Learning Morse Code Translation Through Light and Radio Waves

UCF Senior Design I Divide and Conquer Document

Group 1 Creol 2 Authors

Alexander Simmons	Curtiss Kane	Ivan Huang	Monica Castro-Suarez
Photonic Engineer	*Electrical Engineer*	*Photonic Engineer*	*Computer Engineer*

Mentor

Dr. Lei Wei

Dr. Aravinda Kar

Reviewer

Dr. Saleem Sahawneh	ECE
Dr. Mark Maddox	ECE
Dr.Stephen Eikenberry	CREOL

Chapter 1: Project Description

1.1 Motivation & Background

The invention of the electric telegraph towards the mid-19th century and eventually wireless telegraphy in the early 20th century revolutionized long-distance communications[1]. The laser and optical fiber towards the 1950s and onward ushered in an era of high-speed data transfer that formed the backbone of the Internet and digital communications[2]. Our senior design project aims to combine the best of both worlds into a communication system that can modulate optical signals travelling through an optical fiber into radio waves. The mode of communication will be in Morse code, which will be translated into light pulses. What we hope to achieve is a wireless communication system utilizing optical transmission to reduce loss and interference that commonly occurs with coaxial cables and (if scaled up) demonstrate a lighter, flexible, and weather-proof alternative system.

A typical communication system consists of a transmitter, channel, and receiver. A transmitter takes an input message and encodes and modulates it for efficient transmission. In the case of transmitting digital messages, an analog/digital (A/D) converter will be necessary. A channel is the medium in which the signal is transmitted, such as copper wire or radio waves. A receiver receives the modulated signal, decodes and demodulates the signal, and removes any distortions the signal picks up along the channel (Lathi & Ding, p. 2-3), Our project will focus on transmitting digital signals (Morse code) through radio waves.

Two common modulation techniques are amplitude modulation (AM) and frequency modulation (FM). In amplitude modulation, the carrier signal's amplitude is varied to resemble that of the audio signal. Frequency modulation, on the other hand, involves adjusting the frequency of the carrier wave based on the audio signal. AM is best for high-power, long distance communications, at the expense of signal quality due to limited bandwidth and susceptibility to outside interference. FM signals display higher audio quality as they are immune to outside interference, but coverage area is limited, so FM is typically useful for line-of-sight communications.[4] Our project will likely focus on FM modulation, as our system will be short-range and we would like the signal quality to be high.

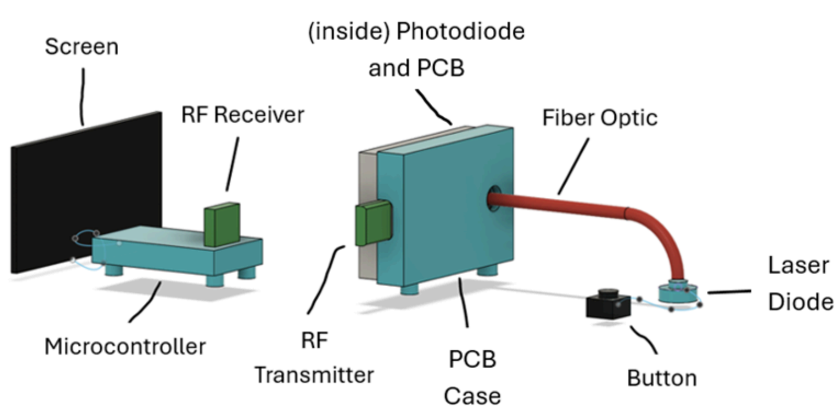
On the optical aspect of the project, optical fibers are glass or plastic fibers surrounded by cladding and coating material, and are used to transmit light from one end to another. The cladding material causes total internal reflection inside the fibers, reducing the amount of light escaping, and the coating is added for physical protection. Each fiber can be micrometers in diameter (about the size of a human hair), but can transfer higher rates of data than metal conductors because visible light signals have higher bandwidths and optical fibers are immune to the effects of outside electromagnetic interference. This also means it's difficult to tap into data from optical fibers due to lack of signal emissions that come from metal conductors, enhancing data security (Keiser, p. 5). Depending on the application, fibers can come in single-mode or multi-mode types.

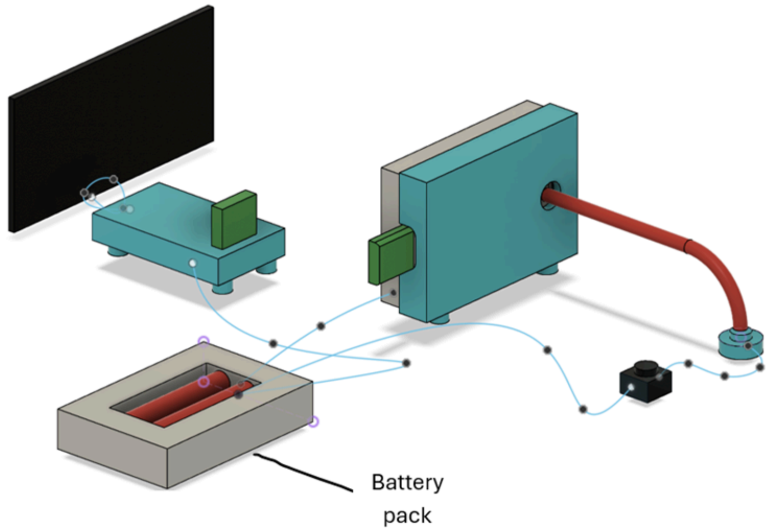
Single-mode fibers have a smaller diameter, allowing a single mode or propagation pattern of light passing through, whereas multi-mode fibers are larger in diameter, allowing multiple modes to travel through. This means that single-mode fibers are useful for long-distance data transmission because its modal dispersion is low, reducing signal distortion, while multi-mode fibers are best for short-distance, high-power applications.[5] We will use a single-mode fiber for this project, even though we will not transmit at a long distance, because of the benefit of lower loss compared to multimode fiber.

This project will utilize a laser diode instead of an LED because of its directionality caused by stimulated emission, which is caused by photons inducing electrons to emit identical photons of the same phase, direction, and polarization. This is in contrast to an LED, which emits photons due to spontaneous emission, where electrons emit photons in random directions (Kasap, p. 281-82). Since we will transmit a message signal through an optical fiber, it is best to choose a light source that concentrates all of the light energy through the fiber, and the laser diode will be best suited for this task. As for the photodetector, we chose to use a photodiode because they are widely used to measure modulated light signals, including digital signals (Kasap, p. 423). Since Morse code is inherently binary, this means a photodiode can detect changes in the laser pulse and accurately measure the duration of each pulse. Photodiodes can also absorb a wide spectral range of wavelengths, typically between 300 nm to 1700 nm for Si and InGaAs PIN photodiodes, with higher responsivity at higher wavelengths (Kasap, p. 399). As we plan on using a green laser diode, we can easily find a photodiode that is sensitive to 520 nm on the market.

As advances in radio technology continue to blur the boundaries between analog and digital modes of communication, it is vital for emergency operators and commercial radio stations to send low-loss, high-speed transmissions that can withstand harsh weather conditions and require less maintenance. Although optical fibers can easily break due to the material used, we hope that further improvements in optical fiber durability can ensure they will have a place in off-grid wireless communications.

1.2 Prototype illustrations





Chapter 2: Goals & Objectives

This project is all about building a wireless communication system that takes advantage of optical fiber transmission to cut down on signal loss and interference while keeping the signal quality high. The idea is to encode Morse code into light pulses, then modulate those optical signals into radio waves for smooth and efficient transmission.

At the core, the goal is to create a solid transmitter-receiver setup using single-mode optical fiber and FM modulation to ensure stable, interference-free communication. From there, the plan is to enhance the system by improving signal quality, increasing transmission range, integrating microcontroller-based decoding, and making the design more lightweight and portable.

If all goes well, the stretch goals will push the project even further—bi-directional communication, error correction, encryption, higher-speed optical modulation, and even scalability for off-grid and emergency use.

Ultimately, this project is about proving that optical and radio technologies can work together to create a more flexible, durable, and efficient communication system that outperforms traditional methods in different environments.

2.1 Basic goals

- Develop a system that encodes Morse code into optical signals using a laser diode. It will successfully transmit Morse code messages through a single-mode optical fiber while ensuring minimal signal loss. Additionally, a receiver will be implemented to decode the optical signals back into Morse code, completing the communication process.

- Use frequency modulation (FM) to ensure clear and noise-resistant signal transmission.
- Utilize optical fiber to eliminate electromagnetic interference (EMI) and enhance signal reliability.

2.2 Advanced goals

- Design a compact, lightweight system suitable for outdoor and off-grid communication.
- Develop a microcontroller-based system to decode Morse code signals in real time.
- Optimize transmission efficiency to extend the communication range while minimizing attenuation.

2.3 Stretch goals

- Implement a system that allows for two-way communication using the same optical fiber and radio wave setup.

2.4 Objectives

This project is all about designing, building, and implementing a wireless communication system that uses optical fiber to encode and transmit Morse code via radio waves. The goal is to improve transmission efficiency and cut down on signal loss compared to traditional coaxial cable-based systems.

By combining single-mode optical fiber, FM modulation, and microcontroller-based processing, this system will offer a high-quality, interference-resistant, and weather-proof solution. Ultimately, the aim is to create a lightweight, flexible, and scalable communication system that can be used for emergency situations, off-grid networks, and modern wireless applications.

Chapter 3: Description of features

2.1 Features and Functionalities

The Optical-Radio Communication System incorporates several innovative features aimed at providing an efficient, lightweight, and reliable communication solution. The **optical transmission system** includes a laser diode transmitter, single-mode optical fiber, and a photodiode receiver. The transmitter uses a red laser diode as the optical signal source, encoding data into light pulses to represent Morse code. These pulses are transmitted via a single-mode optical fiber, which ensures low attenuation and distortion, making it suitable for long-distance communication. At the receiving end, a photodiode detects the light signals and converts them into electrical signals for further processing. The combination of these components offers a portable, cost-effective alternative to traditional coaxial cable systems.

The system's **modulation and decoding** functionalities rely on an analog modulator circuit and a microcontroller-based decoder. The modulator precisely controls the laser diode's on/off state to generate the dots and dashes of Morse code. On the receiving side, the microcontroller interprets the electrical signals from the photodiode, accurately decoding the Morse code by analyzing the timing of the pulses. Custom software processes the decoded data, maps it to corresponding textual messages, and displays it on connected devices. This functionality makes the system flexible and user-friendly, accommodating various signal speeds while ensuring reliable message transmission.

To support its core functionalities, the system includes well-designed **power and control systems**. A regulated power supply for the laser diode ensures consistent signal output and prevents damage due to current fluctuations. The microcontroller manages timing and synchronization for both modulation and decoding, maintaining precise communication and minimizing errors. These features collectively enhance the system's reliability and robustness under diverse operating conditions.

2.2 Input from Customers and Market Analysis

The design of the Optical-Radio Communication System is informed by input from target users and an analysis of comparable technologies. The system caters to three main user groups. **Amateur radio enthusiasts** value lightweight and portable communication solutions, making optical fibers an appealing alternative to bulky coaxial cables. **Emergency response teams** require off-grid, high-speed communication systems, and the low-loss transmission offered by optical fibers ensures reliable operation in remote areas. **Commercial radio stations** have expressed interest in exploring cost-effective alternatives to coaxial cables for linking relay stations or station-to-station communication.

A review of comparable products and technologies further influenced the project's features. Traditional coaxial cable systems, while reliable, are heavier and prone to signal loss over long distances, highlighting the advantage of optical fibers for this application. Existing digital Morse code transmitters, although efficient, lack the simplicity and adaptability of analog modulation, particularly in resource-constrained scenarios where this system excels. Additionally, light-based communication systems such as LiFi inspired the optical design, especially the use of single-mode fibers for long-distance transmission. However, unlike LiFi, which focuses on high-speed data transfer, this project prioritizes robustness and simplicity for niche applications like amateur and emergency communications.

2.3 Summary of Features

The Optical-Radio Communication System combines modern optical transmission technology with traditional radio communication principles to deliver a lightweight, portable, and flexible solution. Its core features include reliable analog modulation, efficient Morse code decoding, and low-cost components optimized for long-distance communication. Custom software ensures seamless integration with existing communication platforms, addressing user needs for simplicity, adaptability, and robustness. These features make the system particularly relevant for amateur radio enthusiasts, emergency responders, and commercial radio operators.

Chapter 4: Engineering Requirements

The Engineering Requirements Table defines the key performance metrics and technical specifications necessary for the system's design and functionality. It includes parameters such as transmission distance, signal modulation, decoding accuracy, power efficiency, and component-specific values (e.g., VCO frequency range, Op-Amp bandwidth, and laser diode wavelength) to ensure reliable, high-quality, and interference-resistant communication.

Requirement	Specification/ Target Value	Purpose
Optical Transmission Distance:	≥ 1 km	Ensures reliable communication over long distances
Morse Code Speed:	≥ 10 WPM	Meets standard Morse code transmission speeds
Decoding Accuracy:	≥ 95% Accuracy	Ensures reliable Morse code interpretation
Data Transfer Rate:	100 bps (50-200 bps adjustable)	Allows flexibility in signal speed for different applications
Expected Power Consumption:	≤ 5W	Optimized for low-power, battery-powered operation
Optimal Transmission Distance:	1-2 km	Ensures optimal signal integrity and low attenuation
Power Efficiency:	≥ 85% efficiency, ≤ 5% voltage ripple	Ensures portability and long operational life
Portability & Durability:	Lightweight & Rugged Design	Suitable for field and emergency communication
Interference Immunity:	≥ 40 dB reduction in EMI	Optical transmission eliminates electromagnetic interference

4.1: Demonstrable Specifications

4.1.1 Optical Transmission Distance

The system is designed to achieve a minimum optical transmission distance of 1 km using single-mode optical fiber. This specification will be tested by measuring signal integrity over various fiber lengths to confirm low attenuation and reliable communication.

4.1.2 Signal Modulation Speed

The system can transmit Morse code at speeds of 10 words per minute or greater. Demonstration will involve encoding a standard Morse code message at this speed and verifying its successful transmission and reception.

4.1.3 Decoding Accuracy

The microcontroller-based decoder will achieve at least 95% accuracy in interpreting Morse code signals. Testing will involve transmitting predefined messages and comparing the decoded output to the original input to validate accuracy. These demonstrable specifications ensure the system's functionality and performance in its intended application.

4.1.4 Data Transfer Rate

The optical communication system will support a data transfer rate of at least 100 bits per second (bps), with testing conducted over varying signal rates between 50 and 200 bps to verify performance and consistency.These demonstrable specifications validate the system's ability to meet performance requirements for long-distance, reliable, and accurate communication.

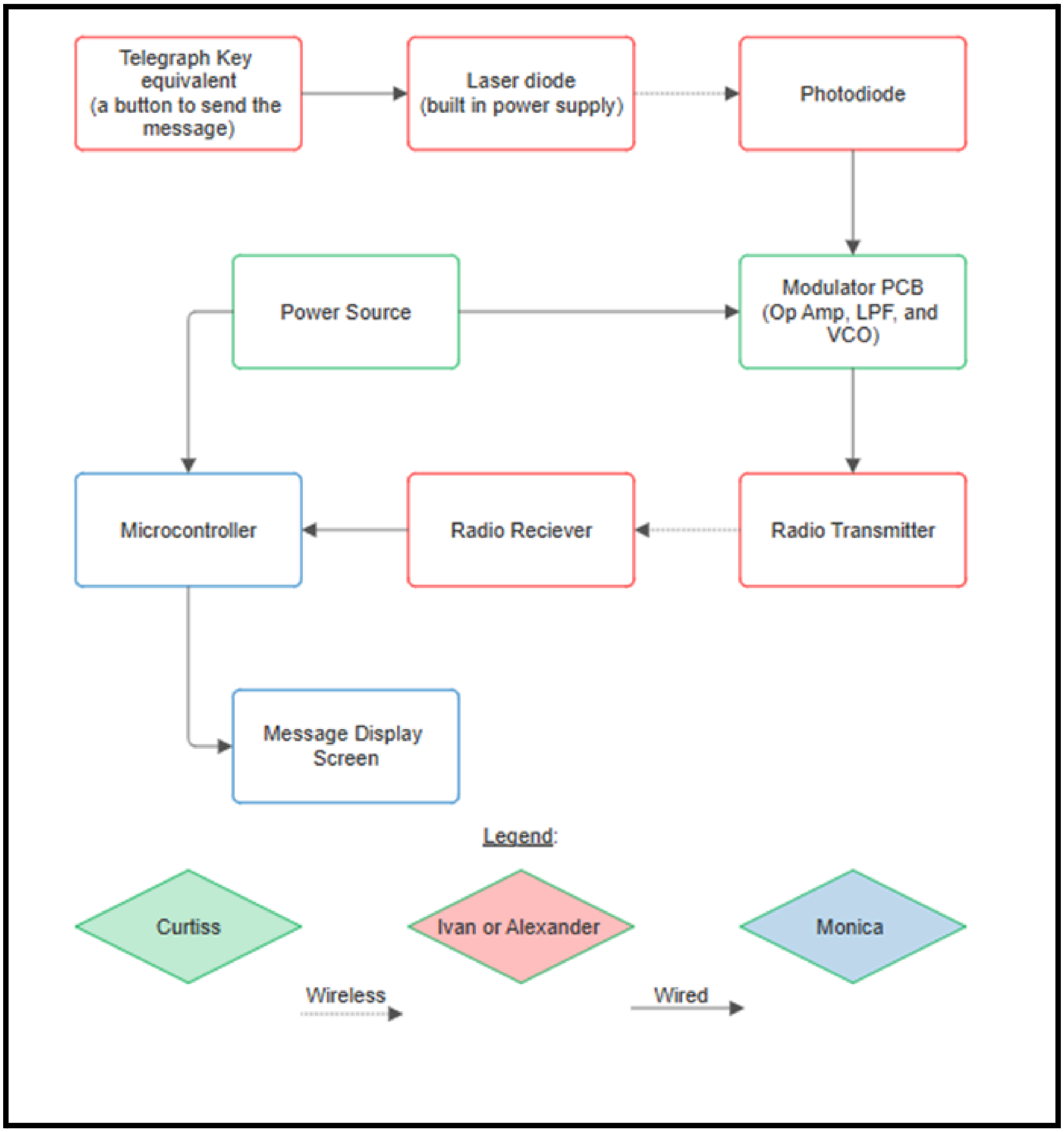
4.2: Component Specifications.

The Required Components Table lists the essential hardware elements needed to build the optical-radio communication system. It includes components such as the laser diode for signal transmission, the photodiode for reception, single-mode fiber for efficient optical transfer, a microcontroller for processing, and an RF transmitter for backup communication, ensuring the system meets performance and durability requirements.

Component	Specifications	Purpose
Laser Diode:	520nm Green Laser, 15mW output	Selected for high visibility and efficiency in fiber optics transmission
Photodiode:	900-1100 nm sensitivity	High-speed response for accurate signal decoding
Single Mode Fiber Optic cable:	9µm core diameter, low attenuation	Reduces modal dispersion and improves signal quality
Microcontroller:	Arduino / Raspberry Pi compatible	Controls modulation, decoding, and display
RF Transmitter:	433 MHz, 500m range	Provides a backup transmission method using RF
Voltage-Controlled Oscillator (VCO):	Frequency range: 20 kHz – 40 MHz, Tuning Sensitivity: ≥ 10 MHz/V	Controls frequency modulation with precise tuning capability
Op-Amp:	Gain Bandwidth: ≥ 1 MHz, Slew Rate: ≥ 0.5 V/µs	Ensures stable signal amplification and filtering
PCB Board:	9cm x 7cm	Houses and integrates all electronic components
Power Source:	Rechargeable Battery Pack (≥ 5V, 2000mAh)	Provides power for the system
Resistors/Capacitors:	Values TBD	Ensures circuit stability and signal conditioning

4.2 Hardware Block Diagram

The hardware block diagram below illustrates the process of transmitting a Morse code message from the telegraph key to its final display on the screen. The project's various sections are divided among the group members based on their areas of expertise, with the color of each box's outline indicating the assigned responsibilities.



Chapter 5: Budget and Financing

The budgeting table below highlights the specific components we plan to use, how much they cost per unit, any important information about the component, and a useful link to where we can acquire said component. Unless specified otherwise, we can confidently round the shipping price per source to be at most $10 per item. With this, we expect the total cost of our components to be around $300, as prototyping begins, more parts may be required.

Component	Price	Amount	Extra Details	Seller Link (if applicable)
Button switch	$6.95	1 (big pack)	14 types, pack of 140	https://www.mpja.com/14-Types-140-pcs-Micro-Pushbutton-Switch/productinfo/33908+SW/
Laser diode	$15.69	2	Model: 520nm Laser Module	https://www.amazon.com/520nm-Laser-Module-Industrial-adjustable/dp/B0CSYSVPS9?source=ps-sl-shoppingads-lpcontext&ref_=fplfs&psc=1&smid=A17O8U969TLM8D&gQT=1
Photodiode	$8.05	5	Model: MTD5052W	https://www.digikey.com/en/products/detail/marktech-optoelectronics/MTD5052W/2798875

Fiber optic cable	$21.60	1	Single Mode	https://www.amazon.com/VANDESAIL-Singlemode-Single-Optical-Transceiver-1m/dp/B0DDPDXGZS?source=ps-sl-shoppingads-lpcontext&ref_=fplfs&smid=A2C3RI8VTVPBOW&gQT=1&th=1
LCD screen	$10	2 Already have	Compatible w/ Arduino and Raspberry Pi	https://www.amazon.com/SunFounder-Serial-Module-Display-Arduino/dp/B019K5X53O?source=ps-sl-shoppingads-lpcontext&ref_=fplfs&smid=ADHH624DX2Q66&gQT=1&th=1
Op-amp	$0.27	5	Model: LM358AP	https://www.mouser.com/ProductDetail/Texas-Instruments/LM358AP?qs=Zu35EjizYSShld7Gr9Muww%3D%3D&mgh=1&gQT=2
VCO	$7.66	3	Model: SN74S124NE4	https://www.mouser.com/ProductDetail/Texas-Instruments/SN74S124NE4?qs=gb35HGp1gQIQA4UksLxehA%3D%3D&mgh=1&gQT=1
Radio transmitter + Radio receiver	$8.95	2	for Arduino & Raspberry Pi	https://tinkersphere.com/wireless-modules-for-raspberry-pi-and-arduino/485-rf-link-transmitter-receiver-module-pair-433mhz-or-315mhz-for-arduino-raspberry-pi-b-b.html?gQT=1

PCB	$5	3	9 by 7 cm +$20 shipping	https://www.pcbway.com/ https://jlcpcb.com/
Resistors/ Capacitors	N/A	Already have	Various types	N/A
Power source	$16.98	2	battery Pack	https://www.amazon.com/Rechargeable-Batteries-Electronics-Equipment-Bluetooth/dp/B0B1JKSY46?source=ps-sl-shoppingads-lpcontext&ref_=fplfs&psc=1&smid=AXR0N95R0RRTF&gQT=1

Photonics Components | Computational Components | Electrical Components

Chapter 6: Existing Product/Past Projects/Prior Related Work

Several existing projects and products share similarities with the proposed Optical-Radio Communication System, particularly in the use of laser-based transmission for Morse code communication. Notable examples include:

1. **Morse Code Communication Using Laser Module**: This project employs laser transmitters and receivers to communicate Morse code signals. It utilizes Arduino microcontrollers to control the laser emitter and process the received signals.
    - **Created by**: Individual contributors on Project Hub
    - **Platform**: Arduino Project Hub
2. **Laser Pager / Morse Code Transceiver**: Developed by Don Buckley, this project uses two Arduino UNOs, each equipped with a laser diode and photoresistor, to exchange messages in Morse code. The system allows for bidirectional communication, functioning similarly to text messaging.
    - **Created by**: Don Buckley
    - **Platform**: Hackster.io
3. **Morse Code Transmission by Laser**: Featured on Instructables, this project demonstrates the construction of a device that decodes light signals received in Morse code and displays the corresponding characters. It highlights the practical application of laser-based Morse code communication.
    - **Created by**: Community contributors on Instructables
    - **Platform**: Instructables
4. **Laser Morse Code Trainer**: A project from Cornell ECE, this interactive Morse code trainer converts hand movements into Morse code characters via laser beam interruption, serving as an educational tool for learning Morse code.
    - **Created by**: Cornell University ECE Students
    - **Platform**: Cornell ECE Final Projects Cornell ECE
5. **Morse Code Over Laser**: This GitHub project by Andrew Khans involves an Arduino-based system where a laser diode transmits Morse code messages, and a receiver decodes the signals, showcasing a practical implementation of laser-based communication.
    - **Created by**: Andrew Khans
    - **Platform**: GitHub

Chapter 7: Project Milestones

To establish a strong dynamic among members and ensure a successful project, multiple events and meetings are necessary. Initially, new members are recruited, and project topics are discussed during the first week of Senior Design I to provide a solid foundation of information for the project.

Senior Design I - Spring 2025	
Week	Task
1-2	Project Selection
3	D&C Documentation (1/24/25)
4	D&C Meeting With Advisors (1/28/25)
5	Update and upload D&C report onto the group webite (2/7/25)
6-9	Start researching and begin 60 page draft (3/24/25)
10	60-Page Milestone / Midterm Report (3/24/25)
11	Midterm Report Group Meeting (TBA)
12	Update and upload midterm report onto the group webite (4/4/25)
13	Begin on working on PCB
14	Contining working on Final report. Start on Mini Demo Video
15	Finish editing Mini Demo Video. Finish up the the edits for Final Report.
16	Submit 120-Page Final Report & Mini Demo Video (4/22/25)

Senior Design I - Spring 2025	
Week	Task
1-2	Order PCB, Order Components
3	PCB Assembly
4-5	Begin to research ways to put everything together.
6-8	Start Assemebly
7-8	Test Protype
9	Test for any malfuntions or potential mistakes.
10	Implement soluntions for those potential mistakes.
11	Test/Optimize
12	Demostrate Project to SD Coordinators and Dean

Chapter 8: Appendix

Appendix A

1. McGillem, Clare D.. "telegraph". Encyclopedia Britannica, 16 Sep. 2024, https://www.britannica.com/technology/telegraph. Accessed 23 January 2025.

2. Fiber Optic Association. "FOA Fiber Optic Timeline". 2022, https://www.thefoa.org/Timeline/index.html. Accessed 23 January 2025.

3. Lathi, B. P., and Zhi Ding. "Modern Digital and Analog Communication Systems". International 4th Edition, Oxford University Press, 2010.

4. RadioActiveMedia. "AM Vs FM Radio: Differences and Similarities". 20 November, 2023. https://radioactivemedia.com/am-vs-fm-radio/. Accessed 23 January, 2025.

5. Photonics. "Fiber Optics: Understanding the Basics". https://www.photonics.com/Articles/Fiber_Optics_Understanding_the_Basics/a25151. Accessed 23 January, 2025.

6. Keiser, Gerd. "Optical Fiber Communications". Fourth Edition, McGraw-Hill, 2011.

7. Kasap, S.O. "Optoelectronics and Photonics". Second Edition, Pearson, 2013.

Appendix B

1. Wikipedia contributors. (2025, January 23). *University of Central Florida*.

   Wikipedia. https://en.wikipedia.org/wiki/University_of_Central_Florida