Laser Propagation in a Maritime Environment

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Goals

- Determine environmental factors that effect propagation of laser light
- Find Amplitude and phase spatial modulation to laser light that will improve intensity on target
- The paraxial equation describes how light behaves in vacuum. We will attempt to determine the Whitsett equation, which will describe how light behaves in an environment
- $\nabla^2 A + k^2 A = 0$

- Predict intensity level on target to within 10% during the given environmental conditions
- Improve irradiated power on target to within 10% of original with amplitude and phase space modulations

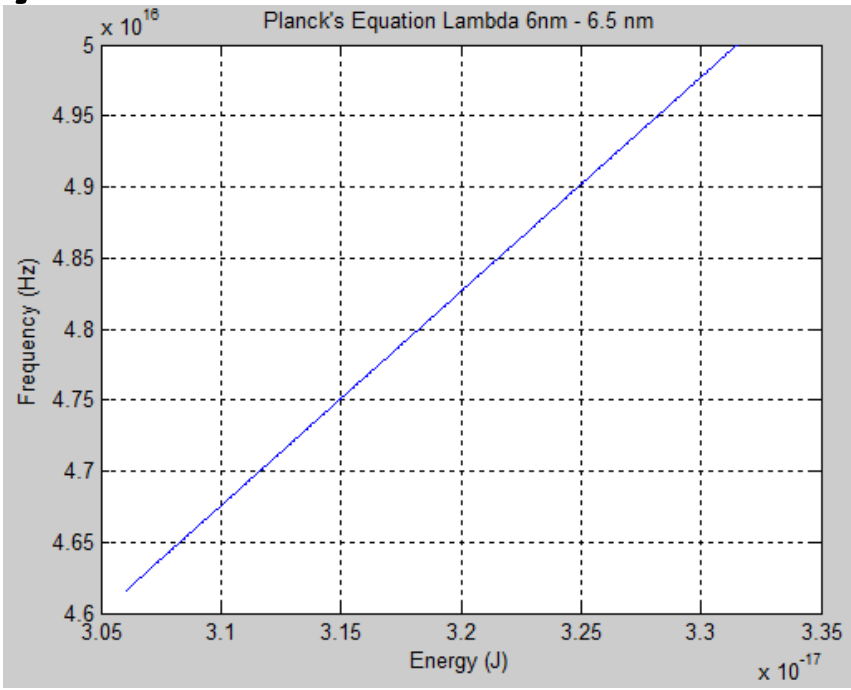
BASIC PROPERTIES OF LIGHT

Monochromatic Coherent
Collimated

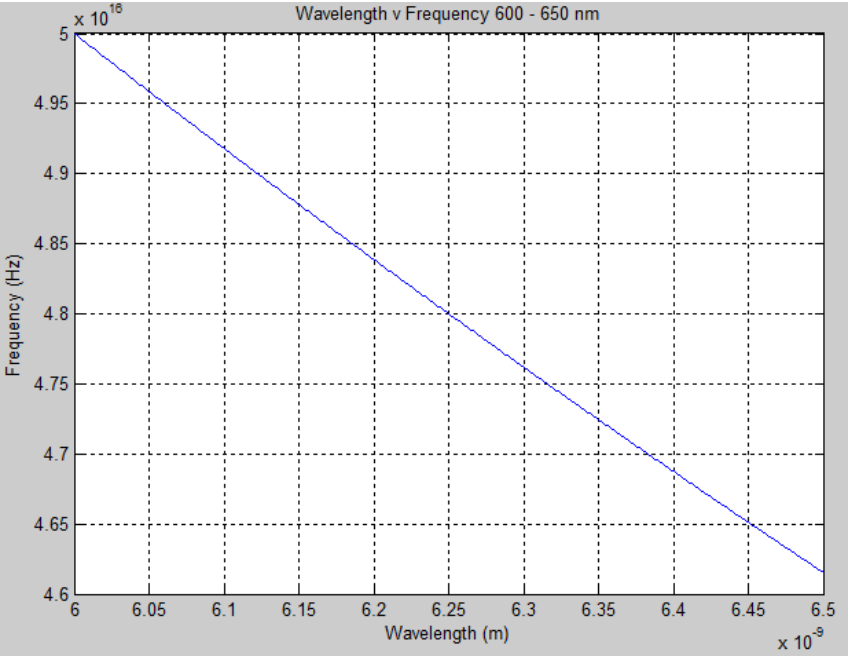
Amplitude - Brightness
Wavelength – Color
Phase (Angle) - Polarization

Energy

- E = *h*f, where *h* = 6.63x 10^{-34} J·s, this is the energy of a single photon
- We will use constant frequency light, we will expect a constant energy
- The energy of our beam will be approximately 3.155 picojoules.
- $P \cdot t = Energy, 1.27 \times 10^{16} \frac{e^-}{s}, 7.85 \times 10^{-17}\ s$
- $4\ mW\ \times 7.85 \times 10^{-17}\ s = 3.155$ pJ



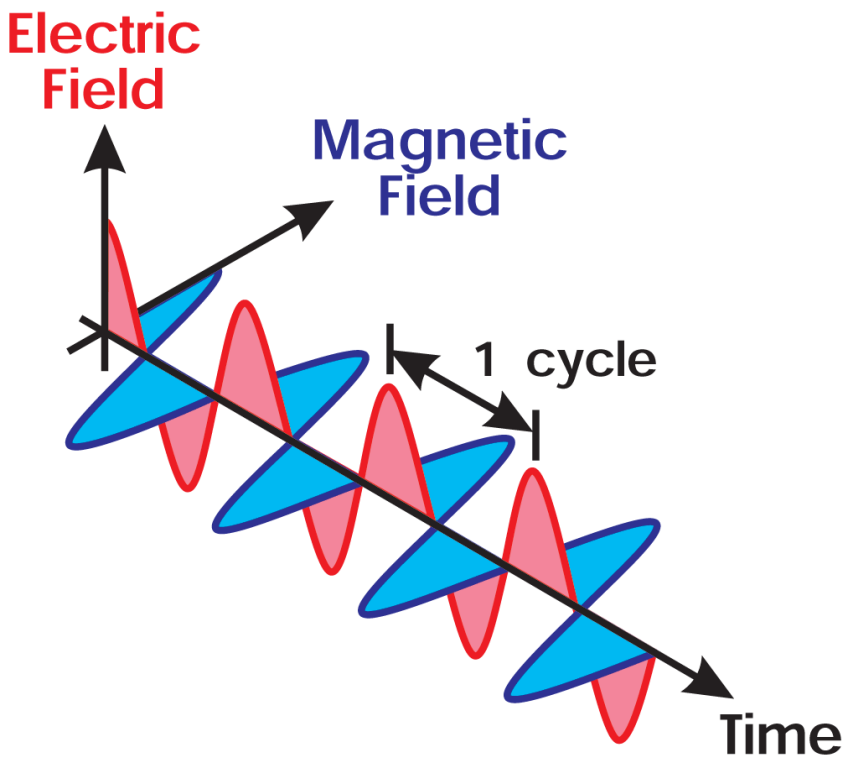
Velocity, Frequency, Wavelength



- $c = f\lambda$, this only applies to a vacuum
- As light impacts aerosol particles, due to the refractive index, the speed changes in different media
- Our laser will have a frequency of approximately 4.76 Terrahertz, wavelength of 630 nm, red light
- Laser light is not natural, natural light is not…
  - Collimated- Photons travel parallel to each other, completely straight
  - Coherent- Photons are totally in phase
  - Monochromatic- all the same wavelength and color
- Lasers are very narrow and concentrated

Basic Properties of EM Waves

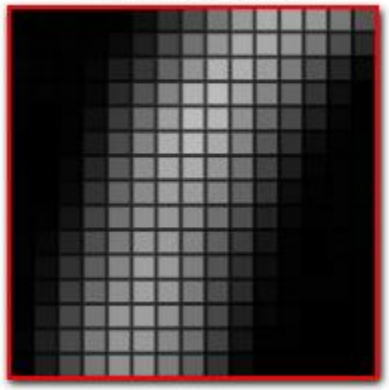
- Light is a special kind of EM Wave particle and a wave behavior
- Faraday's law- the electric field will induce a perpendicular magnetic field, the magnetic field induces a perpendicular electric field
- The E field dictates the polarization of the EM Wave
- The individual Energy of a wave is carried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



EXPERIMENT

Basic plan of project

Digital Sampling



Pixel Quantization

2	3	3	2	3	16	47	78	118	152	170	165	149	119	83
3	2	3	3	11	31	72	113	150	170	168	149	118	78	41
5	3	2	7	28	51	100	147	177	175	155	123	82	38	10
3	3	3	8	41	83	132	177	188	186	132	98	52	15	0
2	0	3	16	59	111	160	188	181	145	105	72	31	7	0
0	0	3	26	75	131	172	186	170	132	85	47	13	3	2
0	0	7	38	90	141	168	172	150	113	67	28	5	3	2
2	0	10	51	103	139	159	155	132	98	52	13	3	3	3
2	2	20	67	114	144	152	139	111	78	34	8	2	3	3
3	7	34	78	123	152	154	131	96	60	21	3	0	3	2
3	13	49	93	134	159	154	126	83	47	13	3	0	2	0
0	16	60	106	142	160	152	123	78	43	10	2	2	2	0
2	25	70	118	150	159	145	116	72	31	7	3	0	0	0
5	31	74	123	149	154	136	110	64	21	2	2	0	0	0
3	29	74	119	144	145	124	96	52	11	0	0	0	0	0

- We will alter our laser's amplitude and phase (polarization) spatially
- Both of these will be accomplished with the SLM device
- The SLM will modulate the light spatially pixel by pixel.

SLM- Spatial Light Modulator
Pixel by Pixel Light Modulations

Experimental Process

- We will fire our laser in various environments (humidity, barometric pressure, precipitation, night and day, etc) and determine what environmental factors most heavily effect the irradiated power of the laser and in what way.
- After determining the different effects, our final goal is to set up our laser, measure the environment and predict how much power will be delivered to the target. We will fire the laser and hopefully we will be within 10% of our estimate.
- Our success will be measured by how high of an average score we can achieve. A higher average score will be indicative of proper understanding of the environmental factors. A percent improvement from the initial research runs will determine how much our SLM has improved propagation.

Day, Night, Precipitation, etc

Environmental Factor	1	2	3	4
5% Humidity				
1atm Barometric Pressure				
75° F				
X MPH Wind				

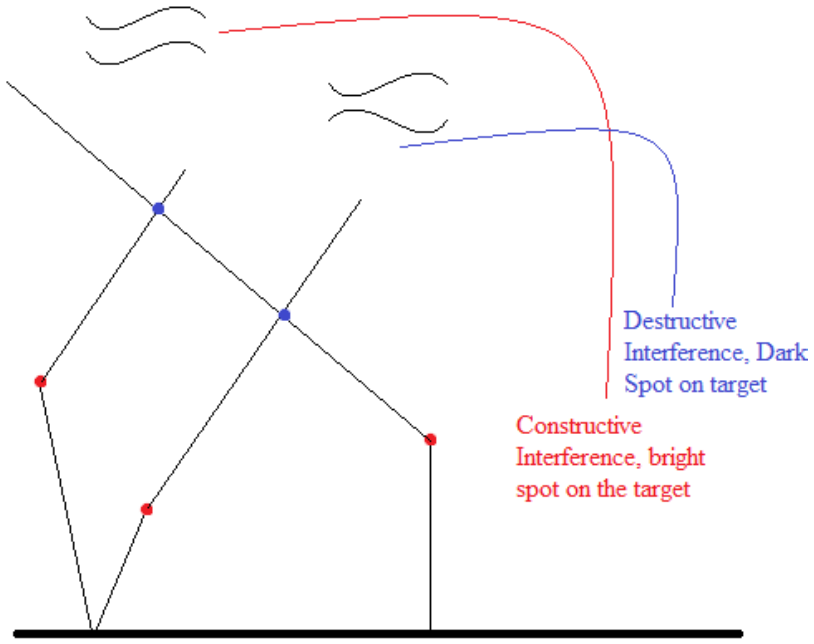
How environment effects the light

- Temperature- related to the Wave number,
  $$\mathrm{k} = \frac{2\pi}{\lambda}$$
- The reflective index of the air particles cause scintillation, according to Snell's Law
- Beam wander

- More research will be done to determine the exact effects of temperature, atmospheric pressure, humidity, precipitation levels, night v day, and other factors deemed important

Scintillation and Beam Wander

- Beam wander is the physical change propagation path of the laser beam, path is nonlinear, the impact point is not constant
- The SLM changes the phase of light, no matter the path a photon takes due to impacts with aerosol, on the target, all photons will be in phase (constructive interference) or coherent

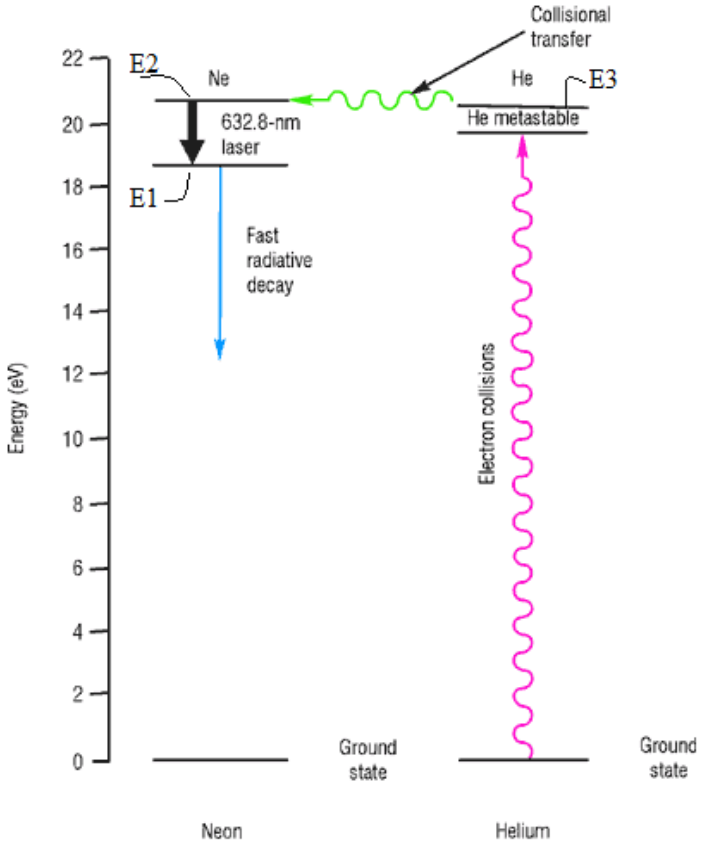


Scintillation is the amount of spreading and dark versus bright spots. We will try to minimize scintillation with Amplitude and phase modulation

EQUIPMENT

Laser

- We will use
  - Red Light, 630 nm, 4 mW
- Helium-Neon laser
- Laser light is generated through excitation of Neon atoms, through collisions with excited Helium atoms. Helium atoms gain energy through electric current
- The light, like all laser light, is monochromatic, collimated, and coherent



Light Sensor

- We will analyze our laser light through the use of a Light Sensor and related computer software.
- The Sensor will capture the laser light at our target, we will then be able to upload it to the computer, break the captured data into frames and analyze with a MATLAB surface plot.

Other necessary equipment

- We will also use
  - Tripod w/ kinematic head
  - Light Sensors, power sensors, IR sensor
  - Polarimeter – determine light's polarization
  - Laptop
  - Red and Neutral Filters (Light and Power)
  - Weather station
  - Beam expander and Spatial Light modulator
  - Light generator (laser)

Whole Process

- Research laser prop in different environments
- Set up laser experimental setup
- Make a test plan
- Analyze our Data
- Test and experiment to determine how well we did
- Form a correlation between spatial and amplitude modifications of light and the environment (if a correlation exists)

References

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