# Budget Worksheet

<table>
<thead>
<tr>
<th>BUDGET ITEM</th>
<th>Department or College Funds</th>
<th>Outside Agency Funds</th>
<th>Personal Funds</th>
<th>Undergrad. Research Funds</th>
<th>GRAND TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Materials</td>
<td>Misc. Electronics for initial Prototyping</td>
<td>-</td>
<td>-</td>
<td>647.58</td>
<td>647.58</td>
</tr>
<tr>
<td>Equipment</td>
<td>Existing Lab Equipment available for use.</td>
<td>-</td>
<td>-</td>
<td>230.00</td>
<td>230.00</td>
</tr>
<tr>
<td>Mileage to gather Data (.36 per mile)</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>GRAND TOTAL</strong></td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>877.58</td>
</tr>
</tbody>
</table>

**NOTES**

Equipment and left-over materials purchased with this grant will remain the property of WSU.

You may not request money for gas purchases for travel. WSU reimburses travel expenses at a set mileage rate only.

<table>
<thead>
<tr>
<th>products</th>
<th>part number</th>
<th>costs</th>
<th>number</th>
<th>total individual cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Atlys™ Spartan-6 FPGA Development Board</td>
<td>Digilent Atlys spartan 6 FPGA</td>
<td>$200.00</td>
<td>1</td>
<td>$200.00</td>
</tr>
<tr>
<td>breadboard daughter board</td>
<td>FX2 Breadboard</td>
<td>$30.00</td>
<td>1</td>
<td>$30.00</td>
</tr>
<tr>
<td>Spartan 6 FPGA</td>
<td>XC6SLX45-2CSG484C</td>
<td>$59.78</td>
<td>1</td>
<td>$59.78</td>
</tr>
<tr>
<td>a to d converters</td>
<td>AD9961</td>
<td>$25.75</td>
<td>4</td>
<td>$103.00</td>
</tr>
<tr>
<td>photodiode</td>
<td>OPF432</td>
<td>$14.95</td>
<td>4</td>
<td>$59.80</td>
</tr>
<tr>
<td>photodiode enclosure</td>
<td></td>
<td>$50.00</td>
<td>2</td>
<td>$100.00</td>
</tr>
<tr>
<td>pcb board fabrication</td>
<td></td>
<td>$100.00</td>
<td>1</td>
<td>$100.00</td>
</tr>
<tr>
<td>miscellaneous parts</td>
<td></td>
<td>$150.00</td>
<td>1</td>
<td>$150.00</td>
</tr>
<tr>
<td>estimated shipping</td>
<td></td>
<td>$75.00</td>
<td>1</td>
<td>$75.00</td>
</tr>
</tbody>
</table>

**Total Cost:** $877.58
Lasers are used to make some of the most astoundingly precise measurements in science and engineering. There are two properties of lasers in particular which make most of these measurements possible; monochromaticity and coherence (Pedrotti, Pedrotti, & Pedrotti, 2007). The monochromaticity of laser light can be thought of as the light having only a single color, unlike most light sources which are a broad mix of different colors. The coherence of the laser has to do with the photons being emitted exactly in phase with each other, while most other light sources are incoherent. Of these two properties, the exact color of the light emitted by a laser is not always known to a high degree of precision — such an example is the light emitted by “tunable” lasers used by many experiments in atomic physics.

There are a number of methods to measure the color, or wavelength, of light. However, most commercial devices are prohibitively expensive and not justifiable for use in an undergraduate lab. In 1999, a paper was published in the American Association of Physics Teachers which described a low cost design for a device known as a Michelson Wavemeter, which could be used to measure the wavelength of light to six significant figures (Fox, Scholten, Walkiewicz, & Drullinger, 1999). An undergraduate physics senior from Weber State University saw this paper a few years later and attempted to construct the device. She constructed the mechanical apparatus as described, which worked well, but she ran into issues with the electronic measurement device described in the paper. The end result was a nearly complete Michelson Wavemeter, sans the opto-electronics needed to make it useable.

The way in which a Michelson Wavemeter is able to measure the wavelength of light is by exploiting the other property we described, coherence. Two lasers beams are reflected through a series of mirrors and beam-splitters, which results in the production of what is known as a fringe, or
interference, pattern. When the device is motionless, these fringes appear as a pattern of bright and dark stripes on the surface they are projected onto. When a part of the device is set in motion, the fringe pattern appears to move – so fast, in fact, that the pattern quickly becomes a blur to the naked eye. The number of fringes that move past a given point on the projected surface is related to the wavelength of light. By using two lasers, one laser of a known wavelength, the other laser’s wavelength can be calculated through the ratio of the number of fringes observed.

We believe that the electronic measurement problem that halted the WSU wavemeter project ten years ago is now able to be solved and improved by our group of undergraduate electronic engineering students within a reasonable budget through the use of high speed photodiodes combined with digital signal processing (DSP). The author of that 1999 paper concedes that the limiting factor in his design was the opto-electronics and suggests that as an area that may be improved.

We plan to use two photodiodes per fringe pattern to obtain a high-speed quadrature measurement which can then be processed in real time using a modern Field Programmable Gate Array (FPGA). The use of two photodiodes in place of the single photodiode of the original design will allow us to more accurately track the fringe pattern, determine the direction in which it is moving, and reject common mode noise (Martin, Gauthier, Gulick, & Laroche, 1988) (Zhao, Logan, Shakan, & Shao, 1999). Additionally, the original design used discrete digital electronics and effectively truncated the amount of information in the input signal by filtering it into either a single high or low state at any given moment in time. We recognize this as another area with great potential for improvement. Through the use of high-speed Analog to Digital Converters (ADCs), we can quantize our signals into 1024 or more states rather than just two. This will allow greater precision in fringe counting as well as enable us to perform advanced digital filtering techniques to “clean up” the signal. The result of these improvements will be an increase in the accuracy of the fringe count, as well as an increase in the precision of the count – we will be able to count fractions of a fringe rather than whole fringes.

In addition to greatly improving the original method of measurement, we will explore an
alternate method. The original design was to count the number of fringes that moved past over a period of time – our idea is to measure the difference in the frequency of the fringes. This type of measurement is common in other fields, such as Doppler radar, but as of yet we have not found published documentation of this being applied to a Michelson Wavemeter. By taking the Fast Fourier Transform (FFT) of the time-domain signal, two separate peaks can be detected in the frequency domain. The ratio of the two peak frequencies is related to the ratio of the two wavelengths of the lasers, and thus the unknown wavelength can be calculated. We have simulated this method in MATLAB, and obtained promising results that a frequency domain measurement may at least equal the precision of the time domain measurement, while adding no material cost to the project, as it will utilize the same electronics. We also theorize that this method may allow the physical apparatus to be simplified, which would allow others to reproduce the design at even lower cost.

Student Role and Experience in the Field of Research

<table>
<thead>
<tr>
<th>Dependent</th>
<th>X Independent</th>
</tr>
</thead>
<tbody>
<tr>
<td>(student helping faculty do research)</td>
<td>(student doing own research)</td>
</tr>
</tbody>
</table>

I have led a team in electronics design for the HARBOR program here at WSU, producing sensing electronics which have successfully been flown to near-space numerous times. I have taken a broad range of courses in Physics as well as Electronics Engineering pertaining to this research topic including Optics, Modern Physics, Data Acquisition and Analysis, and Digital Signal Processing. I will be working together with two fellow electronics engineering seniors on this as a senior design project. Both of my peers have experience in coursework equal to my own in the electronics field.
Final Product

The final product of this project will be a completed Michelson Wavemeter and a scholarly paper in the form of an apparatus note. The Michelson Wavemeter will enable more advanced experiments in physics here at WSU, and the apparatus note may be published in a journal so that other university faculty or students may reproduce our design to further education and research opportunities at their institutions. In addition, we will submit an abstract concerning our design to NCUR 2012, and hope to have results to share with the conference in March.

Project Methods & Timeline

A complete timeline in the form of a Gantt chart is attached as an addendum to this application. The following is an abbreviated timeline of the key milestones:

<table>
<thead>
<tr>
<th>Date</th>
<th>Milestone</th>
</tr>
</thead>
<tbody>
<tr>
<td>12 October 2011</td>
<td>Initial Research Complete</td>
</tr>
<tr>
<td>3 December 2011</td>
<td>Data Acquisition and Algorithm Development Complete</td>
</tr>
<tr>
<td>13 February 2011</td>
<td>Prototype Hardware Design and Testing Complete</td>
</tr>
<tr>
<td>19 March 2011</td>
<td>Build &amp; Test Final Design Complete</td>
</tr>
<tr>
<td>16 April 2011</td>
<td>Documentation &amp; Research Paper Complete</td>
</tr>
</tbody>
</table>

Budget Explanation

Our budget consists of only materials and equipment. Because it is a senior project, we are not requesting a stipend. We have completed preliminary research on suitable electronic components which comprise the core cost of this project.
UNDERGRADUATE RESEARCH LONG TERM GRANT APPLICATION
Additional Questions

- What funding have you received from OUR in the past, Where has your previous project been disseminated.
  
  o I have not received funding from OUR in the past.

- Is this project part of a required course? If so, please indicate the support (monetary and in-kind) provided for this project by the academic department.
  
  o This project will fulfill the required Senior Design I & II courses for the Electronics Engineering Bachelor of Science Degree.
  
  o The product of our design will benefit the physics department. They will be assisting in providing the already complete mechanical apparatus for our design which cost over $2000 in time and materials, as well as allow the use of test equipment and minor electronics parts needed for prototyping the opto-electronics.

- What additional sources of funding have been solicited? Is your department willing/able to fund any equipment they will be retaining?
  
  o No additional sources of funding have been solicited. The department will be providing the use of test equipment, the use of the atomic lab for our workspace, and the already funded mechanical apparatus we are designing the opto-electronics for.

- Where do you plan to disseminate the results of this project
• We plan to disseminate the results at NCUR as a presentation as well as submit an apparatus note for publication in the American Journal of Physics.

• Physics Senior Seminar.

• Electronics Engineering Senior Project Design Presentation.

• If you are requesting a stipend, please list all significant time commitments (5+ hours per week) that you expect to maintain over the duration of your project including, for example, class and work schedules.

  o No stipend is being requested. We will be committing a minimum 900 man-hours cumulatively on this project in fulfillment of the required classes of Senior Design Project I & II.
FACULTY MENTOR RECOMMENDATION FORM

Student Name (last, first): Ecek, Robert (PI)

Project Title: Michelson Wavemeter measurements using time and frequency domain techniques

**Mentor Directions:** After carefully reviewing the proposal and assessing both the viability of this project and the qualifications of the student requesting funding, answer the questions found below. Please expand the sections as necessary (do not attach separate letter). If the project involves the use of human subjects or protected animals, be sure the student secures IRB or ACUC approval. If the project receives funding, it is your responsibility to work closely with the student, monitor the ongoing progress of the project and budget, and evaluate the project’s results. Failure to do so will jeopardize funding for this project and any future projects.

1. How long and in what capacity have you known this student?
   Two years. Rob has worked extensively on the HARBOR high altitude balloon program.

2. Briefly describe the proposed project. Is this part of a larger research project? Is this part of a course? If so, how is the project apart from the nature and scope of activities normally taken for the course?
   They are attempting to fix a project that stalled ten years ago. That project was based on a published research article that we have since determined could not possibly work because the original electronic circuit was not fast enough. Today, faster electronics are readily available and these students have proposed a very reasonable system that should be plenty fast enough to make this very difficult measurement. This is not part of a larger research project, although it works it will be used for other optical physics projects. It is not part of any course that I teach, however the students are using it for their Electronics Engineer senior project. I have agreed to be their advisor.

3. Give an assessment of the project’s significance to the student’s discipline and of the project’s educational and/or professional benefit to the student.
   I believe that there is a very good chance that this circuit will be able to accomplish the task and these students have the skills needed. If it works we plan to publish the results in the American Journal of Physics. I am just learning about the particular circuit chips that they propose to use (FPGA chips) so this will be a learning experience for both the students and me.

4. Comment on the qualifications of the student to successfully complete this project, both in terms of the project’s scope and its time frame.
   Rob (the lead student) has successfully built sophisticated high speed circuits with me for our sub-orbital research program called HARBOR where we launch high altitude balloons into the stratosphere to measure Earth’s atmosphere. He has successfully created very high speed circuits in my optics lab before, too. If any student group has a chance, it is probably this group.

5. Comment on the justification and appropriateness of the project budget, including the necessity of a stipend (if requesting one).
   My only concern is that there is very little wiggle room in the budget. If one of the main components gets damaged we’ll have to replace it out of pocket.

6. Describe your role in the project.
   I will be guiding the students on the optical theory and overseeing their progress. For the most part I plan to let them do this project entirely on their own unless they get stuck.

7. Include anything else that you think will be helpful to the committee in evaluating this application.
7. Include anything else that you think will be helpful to the committee in evaluating this application. This project has sat idle in my lab for a decade only because the electrical part of it needed faster electronics and I have not had the time to do it myself. These students got excited about the project after I explained the physics to Rob as part of my Applied Optics course (PHYS 3190). The novel circuit idea was entirely their idea and after reviewing it carefully I decided that it has a very real chance of solving the speed and sensitivity problems. I will be happy to have this piece of equipment operational at last so that we can use it for measuring the laser wavelengths for other, larger, research projects.

This project ___ DOES __ DO NOT require review by the WSU Institutional Review Board for Human Subjects or the WSU Animal Care and Use Committee.

[Signature]

Project Mentor Signature

Sept. 19, 2011

Date

2508

7907

Campus Mail Code

Phone Extension
WORKS CITED


