STEAMVR™

Tracking Training

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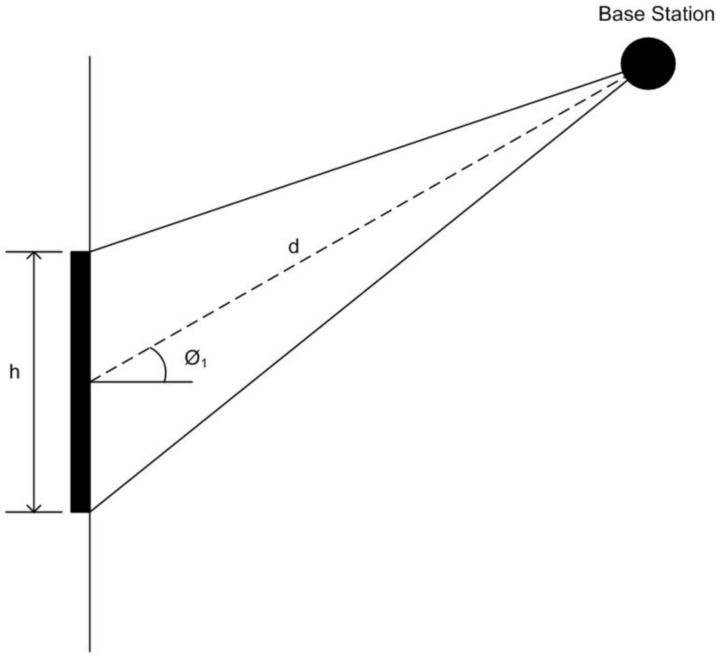
Sensor Covering

Introduction

- Benefits of covering
  - Protects against physical impact
  - Protects from moisture and dust ingression
  - Prevents induced noise and sensor malfunction
  - ESD protection
  - Improves design aesthetic
- Covering strategy is important
  - Four sensors are needed to constrain an object in space
  - Complex geometry and obstructions limit the number visible
  - A cover generally won’t improve performance.
  - Goal is to minimize any effect.

Theory

- Sensors record time stamps for the beginning and duration of a laser strike to estimate the center
- Relate to optics by creating a ray diagram
    - d = distance from base station to sensor
    - h = height of sensor
    - $Ø_1$ = incident angle between base station and sensor



Theory

- Simple trigonometry can be used to determine $Ø_{lead}$ and $Ø_{trail}$.

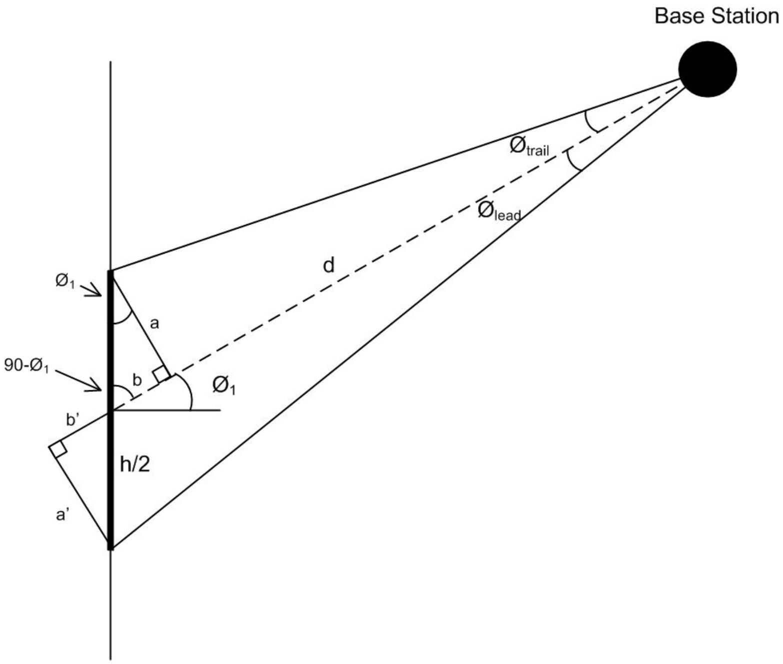
$$Ø_{lead} = tan^{-1}\frac{a'}{d+b'} = tan^{-1}\frac{\left(\frac{h*cos\,Ø_1}{2}\right)}{\left(d+\frac{h*sin\,Ø_1}{2}\right)}$$

$$Ø_{trail} = tan^{-1}\frac{a}{b} = tan^{-1}\frac{\left(\frac{h*cos\,Ø_1}{2}\right)}{\left(d-\frac{h*sin\,Ø_1}{2}\right)}$$

- Angles are small and hard to interpret so "ticks" are used

$$t\,[ticks] = \frac{\theta * f_{counter}}{\omega_{motor}}$$

- Count of system clock cycles over the time it takes the laser to sweep across the sensor.



Theory

- Motor speed: 60 Hz
- System clock frequency: 48 MHz
- Combining everything:

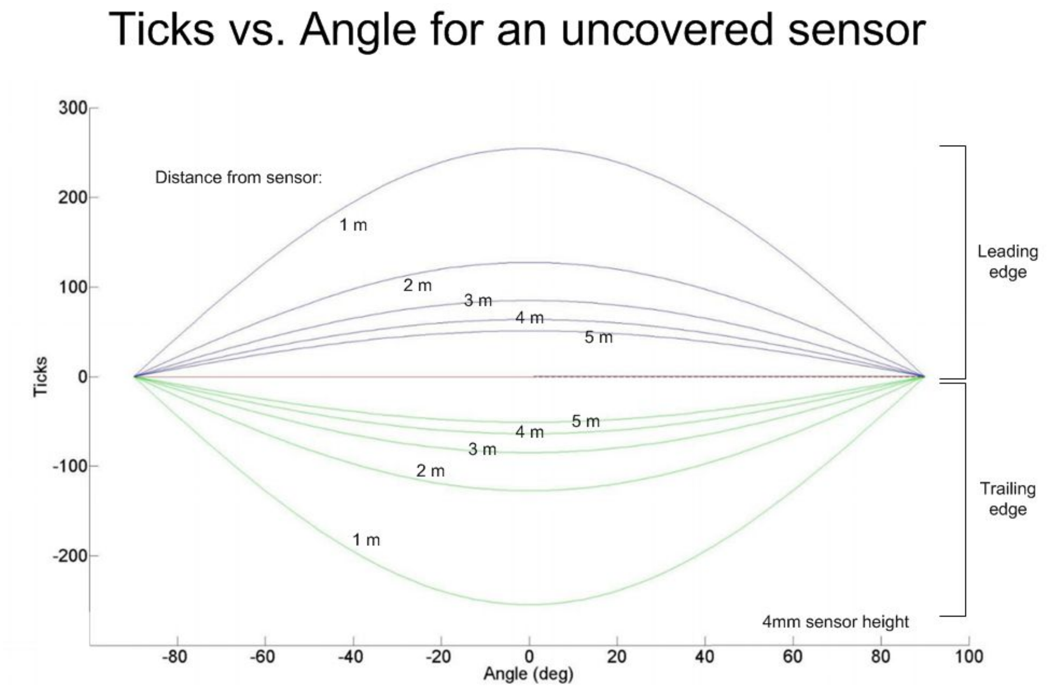
$$t_{lead} = \tan^{-1}\frac{\left(\frac{h * \cos \Theta_1}{2}\right)}{\left(d + \frac{h * \sin \Theta_1}{2}\right)} * \left(\frac{48\times10^6}{120\pi}\right)$$

$$t_{trail} = \tan^{-1}\frac{\left(-\frac{h * \cos \Theta_1}{2}\right)}{\left(d - \frac{h * \sin \Theta_1}{2}\right)} * \left(\frac{48\times10^6}{120\pi}\right)$$

- t_{trail} is made negative for better visualization when plotted

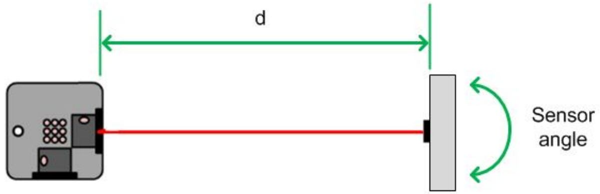
Theory

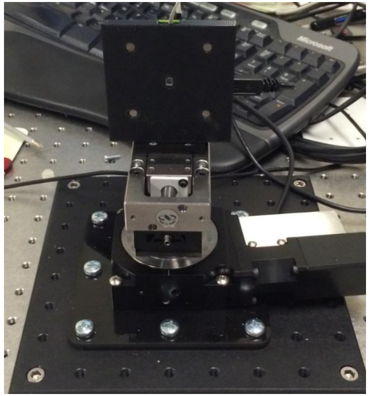
- The equations can be plotted at various angles and distances to predict performance of the opto-mechanical system
- Ticks increase as distance decreases
- Ticks decrease as the angle increases.
- No ticks are registered at ± 90°

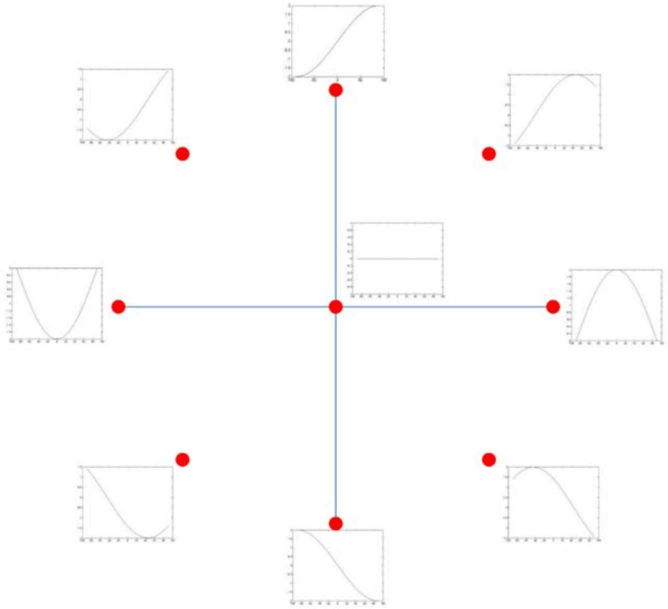


Experimental Results

- A test fixture was created to generate these curves with actual parts and coverings
- Unit calibrated by visualizing estimated sensor center and adjusting sensor x-y position until output was flat







Experimental Results

Specular transparent

Diffuse transparent

6mm spacer

Specular transparent aperture

Diffuse transparent aperture

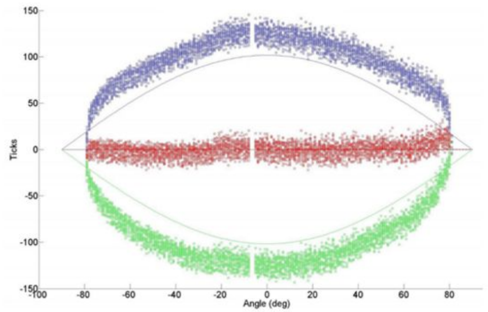
- Covers were created to measure the effect of common design strategies
  - Specular vs. diffuse
  - Aperture vs. no aperture
  - Spacing from sensor to cover
- Testing was done with a red laser. Base station laser is 830nm but the results still apply.

Experimental Results

Selected Results

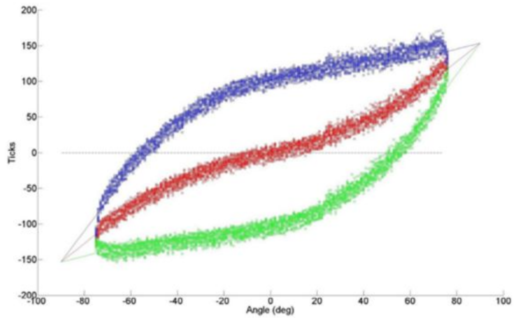
Blue dots represent the leading edge, green the trailing edge, and red the center

Case #1: Uncovered



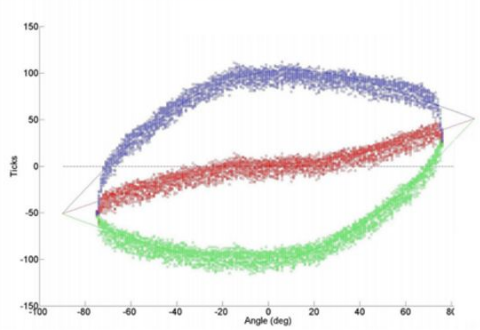
Cover material: None
Aperture diameter: Infinite
Cover thickness: 0 mm
Gap distance: 0 mm

Case #2: Specular transparent



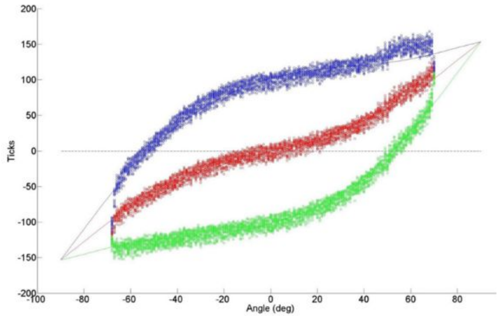
Cover material: Specular transparent
Aperture diameter: Infinite
Cover thickness: 3 mm
Gap distance: 0 mm

Case #3: Specular transparent



Cover material: Specular transparent
Aperture diameter: Infinite
Cover thickness: 1 mm
Gap distance: 0 mm

Case #4: Specular transparent + gap



Cover material: Specular transparent
Aperture diameter: Infinite
Cover thickness: 3 mm
Gap distance: 6 mm

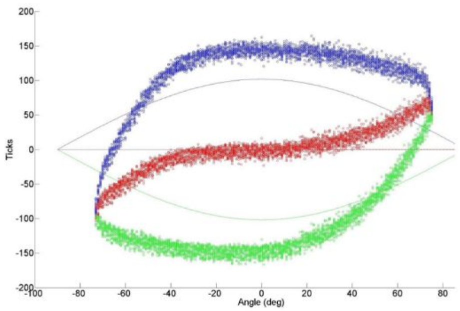
VALVE

Experimental Results

Selected Results

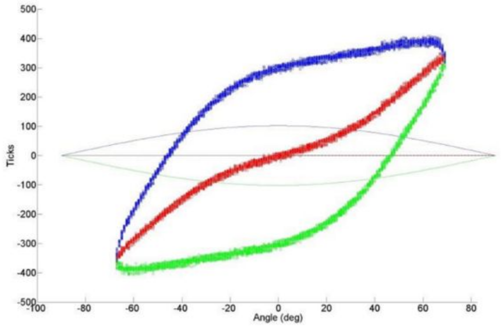
Blue dots represent the leading edge, green the trailing edge, and red the center

Case #5: Diffuse transparent



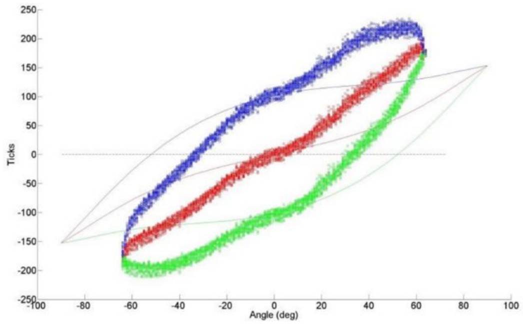
Cover material: Diffuse transparent
Aperture diameter: Infinite
Cover thickness: 1.5 mm
Gap distance: 0 mm

Case #6: Diffuse transparent + gap



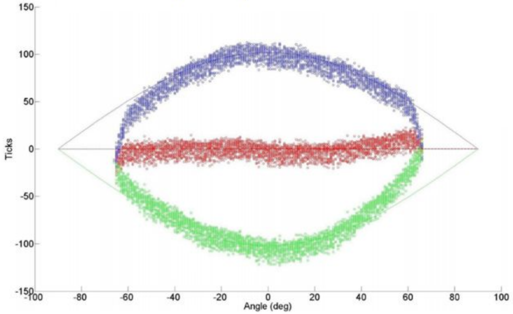
Cover material: Diffuse transparent
Aperture diameter: Infinite
Cover thickness: 1.5 mm
Gap distance: 6 mm

Case #7: Specular transparent aperture



Cover material: Specular transparent
Aperture diameter: 4 mm
Cover thickness: 1.5 mm
Gap distance: 0 mm

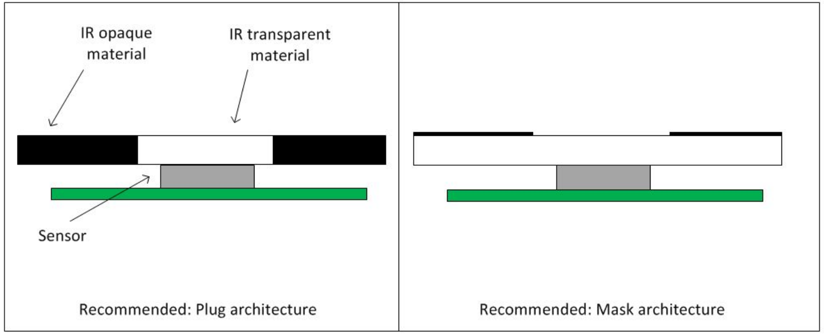
Case #8: Diffuse transparent aperture



Aperture material: Diffuse transparent
Aperture diameter: 4 mm
Cover thickness: 1.5 mm
Gap distance: 0 mm

Covering Best Practices

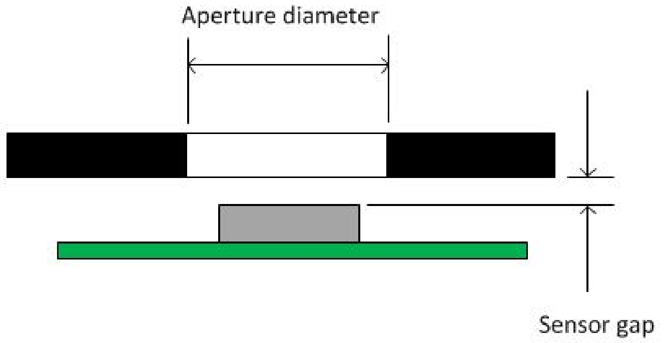
- Architecture
  - Recommended: Diffuse aperture surrounded by opaque material
    - Plug
      - Two shot injection molding
      - Individual windows/plugs fastened to housing
    - Mask
      - Single shot injection molded part painted and laser etched
      - Single shot injection molded part with an IML
  - Not recommended
    - Diffuser with no aperture
    - Clear material with no aperture
    - Placing the opaque mask between the clear material and sensor



Choose an architectural approach as early in design as possible.

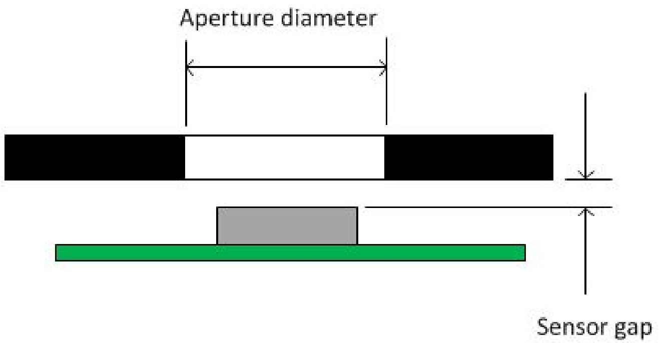
Covering Best Practices

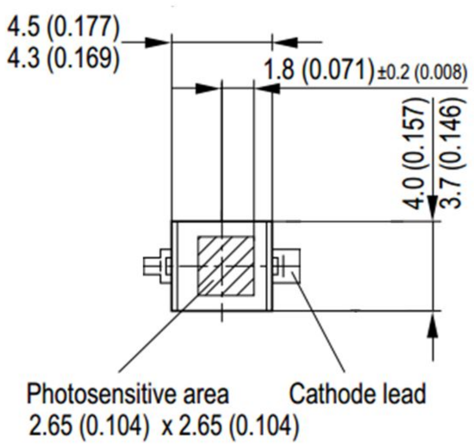
- Aperture properties
  - Outer surface
    - Flat and parallel with top of sensor
    - Some curvature may be okay but should be tested
    - Complex curvature is not recommended
  - Opening size
    - Too small, not enough light gets in.
    - A 6mm diameter is a good starting point
    - Larger windows are possible but need increased diffusion.
  - Thickness
    - Thin as possible
    - Usually limited by manufacturing method.
  - Surface finish
    - Matte texture is recommended
    - Avoid glossy surfaces



Covering Best Practices

- Sensor positioning
  - Sensor gap should be as small as possible
  - Sensor active area should be in center of the opening





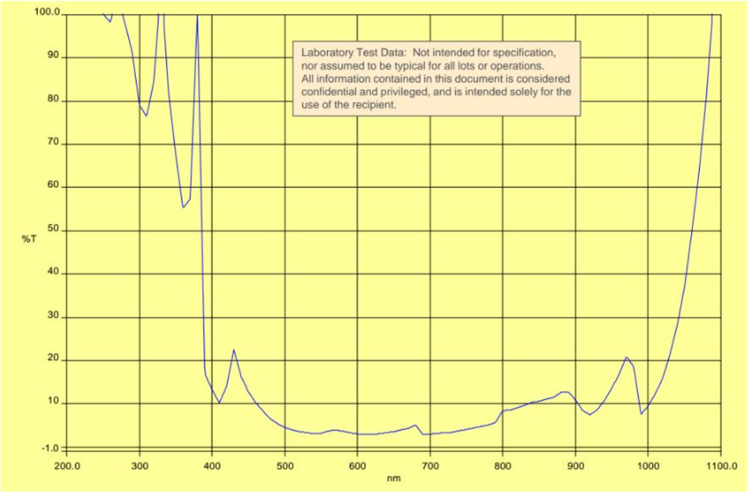
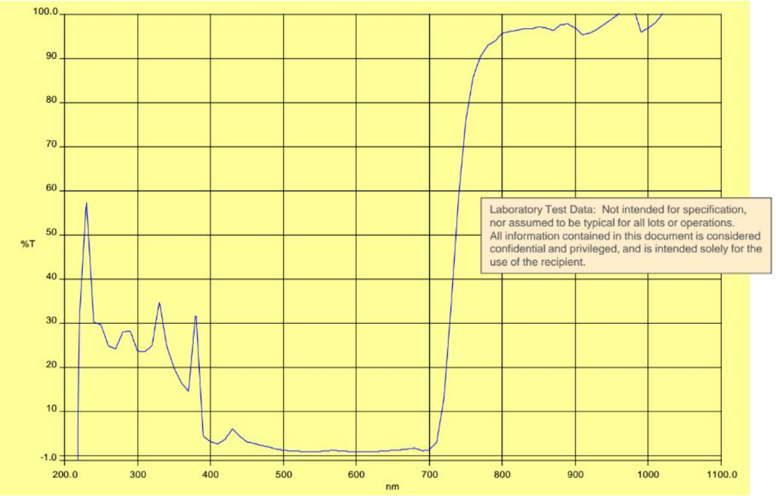
Covering Best Practices

- Materials
  - IR transparent material
    - PC and PMMA work well as a base material and are good for for prototyping
    - In production, filter out visible light with an IR additive
    - Color will be black or very dark reds, blues, etc
  - IR opaque material
    - Few limitations other than being IR opaque
    - Can be color matched to IR transparent material

Recommended transmission properties 0 degree incident angle		
Material	400 - 700 nm	830 nm
IR transparent	<10%	>90%
IR opaque	<1%	<1%

Covering Best Practices

Materials used in reference object

Function	IR opaque material	IR transparent material
Resin	SABIC LEXAN “701”	SABIC LEXAN “BK1A184T”
Transmission vs frequency graph		

Summary

- Theoretical and experimental models created
- Best practices
  - Architecture
  - Geometry
  - Surface finish
  - Materials
- Consider covering strategy early as it can impact the overall design