Problem 1.

1. (40%) The tradeoff between spatial resolution and the imaging field of view has been a longstanding issue for optical microscopy (or any other optical imaging systems). Please name two methods that can help to address this issue and briefly describe how they work.

Ans:

One method for addressing the tradeoff between spatial resolution and field of view is to use the method of Fourier Ptychography. Normally in a microscope the “off-axis “scattered light does not get recorded as an intensity to our sensor and thus we end up with a good resolution at a point but no real field of view. Fourier Ptychography solves the field of view problem by gathering the darker image off-axis and then doing phase retrieval to reconstruct the entire image that you could not normally do with just a confocal microscope. Phase retrieval could be done by a Wigner distribution method as an example.

Another method that takes a more brute force approach to the problem is to use a multiscale gigapixel photographic system. Here the design of the camera is more direct, where a parallel array of micro cameras used. So, when one camera’s aberrations appear its’ response is “stitched” with the next camera’s output. In this way one can create not only an image with good resolution but a wide field of view. Of course some of the obvious drawbacks to such a system is complexity with so many cameras and then developing a system to merge all of the images together.

Problem 2.

2. (20%) Name three techniques that can be used in designing wearable display.

Ans:

Under the taxonomy list of wearable displays: glasses-bound stereoscopic, head -mounted see thru is a technique where a synthetic image is overlayed onto reality. The glasses by google are a commercial attempt at a wearable display. Here a prism projects a layer over light from reality. The idea of wearable displays is an old one, especially for military operations. U.S. Air Force fighter pilots have been wearing displays for at least 35 years. Albeit, military displays are bulky, they have the same principle of trying to overlay a synthetic image over reality.

A second wearable display under our taxonomy list is the more familiar anaglyphs, or stereo 3D effect. Here, each eye is seeing thru a filter with chromatically opposite colors. This spatially multiplexing is then recombined by the visual cortex that allows the viewer the perception of seeing a 3D scene. An example of this in the consumer space are the 3D glasses from Dolby laboratories. Because the intended use is for cinema, the glasses need to offer crisp images and be light weight and durable for many viewings.

A slightly different twist to a wearable display is to multiplex the information to the eye in a temporal, rather than a spatial way. A switching of opaqueness to each lens in a wearable glass, controlled by a shutter signal that is synchronized with a projector creates an illusion that all the images are blended. As is well known in the video community, changes of frame rate faster than 30 frames a second cannot be detected by a viewer, so “opening” one lens cannot be perceived and thus appears continuous. The Nvidia 3D vision glasses are an example of this technology technique.

Problem 3.

3. (20%) Besides the existing topics, what do you think we can add to the future computational imaging courses? (Identify one emerging area in computational imaging research)

Ans:

In the lectures from week 10 on the topic of “Time of Flight”, under transient images you mentioned some applications: diffusers, lensless imaging and scattering. Also in the lecture from week 13, the first part of class you covered scattering thru media. I am not sure, but I would guess that in your biomedical optics class you probably cover the topic of tissue scattering. In my brief literature research into the diffuser cam problem I found that the topic of Wigner distributions has a direct tie into light fields and Fourier Optics. I also saw in a lot of the papers from L. Waller into the topic of diffuserCams that for their forward model, they opted to use ray optics as part of their system model. I saw the same thing to a degree in the PSF prediction paper by Jin. I would add a little to either slide lectures 10 or 13 something about Wigner distributions or expand what you have. (I went back to your earlier lectures and could find no mention, but I may have missed)

Wigner distributions, although developed for Quantum mechanics, where it predicts the behavior of wave functions as well as any other theory that supports quantum mechanics, also has a tie into many rich areas of mathematics. The paper by S. Twareque, et al., “The Wigner Function for General Lie Groups and the Wavelet Transform,” bear out its ties into wavelet theory, Lie Algebra and Lie Groups (Manifold theory) and kernel-based methods, with operators in Hilbert space. The math is quite advanced (for me also!), but it would be worth a few slides to mention given its ties to so many disciplines.

Problem 4.

4. (20%) What are the challenges that you have had for your research project? What kind of resources (the instructor and the school can provide) do you think would help to improve your research?

Ans:

The challenges that I faced in my research project were trying to recreate the tutorial for Antipa research paper on DiffuserCams. The first problem was that the sensor described in the tutorial had to be modified for experiments. However, when I made the prescribed changes, it slightly damaged the sensor affecting my measurements going forward. A second problem was performing calibration needed for a good reconstruction, here the problem was one of stability for the sensor. To perform calibration you want a point source of light to vary across a z-axis but control the distance to the sensor with a distance that measure in the millimeters. Trying to control distance of the above sizes is very difficult without a stable housing. A third challenge I faced was that my picture was saturated because I could not vary my point source. This meant that I took many measurements and only used an experiment that had some variation of pixel values. A fourth and final impediment was just trying to get a dark enough area to perform the experiments but control the Raspberry Pi camera. This last problem was more logistical in nature, but no less a challenge to overcome.

I think that the instructor and UND for optical types of experiments can pair up a student on campus with one off campus, so that the equipment remains on site (UND). In this way, the university can spend a little extra money investing in something with a longer shelf life and can give better results, especially for optical types of research.