OPTICAL COMMUNICATIONS AT NOVASOL

Amber K. R. Imai
College of Engineering
University of Hawai‘i at Mānoa
Honolulu, HI 96822

ABSTRACT

Summer internships teach students how to apply the knowledge they have gained through their college courses in a real world setting. At NovaSol, I was able to apply many skills learned in the classroom, as well as learn about optics and optical communication.

Optical communication is a complex field that has many components. Within the course of this internship, I learned about free-space optical communication, fiber optics, optical signal noise, design concepts, troubleshooting, and testing of the Compact and Sub-Compact.

INTRODUCTION

NovaSol is a Hawai‘i based engineering contractor which specializes in optics. The Optical Communications (Op Comm) group is currently working on the Free-Space Optical Communications Compact Interrogator, a compact version of the original Dual Mode Optical Interrogator (DMOI) which will be explained in greater detail below. The Compact and the new Sub-Compact is currently the main focus of the Op Comm group.

This report will cover the fundamentals of optical communication. I will discuss the benefits and limitations of using optical communication, and the projects that I worked on during the course of this internship.

MODERN OPTICAL COMMUNICATIONS

Optical communication is defined as a means of communication which utilizes the visible and infrared section of the electromagnetic spectrum. It is one of the newest, most advanced forms of communications and employs shorter wavelengths, thus higher frequencies, which allow a higher volume of information to be transmitted over a single channel. This is one of the advantages optical communication has over microwave and radio communication. To transmit an optical signal, a laser or high-intensity light-emitting diode (LED) is used to generate a pulse wave. Lasers are used for long distance communications because they are a high intensity focused beam of light, whereas LEDs are used for short distances due to the losses due to the light being less focused. Pulse waves are received and processed by a photodiode, a semiconductor that converts light energy into either a voltage or current, which can then be interpreted by the rest of the circuit. [1]

NovaSol’s Op Comm group focuses on free-space optical communications, using an infrared laser. Free-space point-to-point optical links are good for relatively short direct-view implementations such as theirs. Misty rain, fog, and dust can greatly affect the stability of the
link between the links, as demonstrated during one of the field tests. Fog and dust have particle sizes that are a few microns in size can completely block the laser beam, making it difficult to keep a stable connection. Misty rain weakens the strength of the beam by distorting the light as it passes through the droplet. However, this form of communication is great for ensuring a secure connection between a minimum of two points, which is not as easy to hack when compared to radio and microwave communication making this application ideal for military usage.

**DMOI, COMPACT, AND SUB-COMPACT**

The DMOI project started in 2002 when NovaSol was awarded a multi-year contract by the Naval Research Lab (NRL) to develop a free-space optical communication system. DMOI’s project objectives is to develop a low powered optical laser link for a family of high bandwidth “last mile” communication systems between ships, planes, and ground units. It was big, bulky and required an engine hoist to lift. By utilizing new technology, DMOI was reduced to the Compact Interrogator, which weighs in at 30 lb and is a little smaller than a cubic foot.

![DMOI and the overall objective of the interrogator units designed and built by NovaSol.](image)

**Figure 1:** DMOI and the overall objective of the interrogator units designed and built by NovaSol. Photo Credit: NovaSol

The Compact is the current model which was demonstrated to NRL this summer. Like DMOI, the Compact has 2 modes of operation; retro mode and direct mode. In direct mode two interrogators, the ground station and the mobile station, communicate with each other directly using infrared lasers. Retro mode is used when the unit “transmits a laser beam to a remote unit that modulates a data stream onto the beam and reflects it back to the unit” [NovaSol website]. This mode relies on retro-reflectors to take in light and reflect it out in the same direction that it entered. Data can be encoded into the returning light beam using a modulator thus creating a two way link to send and receive data. [2]
The Sub-Compact is NovaSol’s newest optical interrogator. It is much smaller than the Compact and weighs just 16 pounds. Using the latest technology, this is the smallest unit that can be made with all of the functionality of the Compact and DMOI.

FIBER OPTICS

The first thing that I was tasked with was learning about fiber optics. There are many types of fibers and connectors, each with a different purpose and different physical properties associated with them. At the core of each of these cables is a very fine piece of silicon glass, therefore these cables must be treated with care.

Within the fiber cable, there are layers. A buffer or jacket is the outer-most layer and covers the entire cable to protect the glass fiber. It is usually is layered with Kevlar or some other stiffening material to ensure the fiber does not break. Just below that is the cladding which keeps light confined to the core. The core of the cable determines many major properties of the cable, such as mode, bandwidth, and transmission rate. A single mode cable has a very thin core, usually with a diameter between eight and 10 microns. This cable carries a higher bandwidth, but requires a light source with a narrow spectral width. It also provides a higher transmission rate, eliminates distortion from overlapping light pulses, which helps to provide the least signal attenuation. Multi-mode cables have a larger core diameter, usually between 50-100 microns. Multimode fibers provide high bandwidth at high speeds, however they cannot be used for long distances as the multiple paths of light can cause signal distortion at the receiving end. [3]
Simulation Program with Integrated Circuit Emphasis (SPICE) is a general purpose analog electronic circuit simulator used to check the circuit design and predict the circuit’s behavior. I used a free version of TINA SPICE, Texas Instruments version of SPICE, to simulate a circuit with an avalanche photodiode to determine which segment of the circuit noise was coming from. The circuit is from the modem used for the interrogators. After modeling the circuit, it was discovered that we were unable to do the noise simulation as previously planned, as a full version of TINA SPICE must be purchased in order to run this section of the simulation with optical components.

MOTION SIMULATOR

In order to test the Compact Interrogators in the past, NovaSol employees needed to rent a small fishing boat for the day in order to test their system. To avoid needing to rent a boat in the future, we worked on constructing a motion simulator which was designed in advance. The motion simulator is made out of 80/20 aluminum and two Aerotech motors to simulate the pan and tilt of the boat. The GUI was made using Microsoft Visual Studio and was coded in C Sharp, the programming language of choice at NovaSol.

Constructing and programming the motion simulator took well over a month due to modifications that were needed to the parts, problem solving when the parts did not fit as they should have in the drawing, and changing the code. By the last day of the internship, we had written the code for a manual and simulate mode and the structure was fully assembled. The tilt motor was incorrectly tuned; therefore it needs to be sent back to Aerotech to be fitted for the appropriate weight.
CONCLUSION

Optical communication is a complex field. Over the summer, my knowledge of optics and optical communication has grown tremendously through both online research and practical application. NovaSol’s Compact Interrogator served as a great platform to learn about this upcoming technology, as well as many of the components that go into it.

ACKNOWLEDGEMENTS

I would like to thank the Hawai‘i Space Grant Consortium and NovaSol for providing me with this amazing opportunity. Additionally, I would like to thank all of the Optical Communication staff at NovaSol for working with me and helping me to understand many of the things I was tasked with. It has been an amazing experience.

REFERENCES

