Resonant-Beam Based Optical Wireless Power Charging and Data Communication

ECE 4901 Fall 2020

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# Table of Contents

Abstract........................................................................................................................................... ii
List of Figures...................................................................................................................................... iii
List of Tables ....................................................................................................................................... iii
Glossary of Terms ................................................................................................................................. iv

1. Introduction..................................................................................................................................... 1

2. Problem Statement......................................................................................................................... 2
   2.1 Statement of Need...................................................................................................................... 2
   2.2 Requirements ............................................................................................................................ 3
   2.3 Specifications ............................................................................................................................ 3
   2.4 Limitations ................................................................................................................................. 4

3. Approach and Design .................................................................................................................... 4
   3.1 Project Design and Models ...................................................................................................... 4
   3.2 Constraints and Standards ....................................................................................................... 8
   3.3 Alternate Designs ..................................................................................................................... 9

4. Project Management ...................................................................................................................... 10
   4.1 Team Member Responsibilities .............................................................................................. 10
   4.2 Budget and Parts List .............................................................................................................. 12
   4.3 Project Timeline ...................................................................................................................... 13

5. Summary ....................................................................................................................................... 14

References .......................................................................................................................................... 15

Appendix ............................................................................................................................................ 16
Abstract

As more devices communicate wirelessly, the demand for a way to wirelessly power those devices is growing. One way to accomplish this is to use lasers to precisely transmit power on a point-to-point basis. A company called Wi-Charge has been able to develop a device that safely transmits power wirelessly using an infrared resonant beam. A senior design team from the 2019-2020 academic year started an investigation into this topic. The team was able to create a testbed that transmitted power and data via a 5-mW green laser. While the testbed was able to transmit power and data wirelessly, it was not a resonant beam, and there are other areas where its design could be improved.

The Department of Electrical and Computer Engineering wants our team to further investigate resonant-beam based communication and power transfer and further iterate on the previous team’s testbed. Our team is to leave the testbed intact and not use any parts from it. Our group should create a testbed that can amplify a source laser, utilize an optical loop to boost power, and implement an automatic shutoff. There are two main issues with establishing an ideal resonant-beam communication channel. They are as follows: the laser cavity that is normally enclosed is now in open air, and the laser passes through the gain medium two times in a single cycle, increasing the likelihood of gain medium saturation.

Due to the issues with developing an ideal resonant-beam channel, our group has decided to create a testbed that still uses an optical loop, but is not a full resonant beam. Our design uses a combination of beam splitters, an optical amplifier, an optical isolator, a mirror and transmitter and receiver circuits to create a wireless power transfer system. The transmitter has an infrared laser that acts as the source in the optical loop. The laser passes through the optical amplifier to increase its optical power. It then passes some of the beam through a beam splitter to the receiver circuit and then loops the remaining. Through our design process, our team has identified some constraints that will affect how we build and design the testbed, how frequently we can access the lab to test it, and when we can schedule our meetings. Through the design process we have also identified other potential designs that we have moved away from or built upon.

Our team has split the various tasks that we need to complete according to technical skill and availability. In addition to this we have created a timeline in which the research, design and building are to be completed. As we move from designing a testbed to getting prepared to build one, we have composed a part list that contains what we need to build the testbed.
List of Figures

Figure 1. Long-range resonant beam design. ................................................................. 1
Figure 2. Senior Design Team 2005’s testbed design schematic. ................................. 2
Figure 3. Our communication channel design, featuring an optical loop inspired by the resonant-beam channel. ...................................................................................... 5
Figure 4. Alternative design of our communication channel using corner reflectors......... 6
Figure 5. Design of our transmitter-end circuit ............................................................... 7
Figure 6. Design of our receiver-end circuit .................................................................. 8
Figure 7. Alternate solution for coupling and decoupling light to and from the optical loop showing tunnels drilled into a corner reflector. ......................................................... 10
Figure 8. Early design showing laser gain medium outside of optical loop .................... 11

List of Tables

Table 1. Project work-breakdown by team member (RACI chart) ...................................... 11
Table 2. Parts list with pricing ......................................................................................... 12
Table 3. Project timeline for Fall 2020 (Gantt chart) ...................................................... 13
Table 4. Project timeline for Spring 2021 (Gantt chart) .................................................. 13
Glossary of Terms

- **Gain medium** – (also active laser medium) A crystal compound such as neodymium-doped yttrium aluminum garnet (Nd:YAG) which, when energized by a pump source, can generate coherent, monochromatic laser light at a specific wavelength. This process is called stimulated emission.

- **Optical amplifier** – A device consisting of a gain medium and a pump source that, when an external electrical power supply is applied to it, amplifies the power of a seed laser.

- **Optical isolator** – A device that rotates the polarization angle of electromagnetic radiation and thereby permits light to pass through it in only one direction. This device should be thought of as the optical equivalent of a diode.

- **Pump source** – A light source such as a flashlamp or an arc lamp that can deliver high-energy light pulses to a gain medium in order to facilitate stimulated emission in a laser.

- **Resonant beam** – An optical oscillator that forms within a laser cavity due to reflectors on both sides of a gain medium. In resonant-beam communication, the entire communication channel forms a laser cavity, and thus the resonant beam forms between the transmitter and receiver.

- **Seed laser** – A low-power laser that is destined for power amplification via an active gain medium.
1. Introduction

As an ever-increasing number and variety of devices communicate with one another over an interconnected Internet of Things (IoT), the desire for completely wireless power delivery and data transmission is greater than ever. Eliminating bulky wire connections would save space, allow for greater mobility, enable faster transfer speeds, and improve system aesthetics. For IoT devices that operate in open spaces with few persistent physical obstructions, such as a room in a house or manufacturing plant floors, establishing links among these many devices via infrared or visible laser beams is an attractive strategy. Unlike radio waves, lasers can provide precise point-to-point communication, are largely immune to the effects of electromagnetic interference, and can deliver high power over long distances with minimal inverse-square losses.

Over the past few years, the startup company Wi-Charge has demonstrated safe, wireless power delivery to smartphones via an infrared resonant-beam design [1]. A simplified, theoretical model of a resonant-beam based communication channel is shown in Figure 1. In a standard laser, an active gain medium (such as the infrared-generating neodymium-doped yttrium aluminum garnet, Nd:YAG, crystal) is stimulated by a pump source (such as a flashlamp or arc lamp) to emit electromagnetic radiation at a specific frequency, while mirrors on either side reflect the emitted waves back and forth through the gain medium to provide further amplification and to produce a coherent, monochromatic beam. In the resonant-beam design of Figure 1, the laser cavity is essentially extended over the entire length of the channel, with reflecting mirrors built into the transmitter and the receiver [2]. Establishing such a long-range resonant beam offers the possibilities of high-power buildup in the loop, self-alignment between transmitter and receiver, and an automatic “cutoff” feature such that power or data will only be transferred when the line of sight is free from obstructions [2].

![Figure 1. Long-range resonant beam design. (Based on a design in [2].)](image-url)
During the 2019-2020 academic year, Senior Design Team 2005 started an investigation into this topic of resonant-beam based communication and built a functional testbed that was capable of transmitting both power and data via laser light [3]. Team 2005’s final design schematic is shown in Figure 2. The team used three 5-mW, green-light, Galileo model lasers from Laserglow Technologies [4], one of which functioned as a control laser while the other two operated as transmitters. Although the testbed of Figure 2 successfully demonstrates power and data transference, there are at least three areas to which our team would like to make improvements. First, the control laser continuously outputs power. If an obstruction blocks the control laser’s line-of-sight, the transmitting lasers will turn off, but the control laser itself will not cease transmission. An automatic shutoff feature is therefore desirable. Second, the communication channel employs simple point-to-point laser communication without reflections. We would like to establish an optical loop, similar to the resonant beam of Figure 1, over the length of the channel. Third, the photovoltaic cell used in Team 2005’s design (shown by the dashed, thin rectangle in Figure 2) does not generate enough current to directly power the LED lamp—a microcontroller and relay switch are used to provide enough power to turn on the LED. Our team would like to increase the intensity of the light incident upon the photovoltaic cell and maximize the cell’s conversion efficiency so that enough electrical current is produced to directly power the LED.

![Figure 2. Senior Design Team 2005’s testbed design schematic.](image)

2. **Problem Statement**

2.1 **Statement of Need**

The Department of Electrical and Computer Engineering would like our team to further investigate the resonant-beam based communication channel of Figure 1 and to build a new optical testbed whose design approaches, or preferably realizes, the ideal resonant-beam model.
effort to improve upon Team 2005’s design, our team has made use of all available resources, including the expertise of our advisors Professor Shengli Zhou and Professor Eric Donkor, both of the University of Connecticut, as well as technical papers relevant to the topic of resonant-beam communication (such as [2] and [5]) and patents assigned to Wi-Charge (such as [6] and [7]). We will primarily be concerned with transferring power through a photovoltaic receiver circuit to an LED, but we will also investigate methods of transmitting data as time and resources permit. Through multiple design phases, we will amplify the power delivered by an infrared laser source using an active gain medium, establish an optical loop from transmitter to receiver using reflectors, and add an automatic shutoff feature to the communication channel.

2.2 Requirements

Our team’s optical testbed will be entirely distinct from Team 2005’s testbed, which will be left intact and not “cannibalized” for parts. As briefly mentioned above, this new communication channel should contain three primary features: source laser amplification, optical looping, and automatic shutoff. To achieve light amplification, we will pass a low-power infrared (1064 nm wavelength) laser beam through a crystal gain medium, which will be actively pumped by an arc lamp connected to an external power supply. The gain medium that we have selected for our design is a neodymium-doped yttrium aluminum garnet (Nd:YAG) crystal, since Nd:YAG is capable of producing infrared radiation via stimulated emission.

The gain medium will be placed between reflectors on the transmitter and receiver sides so that the amplified light can be circulated over the entire length of the channel. Any fraction of the light energy that is not absorbed at reflection points or fed to the receiver will be redirected back into the gain medium for further amplification. This process of energy “recycling” should allow us to build up high power in the loop (within the power ratings of the optical components), or if we want to keep the output power from the amplifier constant, the recycling feature should allow us to reduce the amount of external power we need to apply to the amplifier pump.

Finally, we will include a control circuit with a photovoltaic cell on the transmitter side of our channel. The circuit will be connected to the low-power source laser and will continually check to make sure it is receiving a reflected laser input. If no input is received (i.e. if an object is obstructing the line of sight) the circuit will turn off the laser source, thereby providing an automatic shutoff feature to our design.

2.3 Specifications

Optical Channel:

- **Range**: 1 m
- **Physical path**: Power and data transmission through air and gain medium
- **Cutoff**: If line of sight is lost, transmission should stop
- **Power**: 1 W desired
- **Data**: 100 bits per second
Efficiency: 30% minimum

Source Laser:
- Nominal Wavelength: 1064 nm
- Power: 10 mW
- Output type: Continuous Wave (CW)
- Laser Source Type: Diode-Pumped Solid-State (DPSS)
- Safety Info: Class IIIb

2.4 Limitations

We have identified two main issues with establishing the ideal long-range resonant-beam channel shown in Figure 1. First, we note that in a traditional laser cavity, the beam reflections between mirrors are usually contained entirely within the gain medium, whereas in the Figure 1 design, the light passes many times from air to gain medium and back to air. Because Nd:YAG has a larger refractive index than air \( (n_{\text{Nd:YAG}} > 1) \), the laser beam’s wavelength will contract upon entering the crystal according to

\[
\lambda_{\text{Nd:YAG}} = \frac{\lambda_0}{n_{\text{Nd:YAG}}}
\]

where \( \lambda_0 \) is the wavelength of the light in free space. This unwanted variation poses a problem, since the laser cavity will only support an integer number of half-wavelengths of light [8]. When the wavelength is consistent over the length of the cavity, it is easier to satisfy this condition, but if we add the gain medium, we disrupt the delicate balance that must exist in our cavity and essentially ruin our optical oscillator.

Another concern is that the design of Figure 1 involves passing the laser beam through the gain medium twice in one cycle, the purpose of which is to maximize the number of rounds of amplifications within the loop. However, by attempting to “overwork” the gain medium, we run the risk of saturating and even structurally damaging the crystal.

3. Approach and Design

3.1 Project Design and Models

Given the concerns with the resonant-beam design that were just mentioned, our team decided, after many productive conversations with our advisors, that we should simplify our optical loop design to that shown in Figure 3 below. At first glance, the Figure 3 system looks more complicated than that of Figure 1 due to the increased number of components, but closer inspection reveals it to be easier to implement. In fact, the Figure 3 model is not a true resonant-beam channel since the laser beam is restricted to passing through the gain medium in only one
direction. The design thus gives us more freedom to experiment with the angling and positions of the reflecting components within the channel without worrying about the strict lasing conditions that must be met in a true resonant-beam design.

Let us now explain the design in Figure 3 in more detail. Transmitted power or data originates from a 10-mW infrared pointing laser, and the ultimate receiver is a system of LEDs. Most of the channel is purely optical in nature, except for two electrical circuits shown as grey blocks whose design will be expanded upon later. The biggest question we faced in designing this channel was how best to create outlets which would allow laser light to be extracted from or injected into the optical loop while still containing the majority of the light within the loop. As shown in Figure 3, there are three points where these outlets are necessary: on the transmission side where the beam from the infrared laser source enters the loop and where light exits the loop to the control circuitry, and on the receiver side where light exits the loop to the receiver circuitry. Consequently, at each of these points, we have placed a beam splitter which will reflect a portion of the incident light as needed to sustain the loop while also allowing the remaining portion of light (excluding absorptions) to pass outside the loop. Notice that at the top right corner of the loop where no outlet is needed, a totally-reflecting mirror may be used.

Once it enters the optical loop, the low-power source beam is passed through an optical amplifier which provides a power boost. The device that we call an optical amplifier is simply a Nd:YAG crystal rod and an arc lamp pump source professionally packaged together and to which an external electrical power source can be applied. This greatly simplifies our work since we will not need to worry about building our own laser with separate gain medium and pump components. Next, in order to prevent the amplifier’s output laser beam from reflecting back “upstream” into

**Figure 3.** Our communication channel design, featuring an optical loop inspired by the resonant-beam channel.
its output aperture (which would result in the problem of light entering the gain medium in opposite directions as in Figure 1), we have included an optical isolator in the loop. An optical isolator is essentially a diode for light; by manipulating the polarization of incident light, the device only permits light to pass through it in one direction. Therefore, the optical isolator will protect our amplifier from unwanted reflections going the wrong way around our loop. However, since isolators are designed to only pass light of a particular polarization in the forward direction, we also have included a polarizer between the isolator and the amplifier. The polarizer can also be used as a useful “switch” to pass or block the amplifier output from successfully traversing the isolator, depending on the angle at which it is rotated. This feature could potentially be used as a method of bit pulsing for data communication.

Our parts list provided later in Section 4 makes provision for purchasing corner reflectors, which are multi-faceted mirrors that are designed to always reflect an incoming beam of light parallel to the direction of incidence. Even though these reflectors are not found in the design of Figure 3, we will be interested in incorporating them into an alternative design scheme, shown in Figure 4, which we would build and test only after we have verified the Figure 3 system. The Figure 4 model is very similar to that of Figure 3, including how beam splitters are used to couple and decouple light beams to and from the loop, except that corner reflectors contain the channel at both ends. There are two main advantages to this system over the Figure 3 version. First, the bounds of the channel are more well-defined, and any input or output beams that are deflected by beam splitters branch away from the main loop like tributaries from a main river. This is therefore

![Figure 4](image)

**Figure 4.** Alternative design of our communication channel using corner reflectors.
a better design to use if we wanted to add more receivers or sources to the loop. Second, the corner reflectors have a three-dimensionality and wider acceptance cone (not illustrated well in Figure 4) that the faces of the beam splitters lack. This allows the system of Figure 4 to be adaptable enough to consistently establish the optical loop even as the positions of the transmitter and receiver actively change.

Having described the optical aspects of the channel in some detail, let us turn now to the design of the electrical circuits on the transmitter and receiver ends. The electrical circuit on the transmitter end is used to identify that the optical loop is closed and to control and power both the infrared laser source and optical amplifier. Figure 5 is a block diagram that models the functionality of the transmitter-end circuitry. The electrical circuit on the receiver end is used to create a stable power signal, and to pass the power to the load. Figure 6 is a block diagram that models the functionality of the receiver-end circuitry.

![Figure 5. Design of our transmitter-end circuit.](image)

The transmitter-end circuit consists of three major sections: the input, the controller, and the output. There are two inputs: the power source and a PV cell. The power source provides power to the microcontroller, the source laser, and optical amplifier. The PV cell is used to detect a signal from the optical loop. The outputs of the circuit are the source laser and optical amplifier. The on-off state of these devices is being controlled by the microcontroller and a switching circuit. The microcontroller should be programmed to watch the signal from the PV cell, and if the signal from the PV cell is interrupted, then the microcontroller turns the source laser and the optical amplifier off. After a few seconds, the microcontroller again checks to make sure that the signal from the PV is present, and if it is, the microcontroller turns the laser and the amplifier back on. When the microcontroller turns them on again, it should go back into the initial state where it waits for the signal from the PV cell to be interrupted. The switching circuit is used to help the microcontroller toggle the source laser and the optical amplifier. The microcontroller should also be able to encode and send data using the source laser.

The receiver-end circuit consists of a PV cell, a DC-DC converter, a microcontroller and either a load or leads that can be connected to an external load. The PV cell is used to extract electrical power from the portion of the laser that hits it. The DC-DC converter takes the power
from the PV cell and stabilizes it. The microcontroller is used here to decode the signal if and when the system is used to transmit data. The microcontroller should either have a display or be connected to a device to display or pass the data along.

### 3.2 Constraints and Standards

Our team has identified a few constraints and standards that we will have to be vigilant of over the coming months. Since our project is strictly experimental in nature and will not be provided as a finished product to a customer, we do not need to worry about meeting particular commercial or industrial standards or codes. However, as we are working with invisible laser light on the order of 1 W, it is of great importance that we closely follow all laser safety standards. These are important to help protect our team from potential laser-based injuries. The potential injuries that our members could sustain are skin burns and damage to our eyes. While working on our testbench, the team members will be wearing the safety glasses that have been purchased and left to us by last year’s team. In addition to this we will be following the proper procedures while using the laser. This includes only testing it in designated laser laboratory space. We want our design to be as safe as possible.

The first constraint is technical in nature. When working with narrow laser beams, the precision of our beam alignment will make or break our testbed. The optical amplifier has a small aperture (about 0.5 to 1 cm in diameter based on images, see Section 4.2 for details), and the PV cell has a small sensing area of 100 mm². This means that the optical components in the testbed need to be aligned under a centimeter of error. Another factor that leads to the testbed needing to be precisely aligned is the optical loop itself. This is because the reflectors used in the loop need to reflect the light within the loop without changing the angle of reflection. If the angle of reflection is slightly off, as a beam of light goes through the optical loop, it may eventually leak out of the loop at an unexpected angle and potentially create a safety hazard. It is important that the testbed components are aligned in such a way that the system is safe and is able to function as an optical loop.

The next two constraints affect our team’s access to the laser lab at the University of Connecticut. It is important that we have access to the lab because as stated previously, we cannot
test our design if we are not in the laser lab. For our team members to gain access to the university’s laser lab, we must complete two laser safety courses. We have already finished the first online introductory course, so we just need to take the in-person safety training, which we intend to take as soon as possible in Spring 2021. Aside from needing to take the safety training, our team also may have to deal with additional restrictions to lab access because of capacity guidelines in place due to Covid-19.

The final constraint, a large distance between group members, has impacted our group in many ways already. One of our members was unable to return to the United States at the start of the fall semester due to travel restrictions from Covid-19. Since he is not in Connecticut, he will not be able to access the laser lab and the components and will not be able to work on the testbed in person. Also, because of the large difference in time zones, we need to be vigilant when meetings are scheduled because of how large the time difference is.

3.3 Alternate Designs

The design described in Section 3.1 is currently the model we plan to follow when building our laser testbed. It is important to note that, at this stage in the project, the design we have selected only exists on paper, and therefore as of yet we have no preliminary data or results to report. As we proceed with the hands-on work on the testbed in the Spring 2021 semester, we fully expect that we will need to modify the existing design as we develop new solutions to overcome unforeseen obstacles and to improve system performance. Even during the planning stage in Fall 2020, we have had to rework our design several times as team members raised new concerns and as we gained new insights from our research and from discussions with our advisors. Here we will mention a few examples of some alternate designs we had considered.

As previously mentioned, figuring out how to couple and decouple input and output beams to and from the optical loop proved to be a challenge. Before the use of beam splitters was proposed, we had considered the possibility of creating our own access points to the loop by asking the professionals at the University of Connecticut Machine Shop to drill small tunnels through the corner reflectors. In this way, a laser beam could pass directly into or out of the loop as shown in Figure 7. Despite the reflective coating being removed at these points, the reflections that are necessary to sustain the loop would still be able to occur as long as the tunnels were filled with an index-matching gel, which would harden and could be polished to reflect a portion of the incident light. Ultimately, this option was abandoned because we thought it best not to tamper with delicate optical components, since by doing so we could run the risk of severely damaging them and rendering them unusable.

We also considered a variety of different optical components that we thought would be useful to our design, but which for one reason or another we ultimately did not include in our final parts list. For example, we originally thought that we should insert a beam expander into our system just before the receiver’s photovoltaic cell, which would increase the diameter of the beam incident on the cell. Since a larger surface area of the cell would be utilized than if the beam were not expanded, we would therefore improve the absorption and conversion efficiency of the cell and thus improve
Figure 7. Alternate solution for coupling and decoupling light to and from the optical loop showing tunnels drilled into a corner reflector.

the overall efficiency of the channel. However, not only did we determine that the beam expander was too expensive to include in our list of parts, but once we actually decided on a PV cell, we realized that the area of the cell was only a few square millimeters, and therefore expanding the beam could actually lead to a drop in efficiency. (We had already decided previously that it was unnecessary to include a beam expander before the control circuit PV cell, since that cell only needs to detect a small signal in order to carry out its functions.)

Even for components that were always essential features of our design, we considered how changing their locations and positions within the channel would affect how our system operated. For example, in the first month of our planning, we thought about taking the Nd:YAG gain medium out of the optical loop altogether and instead placing it just before the receiver circuitry, as shown in Figure 8. This early design simplifies the amplification process, especially if we wanted to have multiple devices receiving power simultaneously (Dr. Donkor likened this to each instrument in a band having its own sound amplifier rather than all the instruments sharing one), but we quickly realized that it makes the purpose of the optical loop rather meaningless. But even though we ultimately discarded this option, it did help us to develop a design where a beam passes through the gain medium in only one direction.

4. Project Management

4.1 Team Member Responsibilities

Table 1 lists the main tasks associated with carrying out the project design as described in Section 3 above. Apart from the activities that the Senior Design course guidelines require all members to participate in (such as writing reports, giving presentations, and meeting with our advisor), the majority of the tasks have been assigned to group members based on each member’s availability and technical strengths. One of us (Zhang) cannot be physically present on the
University of Connecticut campus in Spring 2021 due to international restrictions resulting from COVID-19. Consequently, tasks are distributed in such a way that all members can contribute meaningfully to the project regardless of where they are. For example, the two members who have access to a lab and the materials have been tasked with building and experimenting with the testbed, while the physically distant member has been tasked with programming the microcontroller, maintaining the schedule, and placing orders. Note also that, at each step of the design process, we will consistently keep our primary advisor, Dr. Zhou, apprised of our progress.

**Figure 8.** Early design showing laser gain medium outside of optical loop.

**Table 1.** Project work-breakdown by team member (RACI chart).
4.2 Budget and Parts List

A combined budget of $5000 has been allotted to our project to cover the cost of parts: $1000 from the Department of Electrical and Computer Engineering (provided to all Senior Design teams), and $4000 from a University of Connecticut grant to Dr. Zhou. Table 2 lists all the parts we expect to order within the coming week as the semester comes to a close, along with their listed prices (excluding shipping).

<table>
<thead>
<tr>
<th>Component</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>10-mW Infrared Laser Source (1064 nm)</td>
<td>$345.64</td>
</tr>
<tr>
<td>Nd:YAG Optical Amplifier</td>
<td>$900.00</td>
</tr>
<tr>
<td>Faraday Optical Isolator</td>
<td>$1050.00</td>
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<tr>
<td>Infrared Thin-film Polarizer</td>
<td>$115.00</td>
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<td>Retroreflector Prisms, AR Coated: 1050-1700 nm ×3</td>
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<tr>
<td>70:30 (R:T) Non-Polarizing Beamsplitter Cube, 700 - 1100 nm ×4</td>
<td>$839.72</td>
</tr>
<tr>
<td>Photodiode: FGA21, 800-1700nm ×2</td>
<td>$482.62</td>
</tr>
<tr>
<td>DC-DC Converter ×2</td>
<td>$6.93</td>
</tr>
<tr>
<td>IRF9620 FET Transistor ×2</td>
<td>$2.80</td>
</tr>
<tr>
<td>LT1492 Op Amp ×2</td>
<td>$19.72</td>
</tr>
<tr>
<td>Various Resistors</td>
<td>$34.70</td>
</tr>
<tr>
<td>Various Capacitors</td>
<td>$4.80</td>
</tr>
<tr>
<td>Red Led ×10</td>
<td>$1.50</td>
</tr>
<tr>
<td>Total</td>
<td>$4429.98</td>
</tr>
</tbody>
</table>

It is important to make a few remarks about a few of the above parts. Perhaps the most crucial component to our project is the Nd:YAG gain medium. Originally, we considered purchasing a standalone Nd:YAG laser and adding to it the necessary housing and pump source. But as we determined that would be an entire project in itself, we decided to look for a package that contained these components for us. There were custom high-power, free-space optical amplifiers available, but the cost of them alone was much over budget. Instead, we settled on a gently-used amplifier that seems to have been removed from a much more expensive laser system designed for the healthcare industry. Consequently, the amplifier is inexpensive, but because it was not designed to be sold alone, there are not many resources related to its specifications available. Therefore, it will require some additional experimentation to determine how to properly power and operate the amplifier safely and effectively.
The components from the above table that are being used in the transmitter and receiver circuits are the FGA21 photodiodes, two DC-DC converters, two FET transistors, two op amps, various resistors and capacitors, and red LEDs. The FGA21 photodiodes will be used to convert the laser signal into usable power or into a usable signal. We chose this type of photodiode because it has the highest responsivity of the photodiodes that we found. One of the DC-DC converters will be used in the receiver circuit to stabilize the DC voltage received. The FET transistor, op amp, resistors and capacitors will be used in the switch circuit in the transmitter end circuit. The red LEDs will be used as indicators in the receiver circuit that there is power transfer between the transmitter and the receiver. Note that a microcontroller is not listed in Table 4. This is because each group member already owns an Atmega328PB Xplained Mini microcontroller from a previous laboratory course.

4.3 Project Timeline

The project timeline for the Fall 2020 semester, which is shown in Table 3, shows that most of the work this semester has been focused on research and testbed design. We will purchase the necessary materials by the end of this semester, so that we have all the components we need to begin building and testing our designs right from the start of the Spring 2021 semester (Table 4). Currently, we aim to complete the laser setup in February, while designing our transmitter and receiver circuits and programming the microcontroller can be carried out concurrently. Before we integrate all the optical components together into the testbed, we will want to verify the functionality of each component individually and collect data to determine any adjustments that may need to be made before further constructing the platform. As Table 4 shows, most of the verification work should be done by early April, and the platform construction should follow shortly after. We leave about three weeks of additional testing time before the end of the semester for working out any flaws with the system and fixing possible human-caused errors. As time permits, we will extend our system to demonstrate data transmission and reception.

Table 3. Project timeline for Fall 2020 (Gantt chart).

<table>
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<td>Week 3</td>
<td>Week 4</td>
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Table 4. Project timeline for Spring 2021 (Gantt chart).

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5. Summary

Senior Design Team 2102 will build a testbed for power and possibly data transmission via infrared laser light circulating in an optical loop and amplified by a neodymium-doped yttrium aluminum garnet gain medium. The testbed will demonstrate power amplification, optical feedback, and automatic shutoff features like the theoretical resonant-beam based communication channel while simplifying the design to exclude the formation of an optical oscillator. Having decided upon a design solution (which of course may be subject to change as we proceed) and preparing to order the necessary components, project work will commence in the Spring 2021 semester, with work on the optical channel and the electrical circuitry proceeding separately and in parallel.
References


Appendix

Senior Design Project Checklist

**Project name:** Resonant-Beam Based Optical Wireless Power Charging and Data Communication

**Sponsor:** University of Connecticut, Department of Electrical and Computer Engineering

**Team members (majors/programs):**
- David Mantese (Electrical Engineering)
- Trent Riewe (Computer Engineering)
- Qiao Zhang (Electrical Engineering)

**Faculty advisor(s):**
- Dr. Shengli Zhou
- Dr. Eric Donkor

**Skills, Constraints, and Standards:** *(Please check (✓) all those that apply to your project.)*

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<td>Digital circuit design and troubleshooting</td>
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<tr>
<td>Software development/programming</td>
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<td>Embedded Systems/Microcontrollers</td>
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<td>Web design</td>
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<tr>
<td>RF/wireless hardware</td>
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<td>Control systems</td>
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<td>Communication systems</td>
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<td>Other (please specify):</td>
<td>Optical/Laser systems ✓</td>
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**Constraints:**

- Economic (budget) ✓
- Health/safety ✓
- Manufacturability
- Environmental (e.g., toxic materials, fossil fuels)
- Social/legal (e.g., privacy)

**Standards:**

<table>
<thead>
<tr>
<th>List standards/electric codes that you used (e.g., IEEE 802.11, Bluetooth, RS-232, VHDL, etc.)</th>
<th>If applicable, list the name or # here:</th>
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