**1. Self-introduction (20%)** Are you an undergraduate or graduate student? Do you have any research project that related to optics or imaging? If yes, briefly describe it.

I am a graduate student and am working on a research project where we are trying to characterize optics and imaging for a lens less diffuser. Len less optics can be applied to microscopy, and neuroscience in particular because of two key benefits. First, a lens less optical system can be light weight and forego complex lenses, this makes the system portable so that it can be deployed on mice for in vivo brain imaging. Second, by using a diffuser you can make a good tradeoff between resolution and field of view. In the first phase we have developed a model by Jin[1], where a point spread function(PSF) can be modeled by using wave optics and the phase of a diffuser. Next, we can try to verify that our PSF matches by using a digital mirror device with a diffuser that we manufacture from our model. At this point we would have a system where we have learned the linear system response as being invariant and therefore, we could reconstruct and image with any inverse optimization technique. However, if we would like to get a video, we are pursuing the usage of machine learning, to pair outputs and inputs from our verified model.

Further down the road, we would have to change our basic strategy and employ a method a varying convolution if we are to move the image closer to the diffuser. A possible method is outlined by Wei [2].

[1] X. Jin, D. Mao,S. Wei,Q. Dai “Point spread function for diffuser camera based on wave propagation and projection model,” Opt. Express 27, 12748-12761 (2019).

[2] Wei J, Bouman C, Allebach J (2014) Fast space-varying convolution using matrix source coding with applications to camera stray light reduction. Image Processing, IEEE Transactions on 23(5):1965– 1979, DOI 10.1109/TIP.2014.2311657

**2. Biomedical optics concept (20%).** Below is a list of biomedical optics methods that are currently used in biomedical research. Select one and do quick research, then write a brief paragraph (10 sentences) about what it is and what is the advantages of this method.

* • Optical coherence tomography
* • Hyperspectral imaging
* • Photoacoustic microscopy
* • Photoacoustic tomography
* • Multiphoton microscopy
* • Diffuse optical tomography
* • Coherent anti-Stokes Raman spectroscopy
* • Diffuse optical spectroscopy
* • Differential interference contrast microscopy
* • Super-resolution microscopy
* • Optical tweezers
* • Photodynamic therapy

Ans:

The concept of two-photon microscopy (TPM) was first conceptualized by Maria Mayer in her 1931 doctoral dissertation, with the development of the laser in the 1960’s and second harmonic generation in the 1970’s, all laid the foundation for the modern-day invention of two-photon fluorescence microscopy by Denk et al. in 1990. The basic “trick” to two photon microscopy is that for a molecule to absorb both photons, an unlikely event, the actual fluorescence excitation is a very small focus area. This of course give very good resolution, but also has the effect of limiting light from other areas, the background excitation, which would contribute to the area of interest as noise and is suppressed because only our restricted molecule was able to absorb both photons. While a two-photon fluorescent microscope certainly gives good contrast and resolution its real value to biological study of tissues, which strongly scatter light, its depth penetration. Two large applications of TPM are for cancer research, and brain in-vivo imaging for neuroscience. Here TPM allows in brain imaging for less photobleaching which means less toxicity to tissue and therefore longer periods that the subject can be studied without any harm or side effects. The added technology of scanning allows a TPM to build up a 3-d reconstruction image like other modal imaging techniques. To summarize the benefits of two-photon microscopy are: 1. The ability to resolve deeper into the tissue. The suppression of background signal and finally since light is the modal signal, less damage to tissue and the ability for in vivo imaging.

**3. Photons (20%)**. How many photons per second are emitted from a 50 W yellow lightbulb (average wavelength, λ = 550 nm) if 2.5% of the applied energy is emitted as light? Assume that the remainder is just dissipated as heat. (Speed of light: 3×108 m/s)

Ans:

photon\_energy = (3e8)\*(6.62607015e-34)/(550e-9); % Joules- one photon

total\_energy\_photons = .025\*50; % This is watts or Joules/S

% We will assume that we are measuring energy over one second

number\_of\_photons = total\_energy\_photons/photon\_energy;

So photons per second = 3.4586e+18

**4. Snell’s law (20%).** Using Snell’s law, show analytically that a light beam impinging on a transparent planar glass plate exits that plate parallel to the incident direction. What is the parallel displacement (x) of the beam behind the glass plate as a function of glass thickness d, glass index n and the angle of index θi?

Ans:

Line chart

Description automatically generated with low confidence

**So, here we let n = nr . Also, ni is our index outside of this planar glass plate.**

Using Snell’s law we have (1)

Background pattern

Description automatically generated with low confidence

Now we solve for alpha to get (2)

Text

Description automatically generated with medium confidence

We let:



Now, use (2) and plug into (3) to get:

Text

Description automatically generated with low confidence

Next, from basic geometry (equating hypotenuse of two interior triangles) gets us (5)

Background pattern

Description automatically generated with low confidence

Finally, solving for (5) using the angles from (2) and (4) gives us (6)

A picture containing text

Description automatically generated

Note: n = nr and ni is the index of refraction outside of glass.

**5. Total internal reflection (20%).** A glass block (ng = 1.55) is covered with a water layer (nw = 1.33). What is the critical angle at the glass/water interface?

Ans:

% critical angle ni > nr

ni = 1.55; % index refraction of glass

nr = 1.33; % index refractiuon of water

critical\_angle = asin(nr/ni); % critical angle in radians

critical\_angle\_degrees = critical\_angle\* 360/(2\*pi)

critical angle = 59.1 degrees