SPatIal Image Frequency modulation for Imaging (SPIFI) using RGB LED Matrices for 2-Dimensional Image Reconstruction

Second Semester Report
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-Full Report-

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Abstract

In this project we set out to broaden the current technologies of SPIFI with a light source much less coherent than the original HeNe laser induced in SPIFI. The set up consisted of a 32x32 RGB LED matrix light source, a series of Fresnel lenses and condensers, and a photodiode. The collection of data went from the photodiode to a current amplifier through a DAQ. In order to mimic the previous SPIFI system, each LED on the matrix was modulated at a different frequency to replace the spinning modulation disk in the original SPIFI configuration. This controlled frequency modulation for each Led was driven by a De0-Nano with a 50Mhz clock. These pulsating LEDs were then de-magnified by the optics and captured by the photodiode. The temporal information was then converted to the frequency domain and the LEDs were then distinguishable by individual frequency. An average was taken of the FFT for ten trails to set a threshold and a program recorded the information as a reference. This referenced information was then compared to the same set up but with an object in front of the board which caused a drop in intensity for the blocked frequencies. The blocked version of the FFT was then compared to the reference frequencies and frequencies below the threshold set by the reference frequencies was graphed.

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I. Introduction

Imaging techniques at present day impact nearly every industry. They span across our education, communication, medical, transportation, energy, and aviation industries just to name a select few. The medical industry has especially seen an impact of diagnosis processes over the last 50 years. Advancements have brought about confocal microscopy for imaging biological substance of the micro scale and lower, CAT scans to produce tomographical slices of the body, and MRI's to perform 2-D and 3-D imaging of soft tissue. These are just a few of the many modern day imaging techniques that have lengthened life due to faster and more accurate detection. Our objective in our project was to enhance previous imaging techniques to be more transportable and versatile to improve medical imaging and to instill new opportunities for applications. Our project will encompass improving imaging techniques using SPatIal Frequency modulation for Imaging (SPIFI). The objective was obtained by spatially modulating 992 of 1024 different frequencies of light on an LED matrix controlled by an FPGA through a series of Fresnel lenses and a condenser to a photodiode to exhibit the same image process as the current SPIFI setup but with much less resolution. This will allow use of a system without use of the modulation disk and to show a conceptual design of how a higher intensity and a mirco LED matrix can image in 2-dimensions. This spectral coherent light source with SPIFI will allow for object detection and mapping of objects. This will allow us to take spatially encoded intensity using SPIFI to reproduce the image, which can allow for a real-time 2-dimensional image reconstruction.

II. Summary of SPIFI design

SPatIal imaging for Frequency (SPIFI) began as an undergraduate design in 2010. SPIFI was used for spatially-chirped modulation imaging of absorption and fluorescent objects with a single element detector. In this previous setup SPIFI can be summarized to an input beam feeding to a cylindrical lens, this beam was then sent through a spinning disk which will create a carrier frequency thus acting as the modulator of the system, this is then passed through a series of imaging optics, passes through the object, at which a condenser concentrates the signal onto a detector.

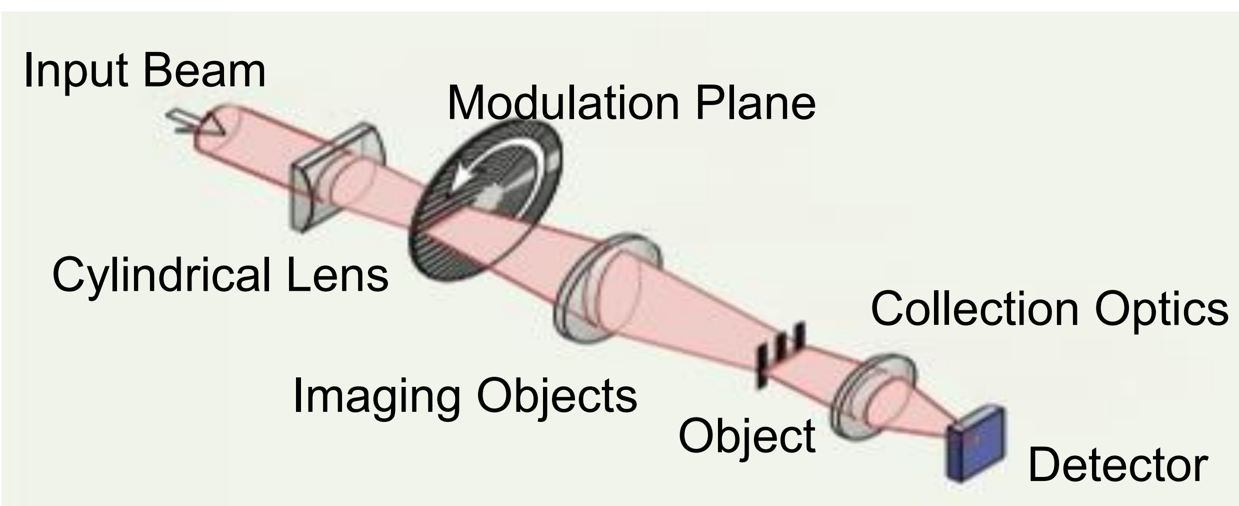

Figure 1. SPIFI Setup

Here we will compose a similar system, which lacks in temporal coherence, but excels in programmability of the LED matrix and applications due to compact size. Our set up was designed using a polychromatic light source, in this case a 32x32 LED matrix, which would then be sent through a series of Fresnel lenses, which would galvanize the chromatic aberration through our medium of air. From the Fresnel lenses the light will pass through a sample which will create absorption in intensity, and then pass through a condenser and will follow the same fashion as the previous SPIFI setup, which will be collected by a photodiode. Here each beam emerging from an individual LED can be mapped as

$$Eled(x,t) = E0 * u(x) * e^{iw0t}$$

Here w_0 denotes each individual angular frequency unique to each LED and u(x) denotes the normalized spatial field along our line of focus, in this case being the x-direction. By pulsing each LED we create a temporally varying modulation in which we will denote by M(x, t), finally we can construct our equation for intensity by applying the a function that will represent the absorption, a(x), in which our overall equation for intensity is the mod squared of the electrical field,

$$Enm(x,t) = E0 * u(x) * M(x,t) * a(x) * e^{iw0t}$$

Here nm denotes the individual LED number of the matrix, where n denotes the row position and m denotes column position, where n ranges from 1 to 32 and m ranges from 1 to 31. It should be noted that the variable m is 1 to 31 due to errors in programming the FPGA and ultimately has the capability to become 1 through 32.

$$I(x,t)nm = |E(x,t)|^2$$

$$I(x,t)nm = Io|u(x) * M(x,t) * a(x)|^2$$

With each unique frequency, each intensity will differ in its absorption and scattering upon impinging the object at hand; these frequencies can be summed as

$$\sum_{n=1}^{32} \sum_{m=1}^{31} \mathrm{I(x,t)nm} = Io|u(x) * m(x,t) * a(x)|^2$$

With each individual frequency the modulation function M(x, t) can be denoted as

$$M(x,t) = w(t)/2 \quad * \ [1 + cos(2pi * k * x * t)]$$

The intensity can then be denoted as

$$\sum_{n=1}^{32} \sum_{m=1}^{31} I(x,t)nm = Io|U(x) * w(t)/2 \quad * \ [1 + cos(2pi * k * x * t] \ * A(x)|\text{^}2$$

It is from these summations of intensity that we will be able to take the FFT of the spatial frequencies and recover the spectral intensities. By taking the matrix with no object we set a criteria and threshold for each intensity by averaging 10 trials. An object could then be placed in front of the matrix and a drop in intensity could be detected by running the threshold criteria and seeing which LEDs fell below that criteria.

III. Budget

We began implementing the project with the goal of producing a single element detector imaging system that would allow for upgraded materials. Our main task at hand was to produce a system that would be feasible within our means as students, and thus did not include high end optical materials. If needed the same task could be performed with higher end materials in order to increase response time, resolution, and scale. Our 2013 Fall Budget is as follows in appendix B. With these items our 2013 Fall budget held at $1289.14.

IV. Test Plan

A. Test Plan Identifier

Our testing plan was to incorporate individual milestones for testing a realistic timeline to insure proper results dealing with two stages, software development and digital image processing. Of course with testing there is always the possibility of error and because of this an excess amount of time was added to the project timeline tasks. Even with extra time, various circumstances were encountered that increased the original test plan timeline. These circumstances included installing and calibrating new software, transferring to all previous programs to a new system, and encountering a shutdown for several days of access to the network for use of software.

B. Test Items and Functions

Our current project will set out to function as a single-element detector imaging system that uses SPIFI to reconstruct 2-D images from spatially modulated frequencies. With this project we will be incorporating the following items.

Specs

De0-Nano

-Cyclone IV EP4CE22F17C6N FPGA - 3 axis accelerometer with 13-bit resolution- A/D converter, 8 channels, 12bit resolution - Memory – 32 MB SDRAM, 2Kb EEPROM - 50 MHz Clock **Adafruit 32x32 RGB LED Matrix**

- 5V regulated input, 2A max - 3-5V data logic level input - 2000 mcd LEDs on 4mm pitch **PM10 Photodiode** -wavelength range .19 µm to 11 µm - active area diameter 19mm -max power 30W - Calibration Wavelength 514 -response time 2 seconds -broadband detector coating **Fresnel lenses** - Focal Lengths ranging from 400-1100nm -various focal lengths 10mm,25mm,32mm,51mm (subject to change)

Condenser Lens -Diameter 30mm-45mm (subject to change) -Clear aperture(mm) >90% -focal length – .08 (subject to change)

DAQ – NI-USB-6356 X Series Data Acquisition BNC connectivity and OEM options available.

8 simultaneous analog inputs at 1.25 MS/s/ch with 16-bit resolution; 10 MS/s total AI throughput, Deep onboard memory (32 or 64 MS) to ensure finite acquisitions, even with competing USB traffic, 2 analog outputs, 3.33 MS/s, 16-bit resolution, ±10 V,24 digital I/O lines (8 hardware-timed up to 1 MHz), Four 32-bit counter/timers for PWM, encoder, frequency, event counting, Advanced timing and triggering with NI-STC3 timing and synchronization technology

With the following specifications a description for functionality of each item is given. The De0-nano FPGA was the underlying foundation of our project. This device directly controlled the LED functionality and ultimately, created the LED matrix to behave as would a spinning modulated disk would. The FPGA was programmed to control the brightness and manage frequencies across the matrix while optimizing output signals for image resolution of the sample being imaged. The FPGA was programmed to have the maximum or -%10 of maximum clock speed, that being 50 MHz. The Adafruit LED matrix was tested to maintain its durability of dealing with high frequencies running through it. The PM10 Photodiode will be tested in various conditions and altered respectively for ambient light sources and how those sources affect the resolution of the image. The Fresnel and condenser lenses will be tested for their chromatic aberrations and will be chosen in respects to this and focal lengths. The NI-USB-6356 X Series Data Acquisition was used to collect the temporal signal and transfer the temporal information to Matlab. The current buffer was used to increase the signal to noise ratio.

C. Approach

The approach that was taken by the team included two different routes of programming the LED Matrix. We approached from two sides, the first being pure Verilog programming of the board to control the RGB LED matrix, the second to program the board with a JTAG server to a port in which the port communicated with processing as the language of choice to control the board. These were tested for speed vs. resolution and from results pure Verilog was chosen to optimize this ratio. We began the testing sequence with individual column frequencies in order to see how the current set up behaves and receives the information. This allowed us to see what frequencies are acceptable for the individual LED frequencies. We then documented the frequencies and distances that seemed to obtain the best imaging resolution and speed. We then transferred the board to have individual LED frequencies and adjusted the position of frequencies on the board with respects to distance to optimize resolution and processing speed. The process of testing LED frequencies was repeated for the distance and processing speed vs resolution. Specific training was instructed by the Bartels' Lab to insure accurate results. Regression steps were taken accordingly based on results.

D. Remaining Test Tasks

As of 4/24/14 the remaining tasks at hand include optimizing 2-dimensional data and 3-dimensional imaging of objects. This task will be started on next semester by one of the current students outside of senior design. This will be done in Fall semester 2014 and includes applying various applications to be tested, and theorized, these will be discussed in more detail once the resolution of the 3-dimensional imaging process is established.

E. Staffing and Training Needs

Since the senior design team was new to the Bartels' lab and was accepted into the lab to use test equipment we were grateful to receive basic lab procedures and training that was granted. We were subject to training on handling specific optical equipment, how to process signals, and what to look for when imaging. We were trained in basic digital image processing and reconstruction using SPIFI. We were also subject to safety procedures such as wearing protective eyewear and handling sensitive equipment.

F. Risk Planning and Contingencies

Since there were hundreds of variables to be considered with testing, basic risks of products had been set forth as in our risk analysis. Some variables that were stressed again and for the first time included lack of personal resources, delays in training, changes to design and pushback dates on milestones, number of tests that were performed that insure low error, overtime work hours, late delivery of material, , shut down of network access, and additional team members added. For lack of personal resources we were subject to the rules and hours of the Bartels' lab, although access was granted on a fairly lenient basis, current testing of experiments delayed testing of our project only once. Delays in training due to current testing and schedules of the Bartels' lab staff were not encountered. As for changes in deliverables, the risk included pushing or altering team member schedules which they could not adhere to the new schedule. As for number of tests, we have to performed many more tests in order to insure accurate and consistent results and more tests will be conducted in the near future. In order to make most deadlines in acceptable fashion, overtime was required of team members, this risk included breaking down team member mentality. Late delivery of material pushed back results due to various schedules of team members. In order to lower processing time, uploading and transferring programs to a new computer. The shut down of the network was encountered for several days by ENS due to Microsoft and their requirements of the campus to shut down Windows XP, which was the operating system we were running off of. Additional team members were not encountered.

G. Test Items functionality and functions not to be tested

With the following items to be tested, being the de0-nano, the 32x32 RGB LED matrix, the PM10 photodiode, the Fresnel lenses, and condenser lens there will be certain features that will be stressed during testing and certain features that will be available and could be tested but will not be tested in this phase of the project. Based on results of the current project these items may or may not be tested in the future, but are listed for future reference. The De0-nano being an FPGA has various uses, besides clock speed and its ability to control the board such as wireless control, has tap sensing, and double tap sensing which will not be tested . As for the LED matrix, only oscillations of frequencies will be tested, various items that will not be tested are creating images, or interlacing with other matrices to create a larger array. The photodiode will be tested for digital image processing, all functions of this device will be used. The Fresnel lens will be used to create aberration and will not be used for non imaging techniques such as illumination or projection. The condenser will fulfill its full functionality by condensing the beams.

H. Software Risk Issues

Our current project focuses on using an FPGA which has high processing speeds. With having the core of our project dependent on the functionality of the FPGA we must minimize risks and identify possible risks that are possible. Here we are faced with the possible risk of development time of developing code due to bugs or using other systems, such as transferring to an earlier version of altera quartis II. Other risks include improper knowledge of relaying the information for quality of resolution to the FPGA to control the LED Matrix, communication in the team, and changing requirements for what is acceptable for resolution quality.. Also noise in the photodiode may be a risk and have to be compensated for.

I. Features to be tested

Features that will be tested include the capability of the boards processing speed, brightness vs resolution of the LED matrix, and combining the many frequencies via mathematica to perform the FFT. For the boards processing speed we will be faced with multiple variables such as temperature, communication from the computer, and communication to the LED Matrix. The LED matrix will be faced with alignment, mounting, and position in respects to the sample all in while comparing the brightness vs resolution of the LED matrix for the produced image. The computational system we will use will be subject to dealing with a polychromatic light source vs monochromatic, leaving test room available for altering and defining new functions to process the spatial information received.

J.. Features not to Tested

Features that will not be tested include tap capability of the board and remote server capability of the board, interlacing multiple boards to create a larger array of frequencies, angled projections of the board to image, and far field limits of the board.

K. Environmental Needs

Since we are currently in a world with various environmental impacts that are easily effected we have made a list of possible environment impacts of project, those being natural environmental and industrial environmental impacts. Since we are dealing directly with electronics, the disposal of these devices if they are to malfunction or break will be recycled as electronic and computer waste. Since we will be putting of no emissions of any sort, this will be our only natural environmental concern. For industrial we are focused on only the wireless JTAG server and will respect the local wireless community by running our port through a well defined server. Since our power consumption is minimal and we will not be in any sort of manufacturing stage during our timeline, we have denoted all industrial environmental needs.

L. Responsibilities

The responsibilities of the project will be handled the same, except for the beginning task of performing two different methods of programming the FPGA board to control the LED matrix. Currently the team leader title is handed to Nicholas Galvan who is subject to Dr. Randy Bartels. Tyler Green, the other team member will be held responsible for meeting timeline deliverables, as well as setting risks, selecting features to be tested and not to be tested. Nick will be in charge of making critical decisions for testing, the overall test plan strategy, as well as setting defining risks. Together the team will receive training from Jeff Fields and Dr. Randy Bartels for use of the lab equipment, and then will be subject to define their own test results.

M. Planning risks and Contingencies

Since there are hundreds of variables to be considered with testing, basic risks of products have been set forth as in our risk analysis. Some variables that will be stressed again and for the first time include lack of personal resources, delays in training, changes to design and pushback dates on milestones, number of tests that will be performed that insure low error, overtime work hours, late delivery of material, and additional team members added. For lack of personal resources we are subject to the rules and hours of the Bartels' lab, although access should be granted on a fairly lenient basis, current testing of experiments may delay testing of our project. Delays in training may also be caused by this factor of current testing and schedules of the Bartels' lab staff. As for changes in deliverables, the risk include pushing or altering team member schedules which then cannot adhere to the new schedule. As for number of tests, we may have to perform many more tests than to be expected in order to insure accurate and consistent results. In order to make deadlines in an acceptable fashion overtime may be required of team members, this risk includes breaking down team member mentality. Late delivery of material may push back results substantially due to various schedules of training staff and future schedule of team members. Additional team members provide the risk of more time added to training and catching those team members up to speed if needed, although our group is solidified, the Colorado School of Mines team may have additional team members then previously denoted.

V. Experimental Design

We began the setup for the SPIFI experiment with the intentions of having excess space for the opportunity of increasing focal lengths and for receiving minimal ambient light from external sources. The optical table that was provided by the Bartels staff was a 3x5 foot optical table newly manufactured from Thorlabs. It was not induced with any hydraulic bearings for stabilization of vibrations. We then began by mounting the De0-Nano FPGA to the back of the Adafruit LED Matrix, where an adjusted screw size of 4/40 was needed. Once this was mounted we proceeded to mount the LED matrix with optical cage rods with two external mounts to hold the LED matrix. This method was chosen due to the fact that the rods allows for adjustment of focal length of the board. Once we placed the led mount at the far end of the optical table we continued to mount two 5x5inch Fresnel lenses. This method for mounting used a clamp, and was secured with epoxy for a temporary solution. A more stable scheme could have included a creating a custom mount using the machine shop of the physics department. We then finalized our design by mounting our photodiode at the opposite end of the table connected to a DAQ and current amplifier. The optical setup for our design is denoted in figure 2.

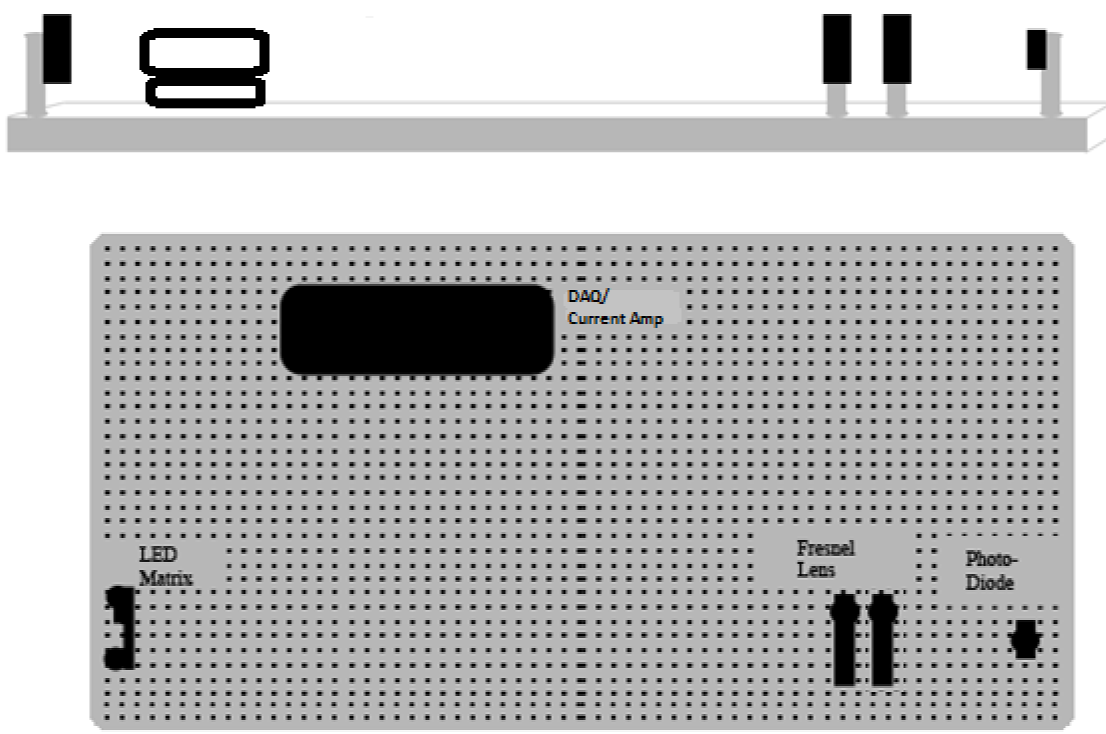

Figure 2- Optical Table Setup

VI. Software Design

A. Objectives

The main goal of any software we created for the FPGA to put onto the LED Board was to have the functionality to modulate each of the 1024 LEDs individually. The software was to control the modulation, but a secondary goal is to make it relatively easy to change the modulation pattern of the LED board without having to change 1024 functions in the software. While color control is not a necessity, it is another secondary goal to be able to drive each LED at a different color while modulating them. Due to programming issues and time a goal of 992 LEDs was met versus the 1024. The goal of software used for a DAQ was to collect the temporal information as data received on the photodiode and relay that information to Matlab so an analysis could be performed. This process was done as quickly as possible in order to get a realistic time scale of placing an object in front of board. The LED matrix has 32 addresses that must be written to. Since there is no built-in PWM on the LED matrix, the desired color must be rewritten very quickly in order for the present color to stay active on the LEDs. Each address takes 24 bytes of data in order to write a different color to each of the 32 LEDs in a single row. By repeatedly setting each LED to a color and then turning each LED off, we are able to make the board blink at different frequencies, 31 addresses and 32 LEDs per address makes 992 LEDs total.

B. Initial JTAG Program

In the beginning, we modified a freeware program that was known to work on an FPGA board to control an LED matrix. Even though this was our primary program running the LED matrix, we went two different routes to program the LED matrix in order to achieve the best result. One team member was in charge of this initial method and ran the modified Verilog program through a JTAG server to be able to modify it further in a form of C called Processing. This was done because we did not have much experience in Verilog programming, but had a moderate amount of experience in C. The other team member attempted to learn and write in Verilog and use the Quartus II schematic diagram software to put functions together. The JTAG server method was primary at the beginning since the Verilog method did not make much headway early on. The JTAG program was able to map colors onto the LED board by scrolling the computer's cursor over different colors in Paint. Unfortunately, since the program had to travel through many ports, it was unable to oscillate the LEDs fast enough for any accurate measurements. It also was unable to produce a very high intensity. Intensity is important for minimizing noise and also because a low intensity eliminates the possibility of making a microscope that uses fluorescence.

C. Verilog and Schematic Design

The second method used only Verilog programming and a schematic diagram build proved to be faster and more robust than the original design. This newer design uses a counter to increment through each address. Once the address is incremented, the program moves to a new block in the block diagram to latch a specific color to the currently selected row. Depending on how many colors are currently in that address' buffer it will decide which LED gets the current color. This simple circuit is driven by an internal FPGA clock of 50MHz that can be divided as need be. The picture below illustrates a top down view of the newer program.

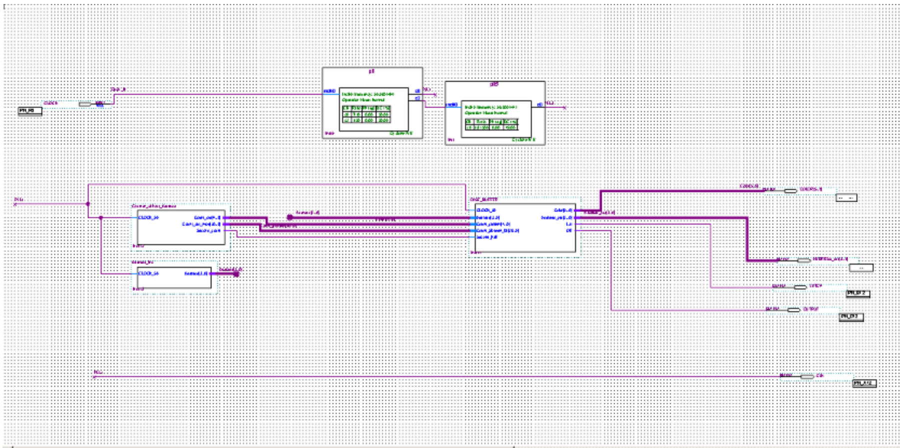

Figure 3. Schematic driving LED matrix

D. Current Progress

Currently we have finished the majority of the project. Several factors are still required by end of semester in order to meet our objective. These factors include setting up a real time imaging process through Matlab and creating a better signal to noise ratio to insure complete accuracy in our results.

VII. Test Results

We began our testing with the setup denoted in figure 2. From this we oscillated the individual LEDs on the Matrix in order to create 2nd Harmonics generation of the signal. In order to check that the LED matrix was properly pulsing we applied an optical iris in front of the matrix to solidify individual LEDs and view their behavior. From this we tested multiple LEDs and found that a different frequency was being exhibited. Although each LED portrayed the same duty cycle different time scales were witnessed on the oscilloscope. Here the duty cycle was found to be 33% as established by the clock on the FPGA as denoted in image 4.

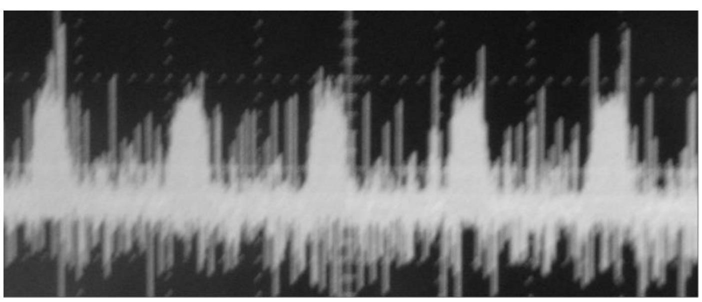

Figure 4. Oscilloscope 33% duty cycle

As seen in image 4, there is an ample amount of noise that is distorting the signal, but still a 33% duty cycle can be seen. After seeing that our board's functionality was behaving in the correct fashion even with noise we set out to test the functionality of the board as a whole in order to detect second harmonic generation. In doing so we produced a signal on the oscilloscope and through image processing took the

FFT of the sampled signal as denoted in figure 5. From this we took the inverse FFT and recovered the intensity profile also denoted in figure 5 solidifying that there was second harmonic detection.

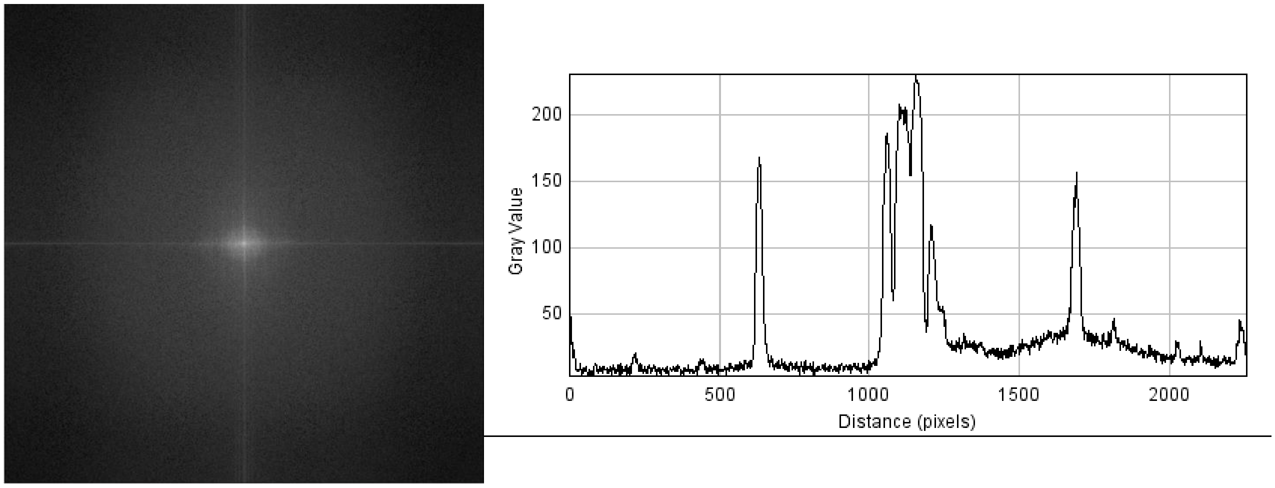

Image 5 - FFT of oscilloscope reading (left Image), Intensity profile in terms of color intensity recovered from the inverse FFT (right image).

After solidifying that the second harmonic was detected, we set out to pulsate the board at different frequencies via color tone to further the chromatic aberration from the Fresnel lens. In doing so we lost the second harmonics and gained a wave packet of what seemed to be saturated intensity peaks. This was believed to denote that the Fresnel lens was performing by shifting the colors in the medium due to their chromatic aberration but since the oscillation speed of the clock was not fast enough they overlapped greatly.

We then altered the coding of our FPGA to drive 992 LEDs at different frequencies. We also set forth to remove the oscilloscope and replace the oscilloscope with a DAQ. When this was done it was found that our SNR was causing errors in distinguishing the frequencies of each LED in the frequency domain. In order to correct this a current amplifier was applied with a set bandwidth of 3Hz to 30kHz. This was chose as the bandwidth since our drive speed of LED board was limited to 17.5kHz to 17.13 Hz. During the programming portion of our FPGA we found that the board was best driven by taking the current LED position and dividing it by its positional number. For example, LED (1,1) would be 35kHz divided by one, LED(1,2) would be 35kHz divided by two, LED(2,2) would be 35kHz divided by 34 and so forth. Due to time constraints we were unable to program column one of the board, thus this column was left blank and our highest frequency was not 35kHz but 17.5kHz. From here we collected the temporal signal shown in image 6.

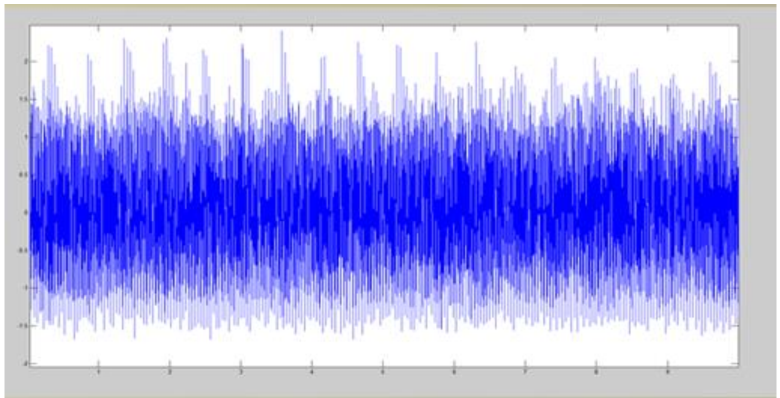

Image 6- Temporal Signal of LED Matrix

We then performed the FFT of that signal via Matlab in order to distinguish the individual frequencies. This was done with no object in front of the board and averaged over ten trials, were from this average an intensity threshold was set for each LED as found in image 7.

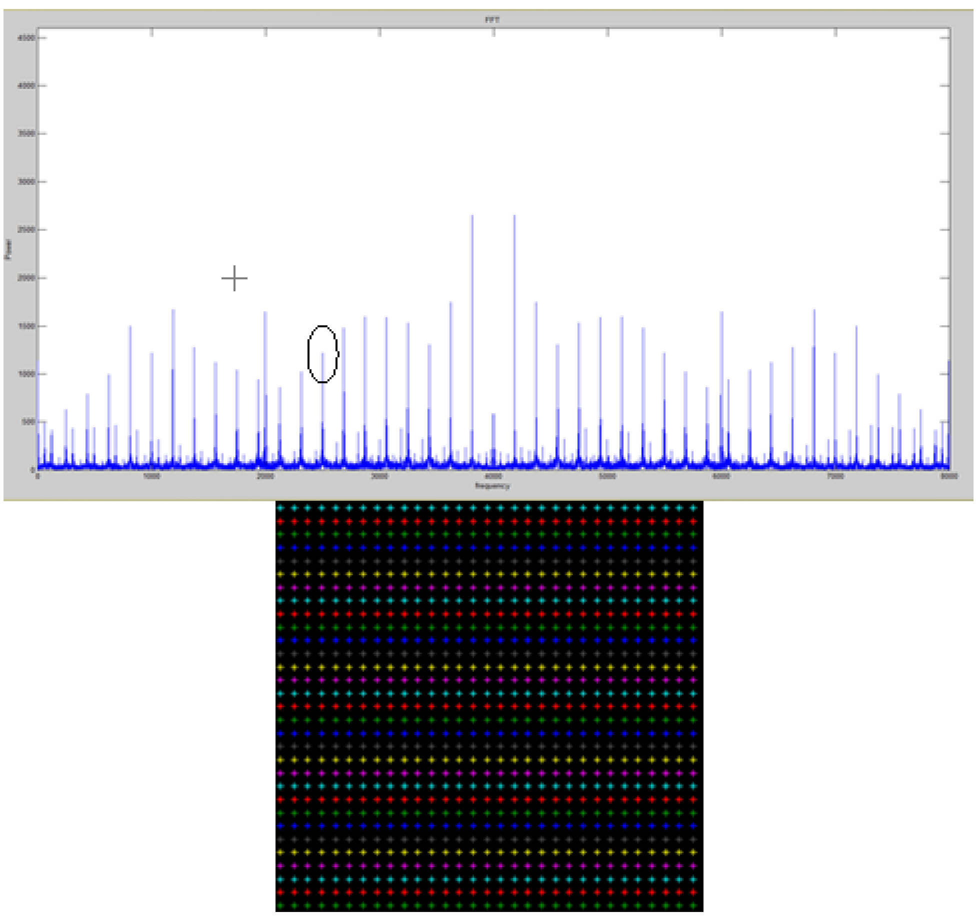

Figure 7- Unblocked LED Matrix representing frequency domain (upper). Unblocked LED board representation (lower)

With this program written in Matlab several errors were encountered but an image with decent resolution was recovered. The first issue was transferring the frequencies to the correct value. Here the known frequency for the highest value was programmed to be 17.5kHz but when converting information from the temporal domain to the frequency domain a max value of 4kHz was found. Figure 7 also portrayed the individual frequencies differently than expected in terms of spread. Where a clear distinction of frequencies should have been clustered from 100 to 17.13 Hz, that spread was found to be even. We then created a program in Matlab to correlate each frequency to its position on the board. When an object was placed in front of the board of millimeter size or larger the intensity of those blocked frequencies was lowered and the detected by the program. The program then correlated these blocked intensities to the spatial position on the board and visually graphed which LEDS were blocked and thus showing the image. This process is shown in figure 8.

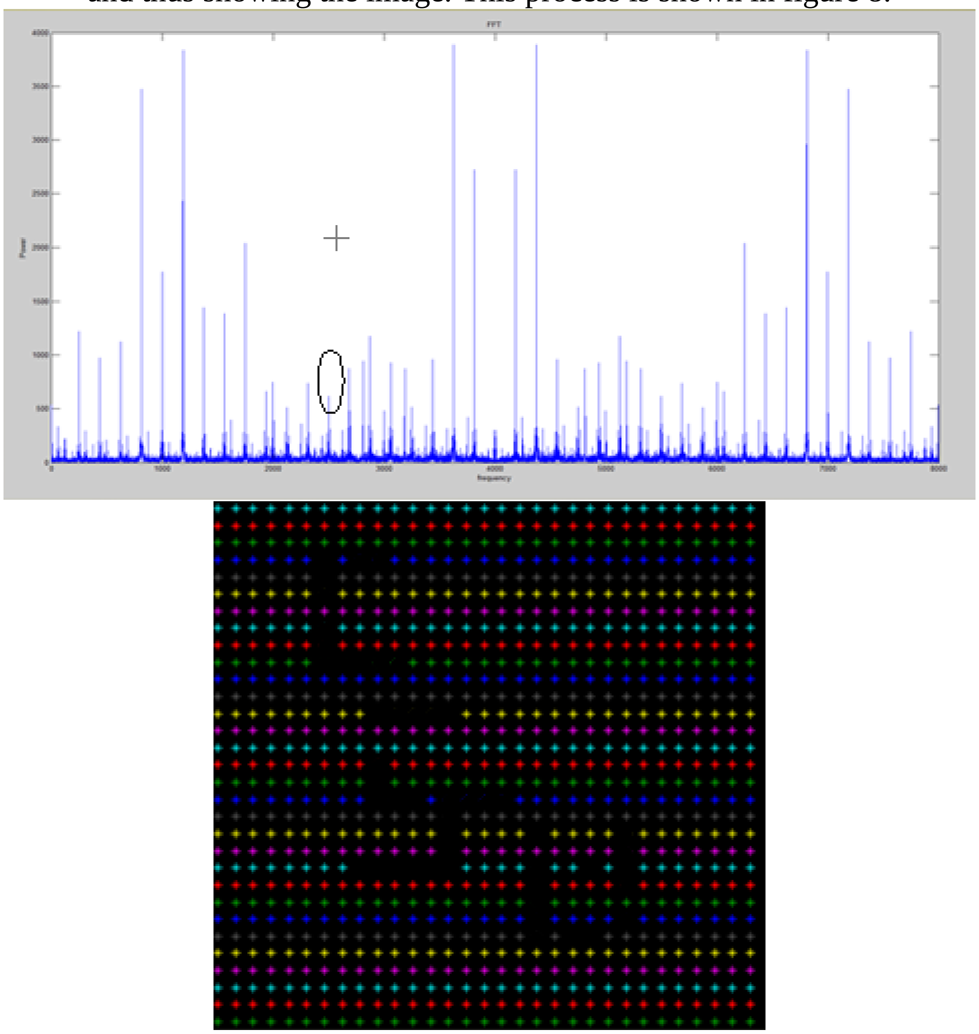

Figure 8- Blocked LED Matrix representing frequency domain(upper). Attempted image reconstruction of CSU letters minor errors encountered

VIII. Future Testing

A. Noise

After achieving 2-dimensional imaging using the matrix, some errors were still encountered due to pulsations in the boards intensity. We will focus on the dark noise and thermal noise of the detector by altering our photodiode to meet our specifications. For the OSNR we will add imaging optics to the lower the focal length between our LED matrix and the Fresnel lens so the light has less exposure to its surrounding medium. Shot noise will also be minimized but a process for this is under review.

B. Frequency Drive Speed of the FPGA

Since our FPGA has a clock speed of 50MHz we automatically know that the limiting factor for drive speed is the LED matrix. Since the LED matrix has an unknown max drive speed provided in the spec sheet we will have to test for that drive speed and see when our signal no longer has a decreased oscillation period based via light output.

FFT Image Analysis Program

We Will then move forward to alter a previous program used on past SPIFI experiments to match the needs of our system setup. With this program we will be able to average thousands of times and smooth our intensity peaks. We will also be able to take real time Fourier analysis of the light source.

C. 2-Dimensional Image Reconstruction

Once we minimize the noise, and solidify our frequency drive speed to the LEDs we will focus on FFT capture of the Matrix while testing objects with non complex surfaces, this may include blocks or tools around the lab. Once we solidify this process we will move towards imaging objects with a more complex structure such as the hand. A resolution criterion will then be set and the scale of the objects will be dramatically reduced to mm sized objects and with hopes of imaging objects on the microscale if budget allows.

D. 3-Dimensional Image Reconstruction

After developing a 2-d imaging technique we will focus on the imaging aspect of 3-D image capture. Due to spatial coherence of the beam, the object scale will confined to cm size and above. With this we again alter our Fourier analysis program to focus on the detection and FFT collection of the scattered light. This will be achieved by imaging objects such as applying a more advanced and refined Fresnel lens.

E. Real Time 3-Dimensional Image Reconstruction

In order to meet our project goal of real time 3-dimensional image reconstruction we will have completed the previous criteria listed. In order to have real time detection rather than still frame, the Fourier Image analysis program will be altered once again. This process must be able to relay the fast Fourier transformed image instantaneously to a sub program that adjusts and applies new frames of the image. This will be progressed in the Fall semester of 2014.

IX. Conclusion

In conclusion we broadened the current technologies of SPIFI with a light source much less coherent than the original HeNe laser. A 32x32 RGB LED matrix light source was used where one column was left unlit. A series of Fresnel lenses and condensers were used for lenses, and a photodiode for the optics portion of the project. The collection went from the photodiode to a current amplifier through a DAQ. In order to mimic the previous SPIFI system and each LED on the matrix was modulated at a different frequencies to replace the spinning disk in the original SPIFI configuration. This controlled frequency modulation for each Led was driven by a De0-Nano with a 50Mhz clock. These pulsating LEDs were then de-magnified by the optics and captured by the photodiode. An average was taken of the FFT for ten trails to set a threshold and a program recorded the information as a reference. This referenced information was then compared to the same set up but with an object in front of the board which caused a drop in intensity for the blocked frequencies. The blocked version of the FFT was then compared to the reference frequencies and frequencies below the threshold set by the reference frequencies were graphed. In doing so crude 2-dimensional images were captured. The project is planned to continue to enhance the 2-dimensional resolution and also move to capturing a 3-dimensional representation of the object.

X. Bibliography

Spatially-chirped modulation imaging of absorption and fluorescent objects on single-element optical detector • Optics Express, Vol. 19 Issue 2, pp.1626-1640 (2011) • Futia, Greg; Schlup, Philip; Winters, David G; Bartels, Randy A

Appendix A – Abbreviations

1. CAT – Computer Aided Tomography
2. MRI – Magnetic Resonance Imaging
3. 2-D – 2 Dimensional
4. 3-D – 3 Dimensional
5. SPIFI – Spatial Frequency Modulation for Imaging
6. LED – Light Emitting Diode
7. FFT – Fast Fourier Transform
8. MHz – Mega Hetrz
9. A/D – Analog to Digital
10. JTAG – Joint Test Action Group
11. E-Days – Engineering Days
12. PWM – Pulse Width Modulation
13. OSNR – Optical Signal to Noise Ratio
14. SNR – Signal to Noise Ratio

Appendix B – Budget

Component	Quantity	Individual Cost	Total Cost
32X32 LED Matrix Panel	5	$111.95	$559.75
Microcontroller	2	$58.95	$117.90
FPGA De0-Nano	2	$59.00	$118.00
Photodiode	1	$112.00	$112.00
Female Jumper Wires	24	$14.00	$14.00
Sound Card ASUS Xonar DX 7.1	1	$79.99	$79.99
Fresnel Lenses 5x5 inch	5	$49.50	$247.50
			Overall Total = $1289.14

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