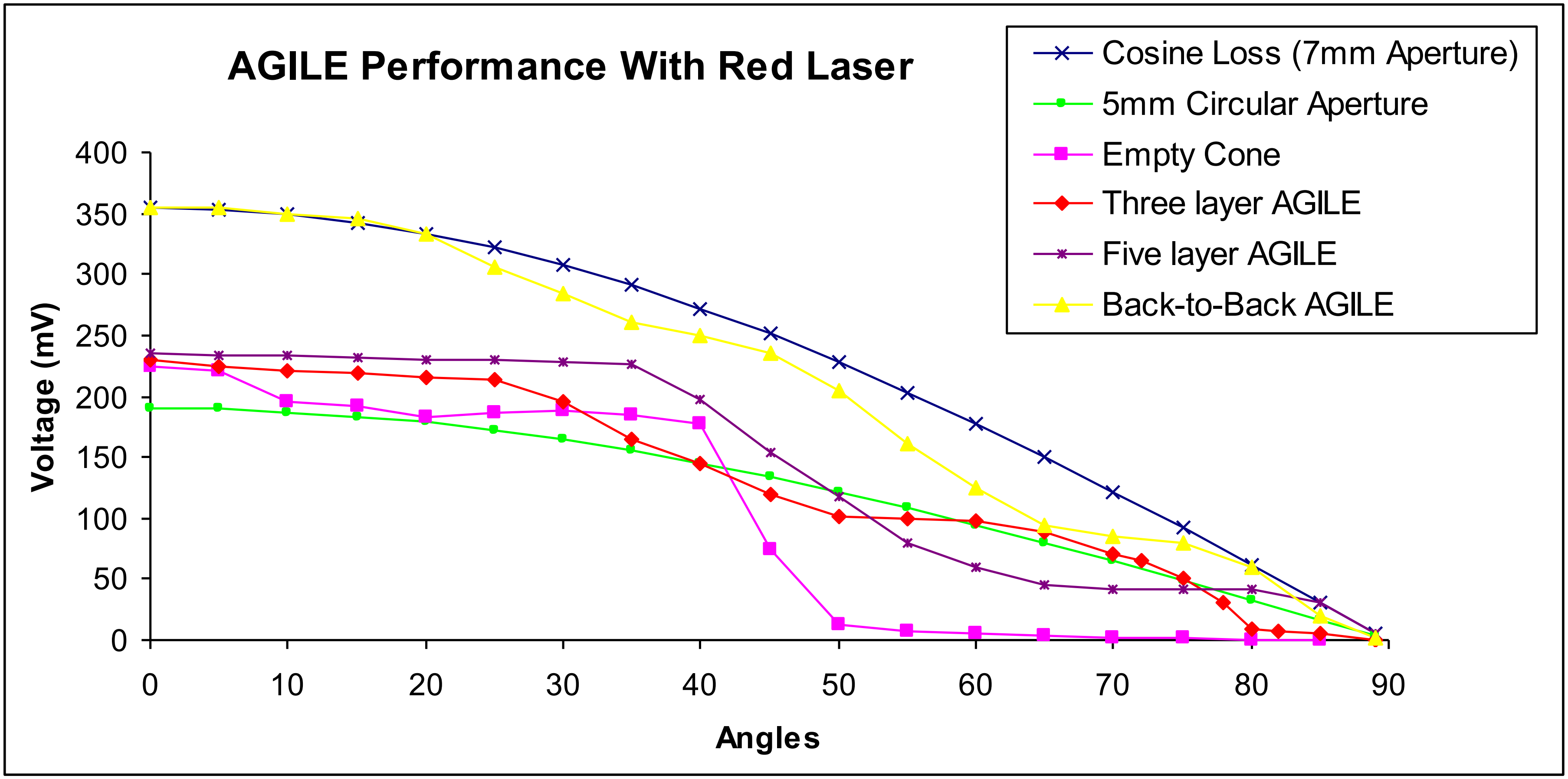
Light intensity gain ratio = I/Io + V/Vo

2) The Isc (short circuit currents) are too small to measure

# AGILE Performance with White LED Light Source



# AGILE Performance Under Red Laser Source



# Discussion of Results

- There seems to be a sine wave superimposed over the curve for some of the red light tests.  This could just be due to the way the single wavelength red light bounces around within the cavity between the agile and the detector, or within the different layers of the agile, or even within the plastic coating on the surface of the solar cell. The sine wave effect seems more pronounced with single wavelength, and hence it is almost gone with white light.

- The back to back structure gives very good performance and seems to catch all the light that can be incident on a 7mm diameter circular aperture. This could also be because light is now incident on a larger part of the solar cell and hence gives higher values on V. But mostly it is because there is better coupling of light to the detector with light going through low to high and then to low index.

- The back to back structure is a success and proves the effectiveness of the AGILE concept

# Concluding Remarks

- A process to make graded index optical lens material was fine tuned, which was the aim of this EE412 project
- Transmission and refractive indices of different laminated stacks of optical materials/optical adhesives was characterized
- Fabrication and testing of AGILEs was completed successfully
- Next steps: make AGILEs with a larger range of RI change with more aggressive area ratios, fabricate arrays of AGILEs and test the performance, investigate cheaper materials and faster fabrication methods
- Special thanks to my mentor Tom Carver and the EE412 professors, staff and students