Laser Light Interference Modeling and Defense

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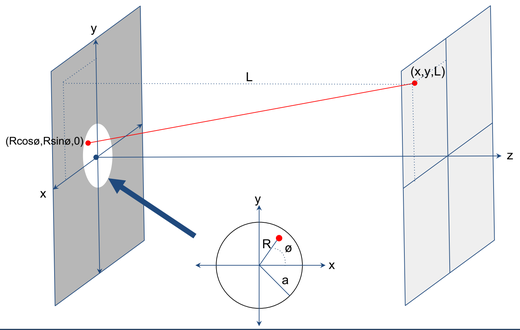
Background

Laser weapon systems are an emerging threat in the world. Therefore, engineers are designing shields that protect from powerful lasers. The shields will work fine until they suffer damage that cannot be immediately repaired. While the shield is damaged, defenders will need to move assets to “safe areas” unaffected by the laser.

The purpose of this project is to take into consideration the properties of light in order to generate a computer program that can successfully predict the “safe areas” at varying distances from a compromised shield.

Schematic



Methods

Assumptions
For simplification, the “cracks” in the experiment are assumed to be small holes of diameters 0.73661 mm, 1.0414 mm, and 1.9812 mm in a sheet of copper.

The distance between the holes and the diffracted image is approximately 7.1 meters in length.

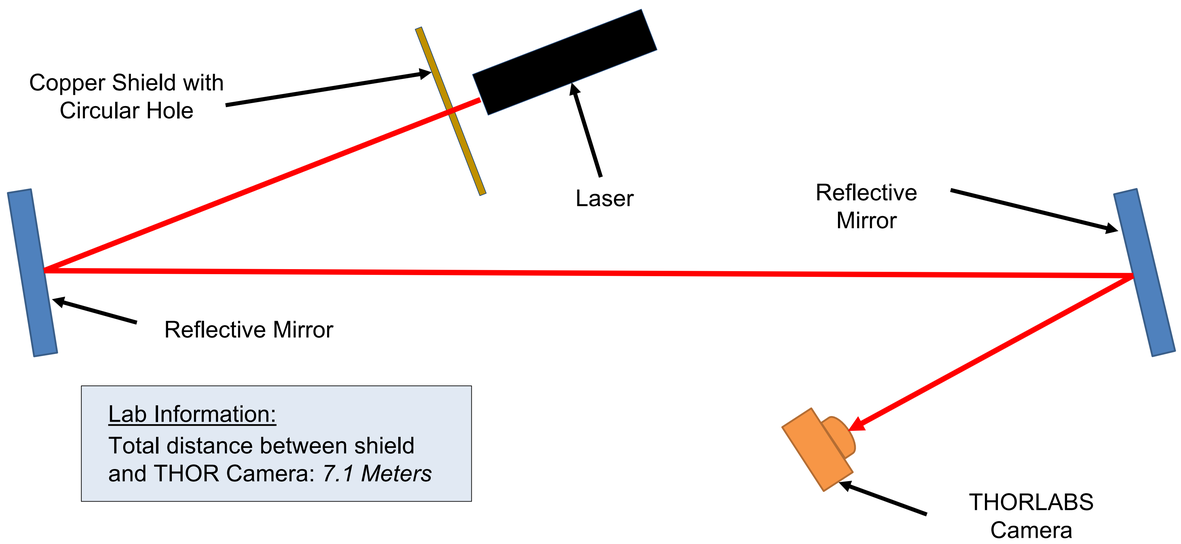
Predictions
Before the experiment was conducted in a lab setting, MATLAB was used to create a computer generated prediction of the interference pattern produced.

MATLAB utilizes equation *I* to predict the intensity at each location on the image.

$$r(R,\emptyset) = \sqrt{(Rcos\emptyset - x)^2 + (Rsin\emptyset - y)^2 + L^2} \qquad k = \frac{2\pi}{\lambda}$$

$$I(x,y) = \int_0^{2\pi}\int_0^{a} \frac{Re^{ikr(R,\emptyset)}}{r(R,\emptyset)}\, dRd\emptyset$$

Experimental Lab Layout



Lab Information:
Total distance between shield and THOR Camera: *7.1 Meters*

Results

MATLAB Code

Intensity Function

```
function I = Intensity3(x,y)
    a=0.0010414/2; %Radius of small hole (meters)
    k = (2*pi)/(633e-9); %Wavelength = 633 nm
    %L = 4.3434; %Distance between hole and projection screen (meters)=(171 inches)
    L = 7.112; %Distance between hole and projection screen (meters)=(280 inches)
    I1=integral2(@(t,R) ...
    ((R.*exp(1i.*k.*sqrt((R.*cos(t)-x).^2 + (R.*sin(t)-y).^2 + L.^2))) ...
    ./(sqrt((R.*cos(t)-x).^2 + (R.*sin(t)-y).^2 + L.^2))),0,2*pi,0,a);
    I = abs(I1).^2;
end
```

Generates Calculated Image

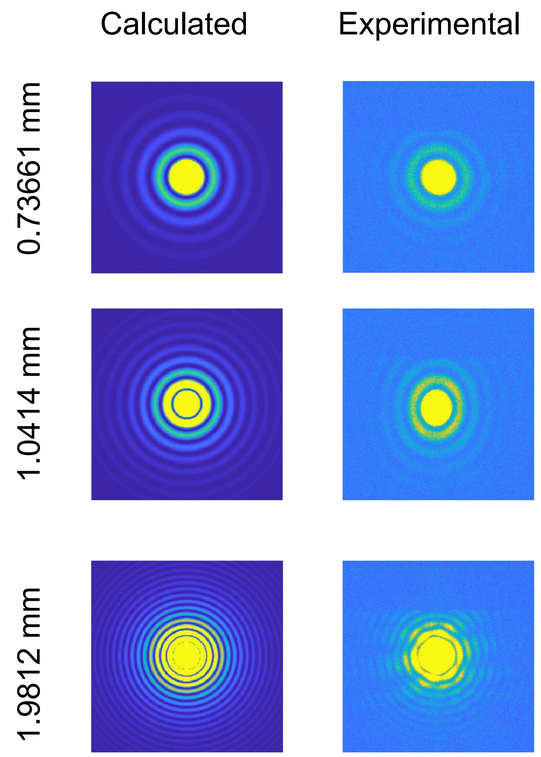
```
size = 200;%width and height of matrix/image
A = zeros(size);
dim = 0.07;%The image's height or width in meters
s = size/dim; %pixels per meter

for c = 1:size
    for r = 1:size
        A(r,c) = Intensity3((r-size/2)/s,(c-size/2)/s);
    end
end
clims = [0 1*10^-16];
imagesc(A, clims);
axis off;
axis square;
hgexport(gcf, 'figure1.jpg', hgexport('factorystyle'), 'Format', 'jpeg');
```

Generates Experimental Image

```
name='d0041.tif';
FileTif = name;

InfoImage=imfinfo(FileTif);
mImage=InfoImage(1).Width;
nImage=InfoImage(1).Height;
NumberImages=length(InfoImage);
FinalImage=imread(FileTif,'Index',1);
b=double(FinalImage);
a=b(36:365,294:623);
clims = [0 250];
x=[0 330];
y=[0 330];
c=imagesc(x,y,a,clims);
axis off;
axis square;
hgexport(gcf, 'figure1.jpg', hgexport('factorystyle'), 'Format', 'jpeg');
```



Not to scale

Images are 7cm x 7cm.

Conclusion

Each of the calculated and experimental images show an Airy disk. The bright rings represent “danger zones” of high intensity light. The darker areas represent “safe zones” where the intensity is considered low or zero. Based on qualitative comparison, the experimental and calculated images appear similar. Therefore, the model’s prediction is valid.

For further validation, a cross section plotting each pattern’s intensity could be generated and examined quantitatively.

Given that the model is accurate, MATLAB has proven in this experiment as an acceptable tool to calculate complex equations and integrals with precision.

References

Directed energy atmospheric lens could revolutionise future battlefields. (2017, January 15). Retrieved April 15, 2018, from https://www.baesystems.com/en/article/directed-energy-atmospheric-lens-could-revolutionise-future-battlefields

Robert J. Bunker (2008) Terrorists and Laser Weapons Use: An Emergent Threat, Studies in Conflict & Terrorism, 31:5, 434-455, DOI: 10.1080/10576100801980294

Acknowledgements

MSC Graphics **3-5856**

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