INTRODUCTION

Breast cancer is one of the leading causes of death among women between the ages of 40 and 55. Because of its’ prevalence in today’s society researchers have been investigating ways of making the detection process non-invasive as well as affordable, while maintaining a high rate of accuracy, so that more women will be motivated to get tested. One advancement made in this area of research is the optical technique known as FDPM-frequency density photon migration. Employing this technique, the optical properties of the breast sample under investigation are deduced by subjecting the breast tissue to light modulated at high frequencies. Based on these optical properties, it is determined whether or not the patient has breast cancer or whether the cancer resident in their breast is of the benign or malignant type. Although this procedure satisfies 2 of the goals set by researchers—it’s non-invasive and fairly accurate—it still fails in regard to affordability. Thus the objective of this project is to implement the FDPM technique in an affordable manner. The way we propose to do so is by adapting the functions of the FDPM instrument in a portable device such as the Palm, so that the costs associated with expensive equipment and a visit to the doctor can be avoided. In addition to waiving the costs traditionally associated with a breast exam, implementing the FDPM technique in the Palm will empower women with the means to test themselves at their leisure. Since it is expected that almost everyone will own a Palm in the near future, it makes perfect sense to introduce such functionality as a breast cancer detector into the Palm.

BACKGROUND AND RELATED WORK

Research

The entire basis of the project derives from a research project already done by a group from Beckman Laser Institute. In order to gain an understanding of the breast cancer detection device’s implementation and application, as done by the research group, we read three different papers written by researchers from the Beckman Laser Institute.

The three papers are as follows:


All of the three research papers describe the basic principle to be used for the project, Frequency-Domain Photon Migration (FDPM). FDPM is a method that uses intensity-modulated near-infrared light to measure scattering and absorption of photons in thick tissues. Thus, this technique is non-invasive. According to their implementation, the group at BLI scans through frequencies from 3 kHz to 1 GHz within 90 seconds to do the measurement. They recorded the data every 5 MHz and also repeated the measurement for a number of different wavelengths. The figure below shows their setup.

Our main task will involve replicating the function of this setup and produce a portable version that will be interfaced with a PDA on a PalmOS system. Furthermore, the three research papers go in depth in describing the fitting algorithms used in order to obtain a valid result from the raw data acquire from the machine. Their studies show that breast tumors exhibit 1.25 to 3 times higher absorption rates that normal breast tissue.

**IRDA Port**

The three groups working on this project needed to research the three most significant protocols for the IRDA port. The three protocols are the Physical Layer (IrPHY), IR Link Access Protocol (IrLAP), and IR Link Management Protocol (IrLMP). Our group was responsible for revealing the specifications of the physical layer for the
IRDA port. Most of our information was gathered from [http://www.irda.org](http://www.irda.org). More specifically, this is the link that provided the specification for all of the IRDA port protocols, [http://www.irda.org/standards/specifications.asp](http://www.irda.org/standards/specifications.asp).

The main functions of the IRDA port Physical Layer (PHY) are to specify optical characteristics, encode the data bits, frame the data, and provide error checking. The IrPHY is composed of three main parts: optical transceiver, UART, and framer. The framer is a software layer that accepts incoming frames from hardware for presentation to the IrLAP layer and accepts outgoing frames to send to hardware for transmission. The framer is responsible for changing hardware speed as requested by the LAP layer and it allows the LAP layer to interact with the PHY layer while remaining independent of the PHY layer. The encoding of the actual bits is the strictly specified in the IrPHY. A ‘0’ bit is expressed as a pulse of light and a ‘0’ bit is expressed as no light. A two-byte CRC (cyclic redundancy checking) is attached at the end of data segments. Begin and end flags are appended to the start and end of a frame. The flag value in hex is 0x7E. A zero is inserted after five consecutive ones appear in the address or data field. Finally, an extra begin flag is added to start of every packet.

**Components**

After doing research on the IrDA port, the group realized that it would not be possible to recreate their device using only the IrDA port. Thus, we set out to recreate their machine as a compact and portable version. The first components we would need are listed below. Each link specifies the specification for the part.

1) VCSEL Laser (from Honeywell)

2) Laser Driver (from Thorlabs)

3) RF (from National Semiconductor)

4) Bias-Tee
   A bias tee is essentially composed of two parts, a capacitor and an inductor. The DC input is connected to the inductor and the RF input is coupled to the capacitor. The capacitor and inductor are then tied together and connected to the laser diode. This will provide a DC shifted level that has an RF signal superimposed upon it. Thanks to Frederic from Beckman Laser Institute for enlightening us about this.
5) Si APD (from Perkin Elmer Optoelectronics)
   http://opto.perkinelmer.com/producttemplates/SubCat2.asp?levelId=14494&s=2&ss=1

6) Heterodyning circuit

7) ADC (from National Semiconductor)
   http://www.national.com/pf/AD/ADC0804.html

Motorola Excimer Board

All of the documentation for the Motorola Excimer board came from these two links:


http://www.motorola.com/SPS/PowerPC/teksupport/teklibrary/excimer.html

   ExcimerUMdraft1_4.pdf:
   This document gives an overview of the entire Excimer board. It essentially lists all of the available resources on the board. The Excimer board contains 1 MB of RAM, 4 MB of FLASHROM, 2 serial ports, PowerPC 603e microprocessor, Berg connector I/O interface, and a COP connector. The document also provides a hardware memory map and a DINK memory map that will be used for programming the board.

   ExcimerLab.pdf:
   This document provides instructions on how to run C programs on the excimer board. It gives a couple of exercises as an introduction to accessing hardware and memory on the Excimer board. It also gives a tutorial on how to do assembly programming on the board and how to link assembly and C code.

   Excimer_X3.pdf:
   This document provides the actual schematic capture for the entire Excimer system. It offers a block diagram of the system as well. The most useful item in the schematic is the pinout for the Berg expansion I/O pins.

   Minsysdesign.pdf:
   This document provides an overview on the design principles utilized in the conception of the Excimer board. The document was useful in giving insight to the systems level operation of the Excimer board.

   MPC603EUM.pdf:
   This document provides information on how the MPC603e processor functions. The most useful item in this document is a listing of the exception vector offsets. We found the interrupt that we absolutely need, external interrupt (0x00500).


**PROJECT SPECIFICATIONS**

Let us preface the discussion of the project specifications by restating the objective of this project. The objective of this project is to create a portable device capable of functioning as the FDPM does for the purpose of breast cancer detection. The intention is to have a PDA serve as such a device. With this in mind, the discussion of the project specifications will be divided into 3 categories: signal generation, signal detection and data interpretation. To aid in the discussion, we will begin by presenting a high level view of the role that each of the 3 components mentioned above will play:

The basic plan is to have the signal generator transmit a signal to the breast tissue and to have the signal detector receive the signals that are being reflected. The data collected by the detector would then be ported to the PDA for processing, where the PDA would then report the results of the test in some graphical manner based on the absorption properties of the breast tissue. This procedure is to be carried out over a period of ~90 seconds, after which enough data should have been collected to make a diagnosis. With this said, a more detailed account of the specifications in each of the three categories will be given.

**Signal Generation**

The signal will be generated by means of a laser diode and will be in the near-infrared region of the spectrum (700-1100 nm). So that we can transmit signals varying in frequency between 5 MHz-1GHz an external frequency modulator will be used. The laser driver, which must be used to ensure proper working of the laser diode, must be able to provide at least 20-30mA of current. Thus, together with the laser diode, laser driver and frequency modulator the transmission side of the system will look as follows:
Signal Detection

To detect the signal being reflected from the breast tissue an Avalanche Photo-Diode, or APD for short, will be used. The APD must be able to handle frequencies as high as 1GHz. For processing, the analog signal coming from the APD must be converted to a digital signal using an ADC. But since there are no ADCs which can handle frequencies as high as 1 GHz a heterodyning circuit will have to be placed between the APD and the ADC to extract a lower frequency signal containing the same phase and amplitude information as the given high frequency signal. The digital signal coming from the ADC must then be passed to a demodulator to extract the phase and amplitude signals which are then interpreted in software by performing an FFT. The figure below illustrates more clearly the relationship between each of the components just discussed, which together make up the reception side of the system.

RX

Data Collection/Interpretation

Since the breast tissue can at any time, during the 90 second period of signal transmission, reflect the light that is passed through it, we must somehow be alert to when there is data to be collected. We must also be able to store the data that is being received before we send it to the Palm, so that the maximum amount of data that the Palm can process is being sent at any given time and not any more or less than this limit. To carry this out an evaluation board will be used. This board will take the data being sent by the ADC and store it in its RAM to be sent to the Palm once the requisite amount of data has been collected. As a dynamic device, it will be able to read from its I/O pins whenever there is data to be read. The figure below illustrates the function of the device in relation to the other devices.
PROJECT DESIGN

The entire project consists of three main areas: the device prototype, module prototype and the Palm. The block diagram of the three components is shown below.

![Block diagram of entire project](image)

Figure 1: Block-level diagram of entire project.

DEVICE PROTOTYPE

The device prototype is mainly responsible for the signal generation and signal detection. It can be broken down into two main areas, the signal generation will be referred to as the transmit side (Tx) and signal detection will be referred to as the receive side (Rx). The block level module is as follows:

![Transmit (Tx) and receive (Rx) blocks](image)

Figure 2: Separation into transmit (Tx) and receive (Rx) blocks of device prototype.

Transmit Side (Tx)

The transmit side of the device prototype consists of 5 components. They are the laser diode, bias tee, laser driver, RF modulator, and power supply. Figure 3 shows the manner in which all the components will be connected.

Laser Diode – We decided that it would be best to use a VCSEL (Vertical Cavity Surface Emitting Laser) for the laser diode. The reason for this decision is that a VCSEL requires less current to drive it into lasing action, typically only a few milliamps. This very important, because our device needs to be portable and thus should consume very little power. One lead of the laser diode will be connected to a bias tee and the other lead will be connected to ground. This disadvantage in using this type of laser diode is that it is
more expensive than the conventional laser diode.

Figure 3: Diagram of Tx side for device prototype

Laser Driver – We decided on using the Thorlabs laser driver for our device, because it can provide sufficient power for driving our laser. It can provide up to 250mA of current; although we won’t need that much current. One advantage of this driver is that it is portable and can be easily soldered into a PCB. This aspect is very important, because it allows our physical dimensions to stay fairly low. The disadvantage with this laser driver is that Thorlabs does not offer a detailed specification sheet for it. Therefore, we do not know which pins correspond to what functions until we order the item. The minimalist approach will involve using at least three pins. One will be connected to the power supply, the output will be connected to the bias tee and another will be connected to ground. Figure 4 shows the laser driver.

Figure 4: Thorlabs laser driver

RF oscillator – There are two ways that we achieve proper oscillation: 1) turn the laser on and off at a desired frequency, or 2) have a DC shifted level and impose an RF of desired frequency upon it. We decided to go with the latter approach. The former is harder to accomplish because we will be working in the high frequency domain. There is no laser driver in the market that can provide modulation in the 100’s of MHz range. The closest one available is made by Wavelength Electronics and only has a maximum modulation of
2 MHz. By using a frequency synthesizer designed for cordless phone we can easily generate the frequencies we require.

Bias Tee - The laser diode will be connected to a bias tee, which is essentially made up of a capacitor and an inductor. The RF oscillator is connected to the capacitor and the laser driver is connected to the inductor. This will allows us to have the proper modulation. This allows us to stop searching for a laser driver that can turn on and off at a high frequency.

**Receive Side (Rx)**

![Block diagram of the receive side (Rx) for the device prototype](image)

- **Si APD** – We decided to use a Silicon photodiode rather than a GaAs photodiode, because the spectral response is better for the two wavelengths that our laser diode operates in, 760nm and 830nm. We also decided to use an avalanche photodiode (APD) rather than a PIN photodiode, because it provides a high gain and thus will be perfect for weak signals such as ours. The disadvantages of the APD are that it has higher noise and also requires 100V to reverse bias it.

- **Heterodyning circuit** – The heterodyning circuit essentially allows us to convert our high frequency signal to a lower frequency signal. This is very significant because we do not have ADCs that can sample at the frequencies we desire.

- **8-bit ADC** – The ADC is our direct interface to the Excimer board. It will be interrupt driven and will notify our module if data is ready. Combined with the heterodyning circuit, it will easily be able to handle our signal. We decided that we only needed one ADC, because the demodulation of our signal will occur in software.

- **Power supply** – This is a larger design decision in the Rx because due to the APD. Because our APD requires a 100V reverse bias voltage, we will have to use an external power source for now, until we find a different method of supplying that type of voltage.
 MODULE PROTOTYPE

Motorola Excimer Board

The Motorola Excimer board will be used as an expansion module prototype, because it contains memory, processor, flash ROM, and I/O pins. The module will have three parts to it: data acquisition and oscillator control, data storage and demodulation, and interface to the Palm. The first part of the module will occur primarily through the expansion I/O pins. The data storage and demodulation will be done through the use of memory and the PowerPC processor. Finally, the interface to the Palm will first be done through the serial port and eventually through the expansion I/O pins.

Data Acquisition – This event will occur once the ADC sends an interrupt. Excimer will then issue a ~WR and then the ADC will be able to send data for storage into memory.

Oscillator Control – The voltage-controlled oscillator on the frequency synthesizer will be controlled through the expansion I/O pins as well. There are enough pins since, the ADC only requires 8 pins for data.

Demodulation – Using C code and the power to execute programs on the Excimer board, we will do this on the Excimer board and in software.

Programming Environment – The Excimer board is programmed in C and Assembly. The assist our programming, we are using the COP pins and the Wiggler to debug our programs.

DEVELOPMENT PLAN

PROGRAMMING ENVIRONMENT

We will be using C and assembly to program the Excimer board. Programming will be done with the help of GNU tools. In order to test our programs, we will be running them under the DINK environment and we should harness the power of the
Wiggler to debug our program as well. Through the Wiggler, we can step through our entire code.

SCHEDULE

1) Research the technique used by the Beckman Laser Institute to differentiate cancerous tissue from normal breast tissue.

   Time = 1 week
   Status = accomplished

2) Research whether or not the IRDA port on the Palm is enough to do the FDPM technique as specified by the Beckman group.

   Time = 1 week
   Answer = No, the IrDA is only meant for data communication and therefore not possible.
   Status = accomplished

3) Find all the components needed as specified in the project design

   Time = 2 weeks spent but still concurrently searching for some parts
   Status = half-resolved
   Left = We need to find the following components: heterodyning circuit and power supply.

4) Solve all of the issues on how to integrate all of the components together to form our device prototype.

   Time = 2 weeks spent but there still some issues that are unresolved but concurrently being solved with programming issues

   a) How to achieve proper modulation?
      Answer = see Project Design
      Status = resolved

   b) How to control modulation to do a sweep of varying frequencies?
      Answer = We will stick to one frequency for now to assure that all of the other components work as specified. Once that is accomplished we will program the I/O pins to control the voltage-controlled oscillation on the frequency synthesizer.
      Status = half-resolved
      Left = program I/O pins to control VCO of frequency synthesizer

   c) How to provide power to the entire device?
Answer = We will have to use an outside power source for now until we find a suitable alternative.
Status = half-resolved
Left = We need to find a suitable alternative

d) How to handle high frequencies on the receive side?
Answer = We will use heterodyning techniques to resolve this issue.
Status = half-resolved
Left = We need to find a suitable heterodyning circuit, and will need a tremendous amount of help from the Beckman group.

5) Complete any programming of the I/O interface to the device and the demodulation scheme
   Status = 2 weeks spent and concurrently being addressed with other issues
   Status = unresolved
   Action Items =
   • Assembly code needs to be compiled properly, because we are having trouble compiling our code
   • C code needs to be able to do the demodulation of our data
   • Wiggler needs to be working properly, because we are having problems getting the Wiggler to function properly.

FUTURE PLANS

These plans are ordered in priority with (1) having the highest priority.

1) Acquire raw data (2 weeks)
   - We need to have the ADC and I/O pins communicate properly and handle the interrupts and data acquisition in software

2) Dump raw data into the Palm using the serial port (done)
   - Joseph Torralba (another group) has this working already. We will have to ask for his help on how to do this in order to save us some time.

3) Resolve any remaining integration issues. (1 week)
   - We will utilize the Beckman group’s knowledge on how to solve the rest of these issues.

4) Demodulation (1 week)
   - We need to find techniques on how to do the demodulation in software.

5) Oscillation control (1 week)
   - We need to have the voltage-controlled oscillator on the frequency synthesizer be properly programmed and be able to communicate with the I/O pins of the Excimer board
6) Handspring expansion slot (2 weeks)
   - We will have to create a connection between the I/O pins of the Excimer port and the expansion slot in order to prototype the expansion slot connection. We will need to be able to dump raw data through the I/O pins.

TESTING METHODOLOGY

This the step-by-step approach in order to ensure the all of the components will work together properly.

1) Start with a low frequency signal and using a regular photodiode and ADC, acquire data and store properly into memory. Check if the data expected is in memory.
2) Dump data into the Palm. Check if expected data is in the Palm.
3) Vary the signal frequency. Check the data in the Excimer memory and Palm to see if it is the expected values.
4) Using a photodiode outside from the device, check the frequency of the laser diode in our device prototype.
5) Vary the voltage in the voltage-controlled oscillator and check the frequency of the laser. Make sure to use an outside power source to vary the voltage.
6) Using the I/O pins to control the VCO, check to see if the laser diode signal frequency can be varied as specified in the program.
7) Check to see the expansion slot connection prototype works. Dump data through the expansion slot and check the validity of the data.
8) Integrate everything and test on tissue samples.

PROJECT EVALUATION

SPECIFICATION:

Our specification was average, we were able to find the main components needed to construct the device. However, what was lacking in our specification was how to integrated the components together. For example: we did not specify a bias-tee, but we needed one in order to connect the modulator, laser driver, and laser diode together. We have not yet built our device since we do not want to spend hundreds of dollars in components until we can test out the control portion (i.e. Excimer) of the project.

DEVELOPMENT:

It is difficult to assess this aspect of the project since it is still fairly early in the development process. Most of the quarter was inherently a feasibility research, and it is only at this time that we will be able to actually act upon our design.
CONCLUSION

In conclusion, we’ve learned that a design that seems reasonable on paper, may not be so easy to implement in practice. The stumbling blocks we came across were not so much conceptual in nature, but were more associated with the tools we were using to control the various devices. For example, in order to program the Excimer board we needed to familiarize ourselves with a debugging tool called the Wiggler. However, because of a lack of documentation about its use we haven’t been able to debug the code that we’ve written. So, though we have ideas as to how to manipulate the Excimer so that we can store data and output it to the HandSpring we can’t really begin implementing them till we’ve figured out how to use the Wiggler. Another tool we’ve been struggling with is the GNU assembler, which is required to generate an object file from our assembly code. These are issues, however, which are solvable with time so we hope to get a grip on these tools so that we can begin testing out our ideas. What remains to be done is the programming of the Excimer board so that it can store the data being sent to it from the ADC and so that it can send the stored data to the expansion slot of the HandSpring for processing. Although we’re currently focusing on transmitting one frequency, we eventually hope to be able to sweep through a range of frequencies. Thus, as it stands, we have quite a bit of work left to do before we can even consider the data interpretation facet of the project, which will involve applying the theory of FDPM to the data that we collect.

We find this project to be extremely interesting since it draws from a large number of areas, such as DSP, optics, RF, systems design, low-level, and high-level programming. We feel as though that the project is feasible and we are only beginning to realize our design. We will be continuing on with the project next quarter and hope to make tremendous breakthroughs.

CREDITS

Write-up:

Renuka – Introduction, Product Specification, Evaluation, Conclusion
Jerome – Project Design, Development Plan

Components search:

Renuka – ADC, photodiode
Jerome – laser driver, frequency synthesizer
Beckman group – laser diode, bias tee

Programming:

Renuka and Jerome worked together on trying to program the Excimer, since we only have one Excimer board.
Thanks to Joseph for showing us how to send data from the serial port of the Excimer board to the Palm.

Thanks to Shinko on showing us how to connect the Interrupt of the ADC to the Excimer I/O pins.

Thanks to Beckman group for all their support and we look forward to continuing this project next quarter.

**BIBLIOGRAPHY**

See background and related work.