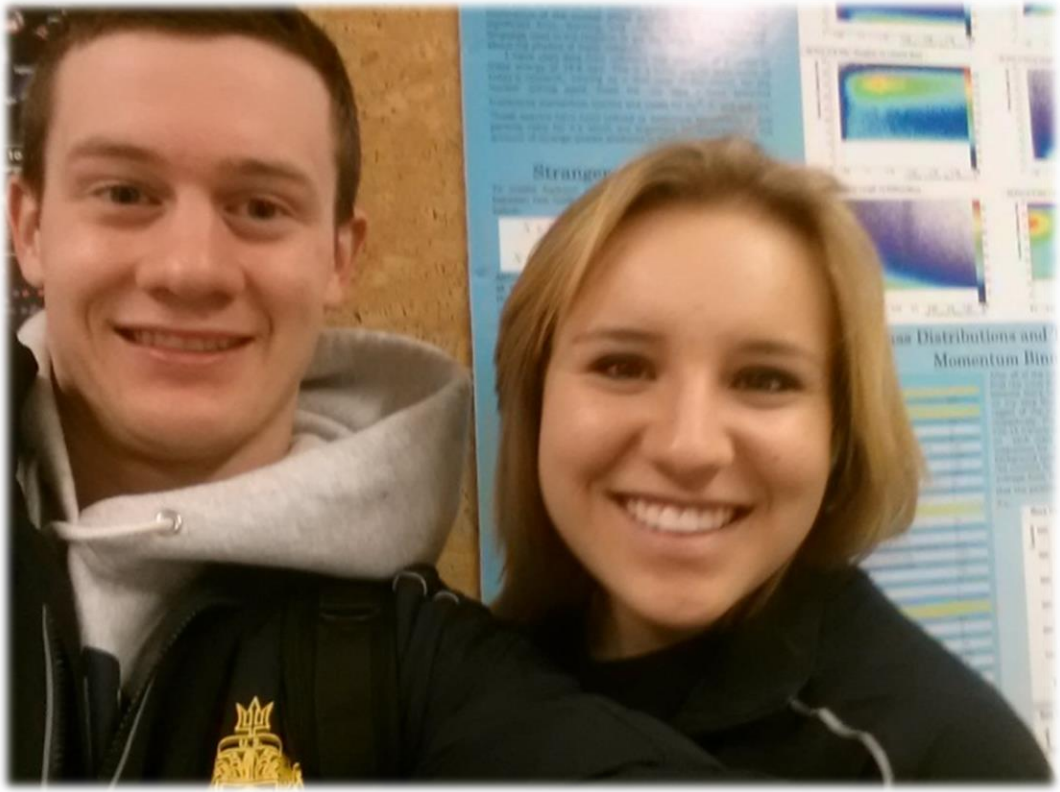

Analysis of Laser Light Propagation

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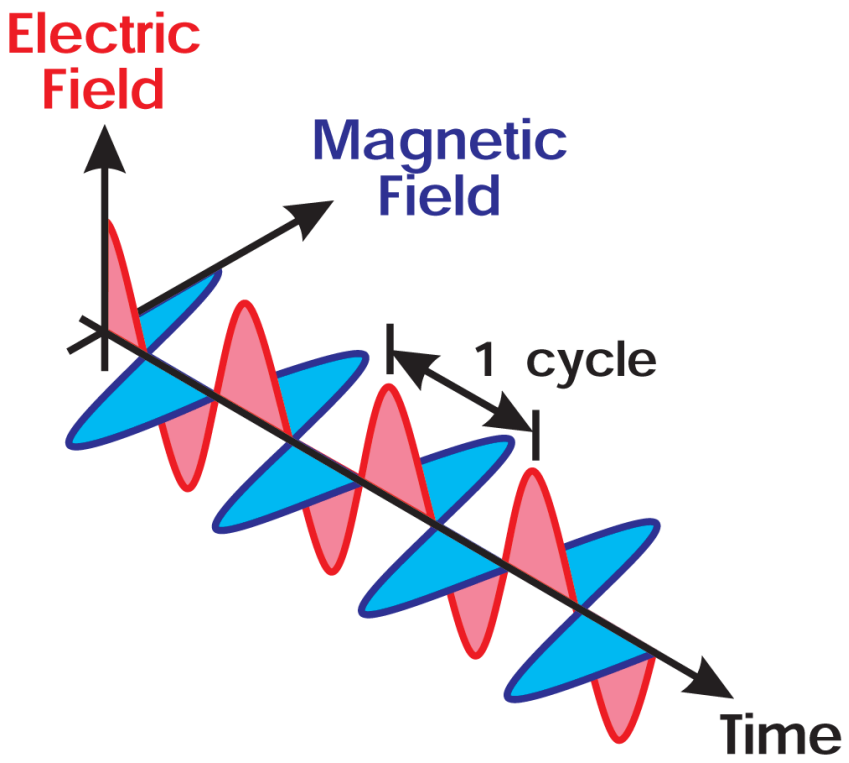
Motivation

- What is a laser beam – constant intensity of light, that is monochromatic, coherent collimated
- Talk about history of laser – importance of laser research
- Why is laser research impt – for navy, weapons systems, comms

Basic Properties of EM Waves

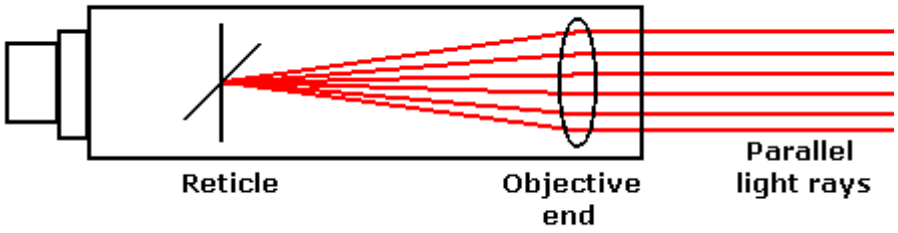
- Light is a special kind of EM Wave particle and a wave behavior
- Faraday's law- the electric field will induce a perpendicular magnetic field, the magnetic field induces a perpendicular electric field
- The E field dictates the polarization of the EM Wave
- The individual Energy of a wave is carried in the photons. Each photon carries energy, the impact of the photons heats a target, or in our case, excites the sensors



Get a picture of monochromatic and coherent pictures on google

BASIC PROPERTIES OF LIGHT

Monochromatic
Coherent
Collimated

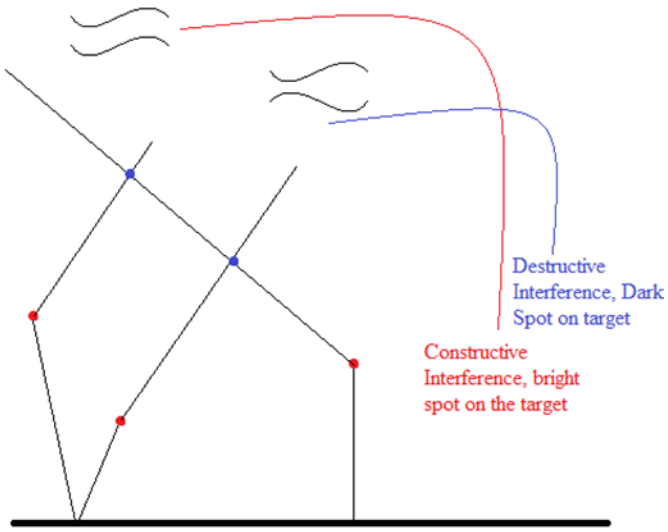


Amplitude - Brightness
Wavelength – Color
Phase (Angle) - Polarization

- What is index of refraction, n in snell's law, for talk on how SLM changes light
- Law of refraction changes the light in the SLM
- Beam changes path due to change in index of refraction
- Picture of SLM and one screen
- Say that SLM provides spatial light distribution

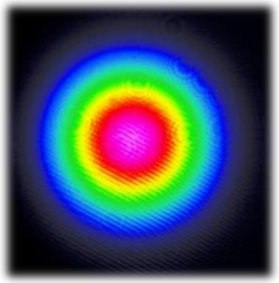
Intro

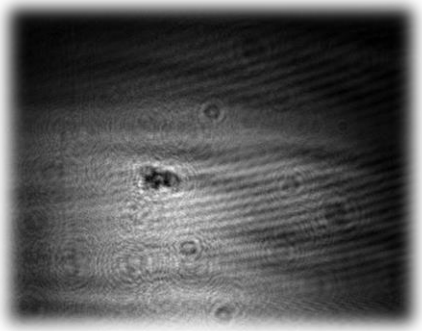
- Scintillation and Coherence
- GOAL: Reduce the variation of laser light fluctuations and maintain high average light intensity on the target. Reduce scintillation index, normalized variance.
- Loss of coherence with environment interaction

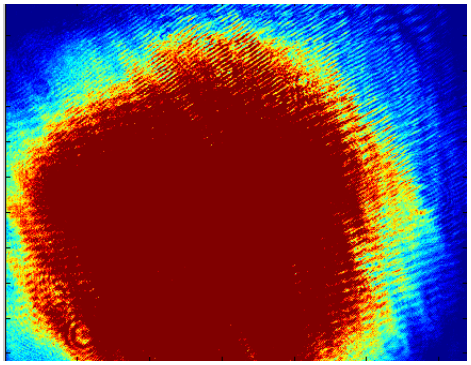


- Draw Gaussian function
- Draw Bessel Function
- Show the audience the functions and say this is how they change
- MATLAB – randn besselj, plot them and put the pic up on here
- Put the 4096 screens up for both, plot based off of the 4096 and 0.025 beta
- Not necessarily on slide – why these beams are impt for research – when beam propagates through an environment, the behavior is best approximated by bessel and random medium is approximated with gaussian function

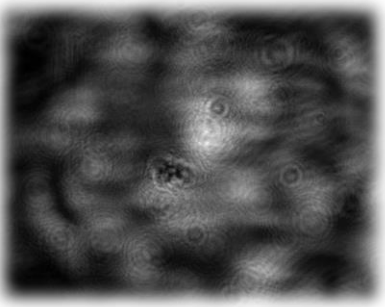
Intro

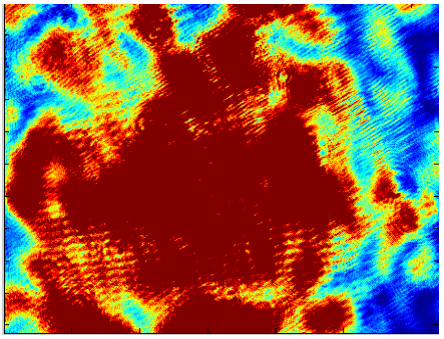






Black

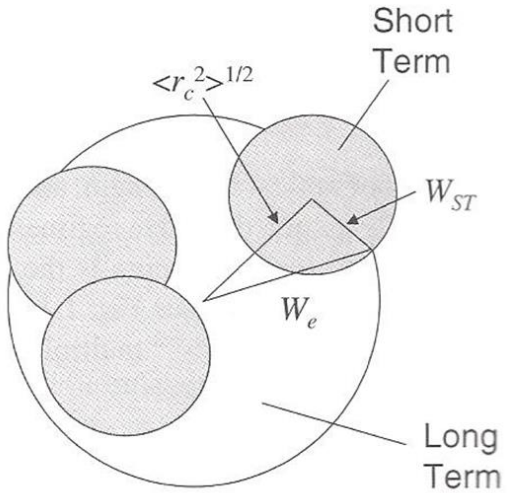




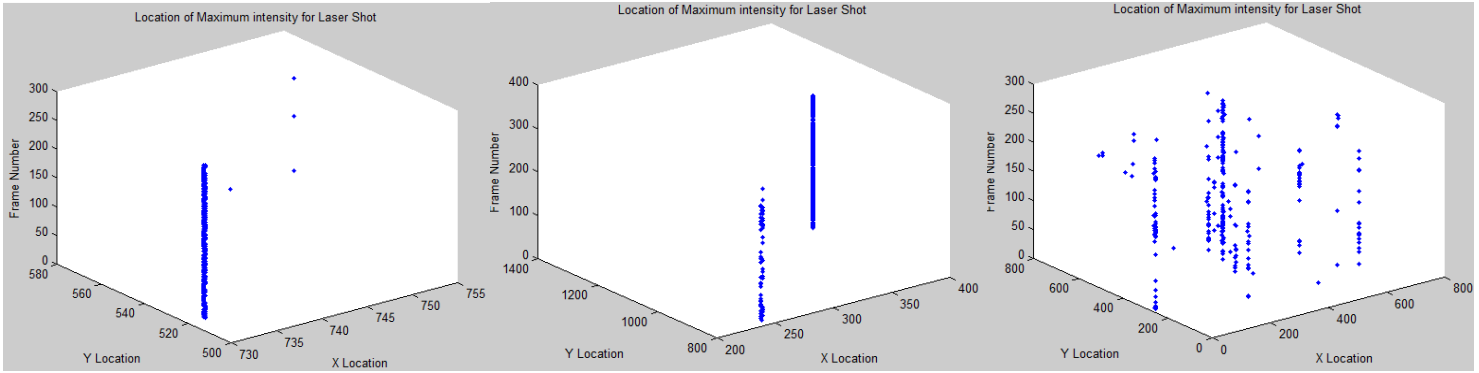
The correlation width is 128.

- Low Turbulence
- 630 nm, 2mW laser
- SLM, CCD Camera
- Gaussian and Bessel
- Ran experiment on 13 different occasions
  - 108 laser runs, 108 black runs
  - 6 screens * 3 screen sets*2 types*3 distances

Beam Wander



SLM #	Distance	Xbar	Ybar	STD X	STD Y	STD Hypot	DistX(µm)	DistY(µm)	Hypot Dist(µm)
set2									
4	50	732.55	521.9	3.49	7.99	8.72	16.23	37.15	40.56
set3									
16	100	360.85	1137.22	52.87	141.83	151.37	245.87	659.52	703.86
128	50	317.14	343.73	168.53	184.56	249.93	783.65	858.21	1162.17



Method

The figure to the left shows the DCx Camera positioned on the tripod.

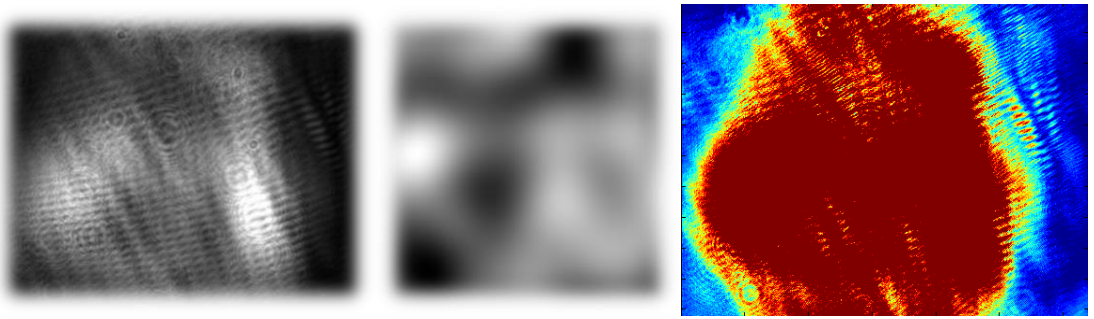
Method

On the left, laser, expander, and SLM aligned with the DCx camera, to the right, displays the path of the laser as it travels from the expander to the SLM and then to the DCx camera (intensity sensor) for recording.

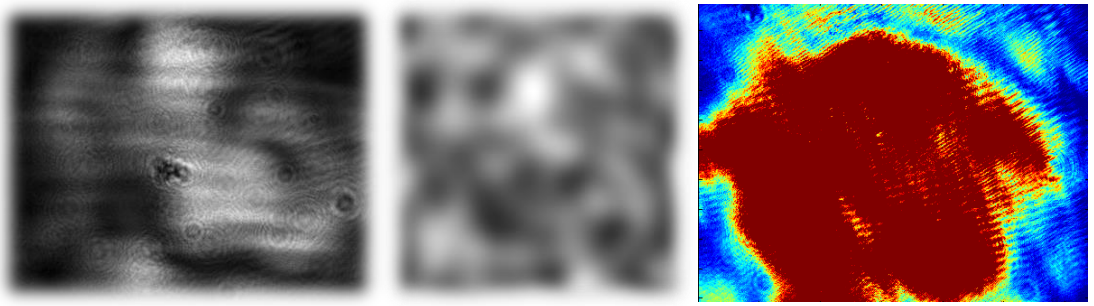
Other experimental equipment

- Tripod w/ kinematic head
- CCD Camera
- Light Sensors, power sensors, IR sensor
- Laptop
- Red and Neutral Filters (Light and Power)
- Beam expander and Spatial Light modulator
- Light generator (laser)

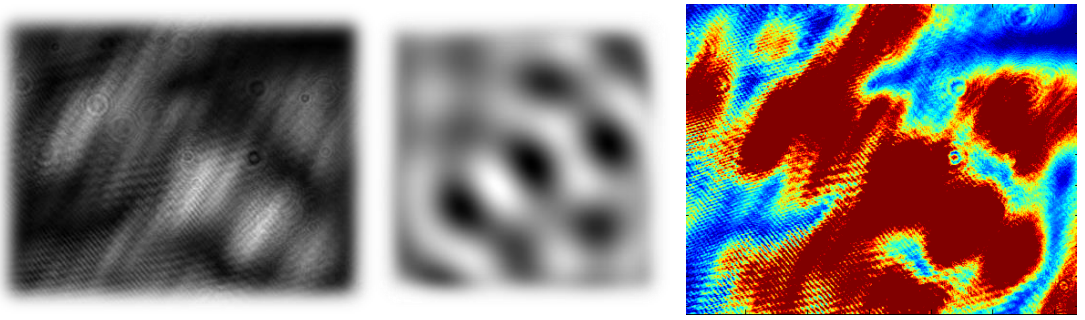
Bessel V Gaussian Beams



4096 Gaussian



1024 Gaussian



1024 Bessel

Bessel vs Gaussian Beams

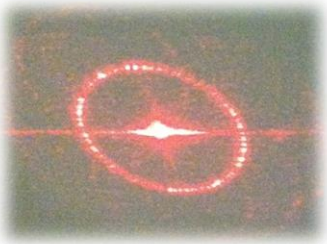
On x axis – it is not SLM Number – it is correlation width squared

Beta 5 D=5m

Beta 1 D=10

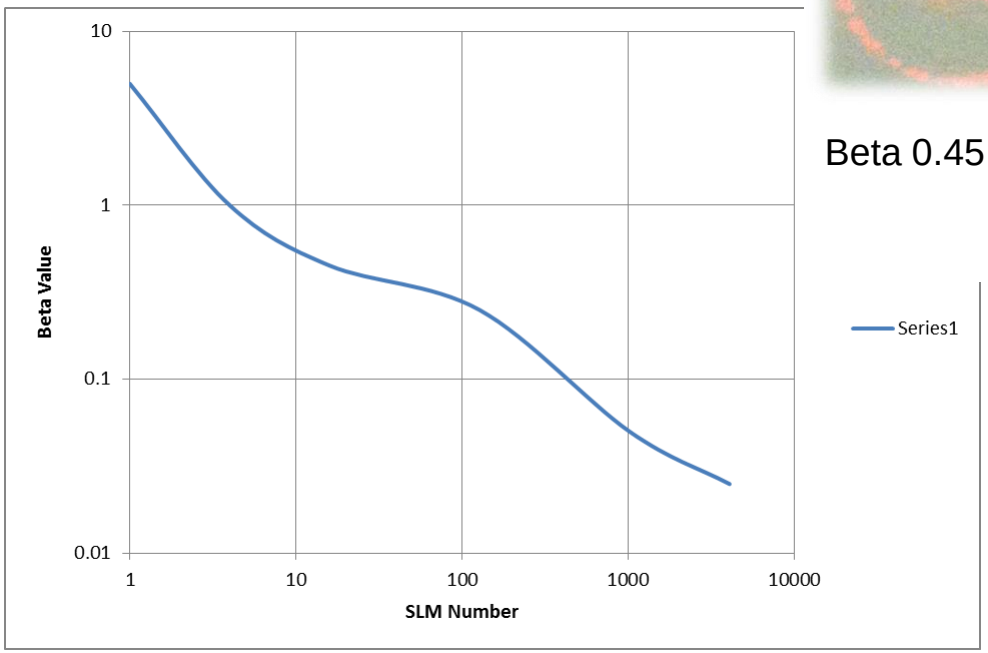
SLM 16 D=10m

Beta 0.45 D=10m

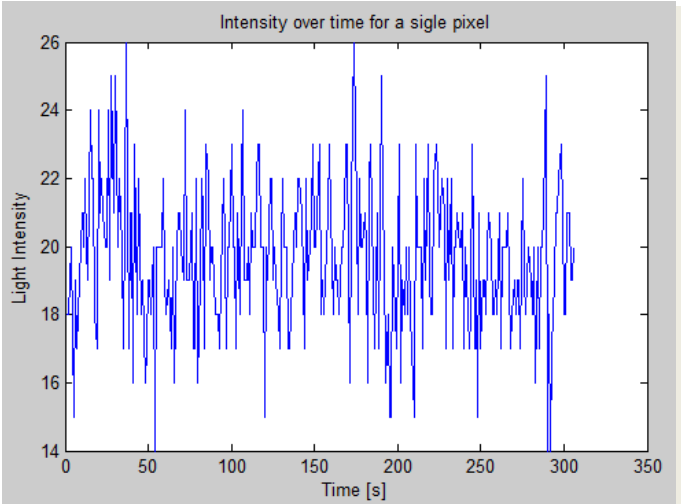


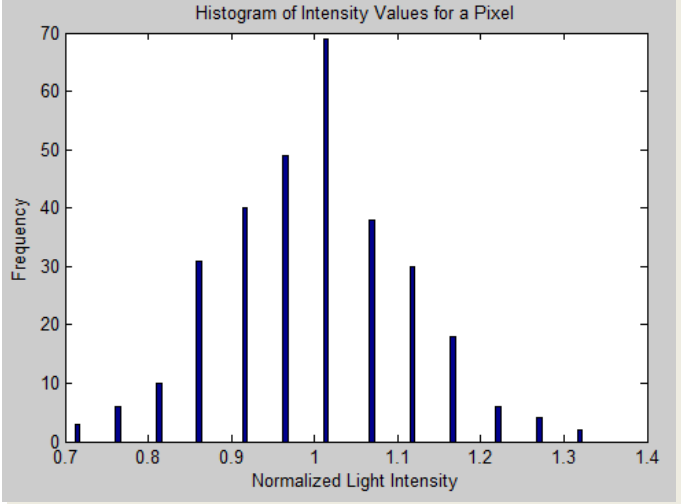
Beta 0.25 D = 5m

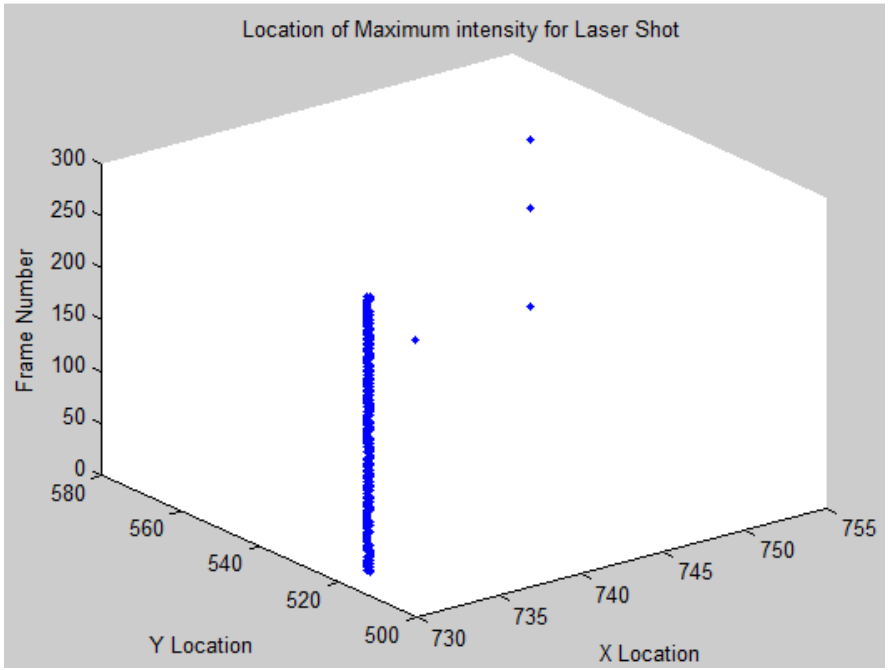
SLM	Beta
1	5
4	1
16	0.45
128	0.25
1024	0.05
4096	0.025



Desired Results





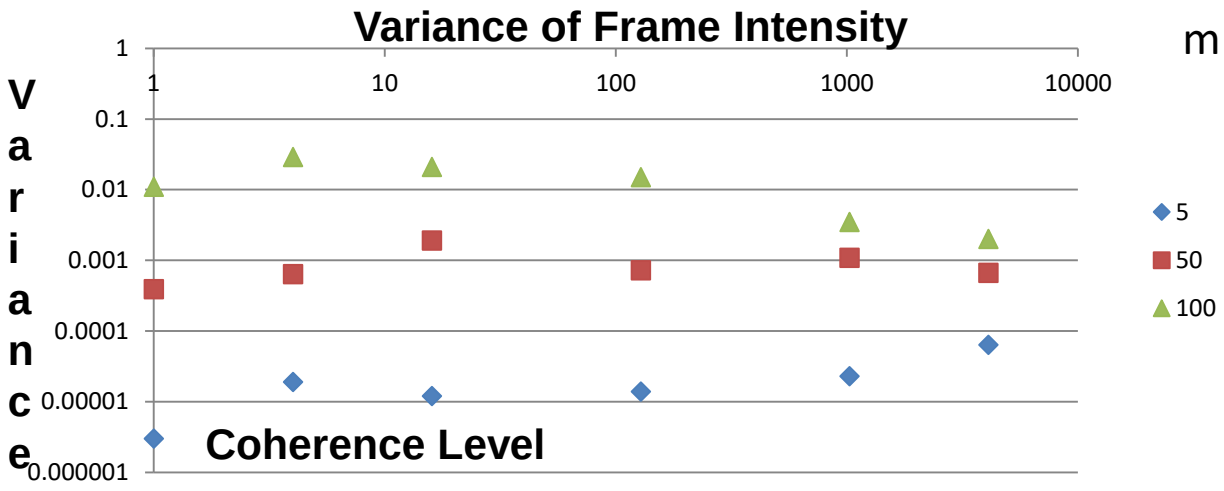


The MATLAB plots are the frame intensity for SLM screen 16, set 3, at 100 meters
Beam wander for SLM screen 4, set 2 at 50 meters.

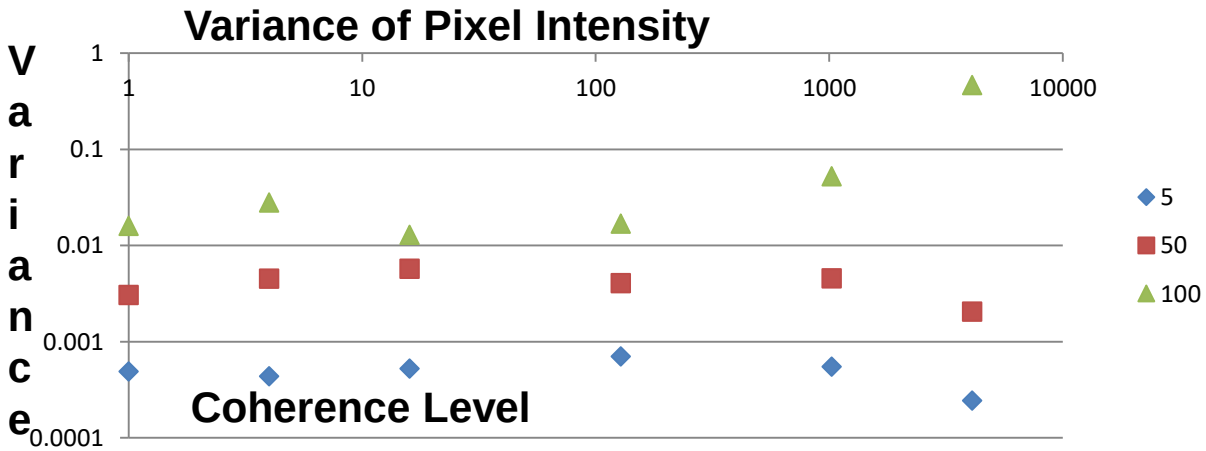
RESULTS

Add the black data points onto the graphs, make the black as a different shape only for 100 m propagation

Gaussian Set 1 Results



Bessel Set 2 Results



Conclusion

- Research needs to be continued to expand on what was learned
- Gaussian with correlation width 16 and the equivalent Bessel Screen show signs of success for reducing variance of intensity
- Beam wander was generally small
- Analyzing information for pixels is unreliable and unnecessary
- From the research, using different screens with the same statistical values will produce statistically similar results.

Gaussian Beams

Distance / Screen set	Set 1	Set2	Set3
5	X	X	X
50	X		
100			X

Bessel Beams

Distance / Screen set	Set 1	Set2	Set3
5	X		
50	X	X	
100	X	X	X

Research's Link to the Navy

- Directional Communications
- Weapons – LaWs system just released in the Persian Gulf
- Importance to the Navy
  - Beam Wander
  - Minimized Variance
  - Maintain Average Intensity

Find the article that says $1 per shot

Steps to take in the future

- GOAL: Reduce the variation of laser light fluctuations and maintain high average light intensity on the target. Reduce scintillation index, normalized variance.

- Conduct more trials
- Focus the SLM Screens applied around 4-128
- Determine patterns relating to when variance was minimized
- Keep running the experiment many more times to establish knowledge and reliability

CONCLUSION

- **With an SLM it is possible to reduce variance while maintaining intensity**
- **Research must be done to determine exactly how**

References

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- Sprangle, P.; Ting, A.; Penano, J.; Fischer, R.; Hafizi, B.; , “Incoherent Combining and Atmospheric Propagation of High-Power Fiber Lasers for Directed-Energy Applications,” *Quantum Electronics, IEEE Journal of* , vol.45, no.2, pp.138-148, Feb. 2009