Laser Modulation Development for Transponding Applications

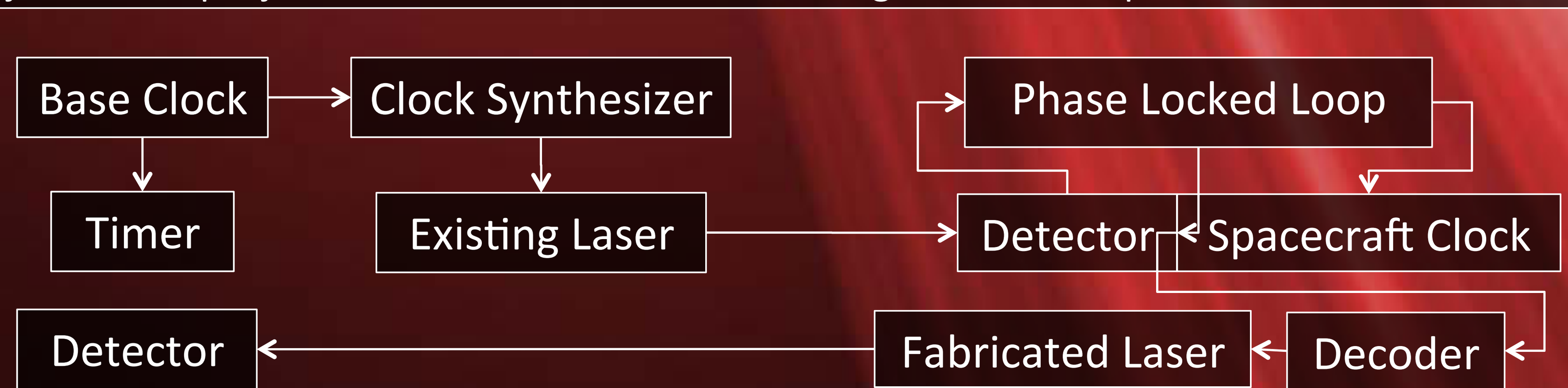
Introduction

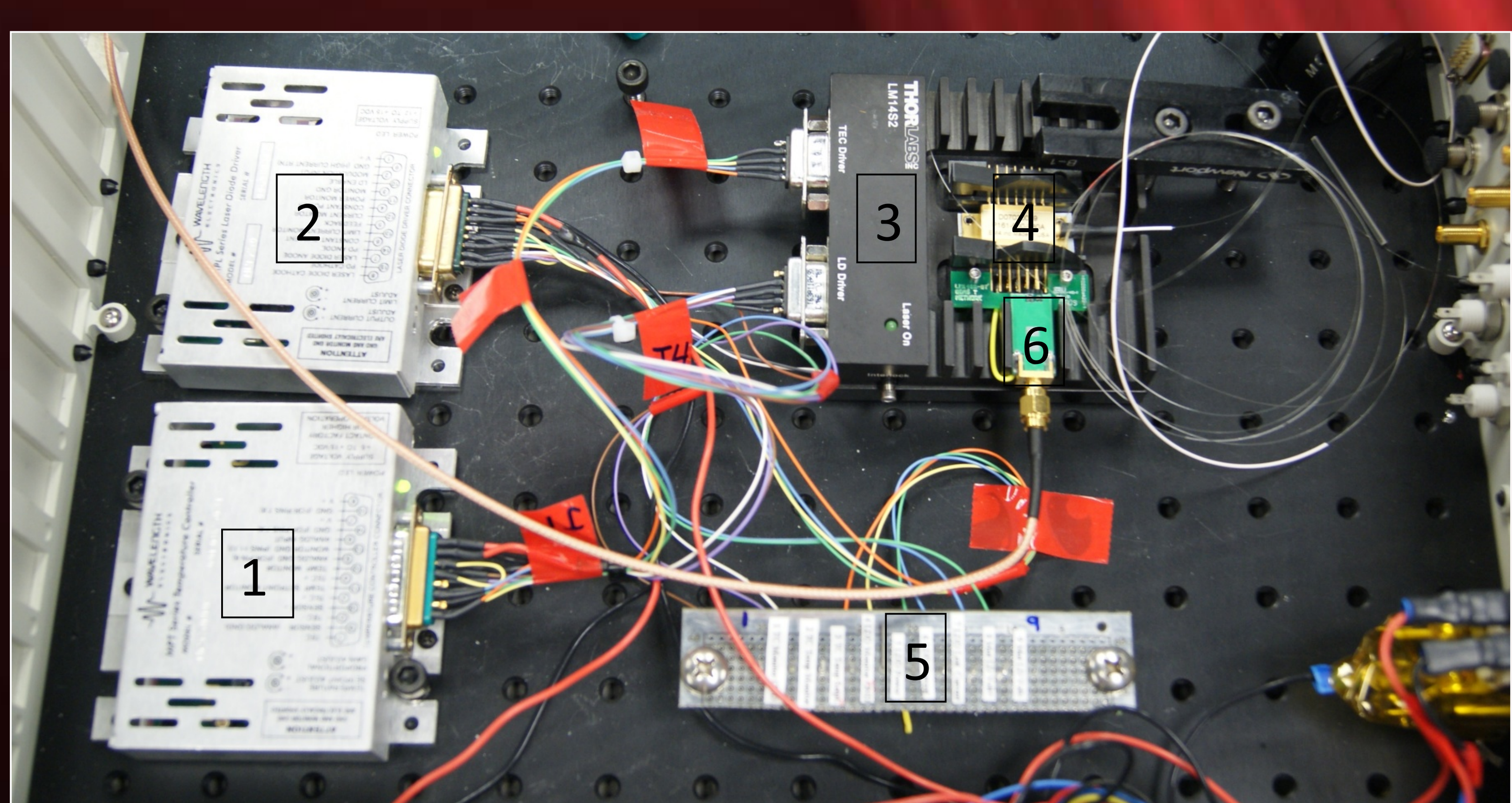
Laser ranging is a rapidly growing and increasingly useful field for measurements of gravity fields and topography of planets in our solar system. Particularly, interplanetary ranging is integral to the pursuit of knowledge regarding the structure of the solar system and information regarding its planets. Current laser altimeters, such as the Lunar Orbiter Laser Altimeter (LOLA), can be used to measure small (<1000 km) distances with a single laser. This project seeks to create a laser modulation system that will permit the laser target to have an active response, creating a transponder. A set of lab electronics has been built to demonstrate the feasibility and accuracy of such an active transponder. The most important concern involves the accuracy at which the laser system can accurately measure distance. This accuracy measurement is a measure of jitter, or to what extent noise in the system causes the laser to deviate from ideal conditions. Each picosecond of jitter translates into 0.0003mm of uncertainty in measurement. The goal is to measure interplanetary distances to a part in 10^13, a few centimeters between planets.

Methodology

First, created diagrams which illustrated a wiring system between the component boxes using Microsoft Visio. Cables were made by soldering wires between several RS-232 connectors. Simultaneously, two power supplies were mounted to the same board with optical mounting hardware. After polarity and voltage testing, the boxes were plugged in and the diode current was raised until light was seen. After this step, modulated the laser with a bias tee. The laser diode in use did not have an integrated inductor, so one had to be installed on the mount circuit board by cutting several copper traces and soldering on a surface mount inductor. After this, the TTL transistor output was connected to the laser system. Due to the slowness of the transistor output, a pulse generator with an external trigger was utilized to generate clean wave pulses for the system.

Finally, the laser was inserted into the transponder. The signal generated in the ground portion of the system passed through an existing laser and detector before reaching the spacecraft circuit. This signal was then sent to the pulse generator which controls the laser assembly detailed below. The laser light was then collected with a detector attached to the laser with fiber optic cable. Data was collected with an external oscilloscope that can calculate the accuracy of a component in the system by comparing a output pulse to the pulse that generated it. When comparing two pulses, the slower pulse is triggered by the oscilloscope and the distance between the leading edges of the two pulses is measured several hundred thousand times. The standard deviation of this set was calculated, and that number was the averaged jitter between the two signals. One jitter measurement made here is between the pulse generator and the photodetector, which measures the jitter of the laser itself. The other is between the spacecraft clock and the detector of the spacecraft laser. This measures the laser jitter and the spacecraft circuit jitter. Multiple jitter measurements are added using a root sum squared calculation.





The laser assembly, a temperature controller (1), a laser diode driver (2), a laser diode mount (3), and the laser diode itself (4). Also on the board is a test plate (5) to check voltages and currents of the components and a bias tee (6) to accept the incoming signal.

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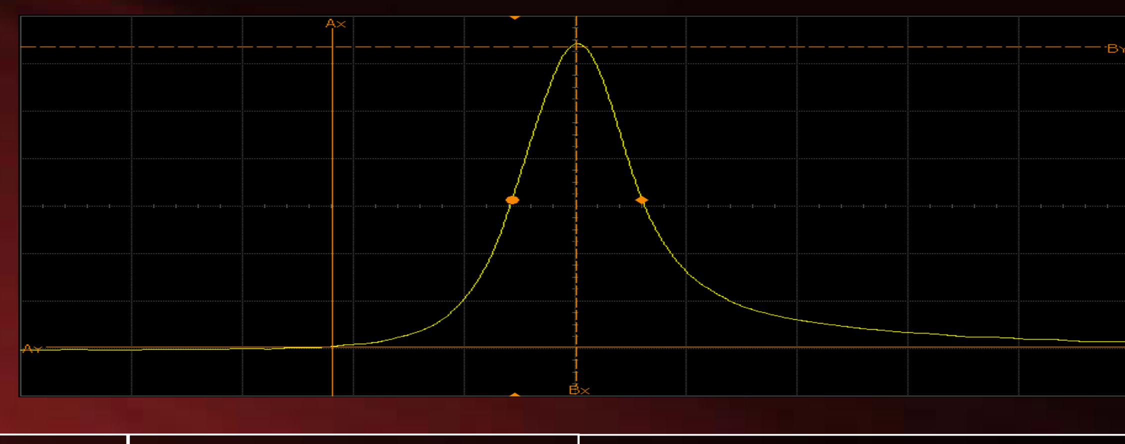
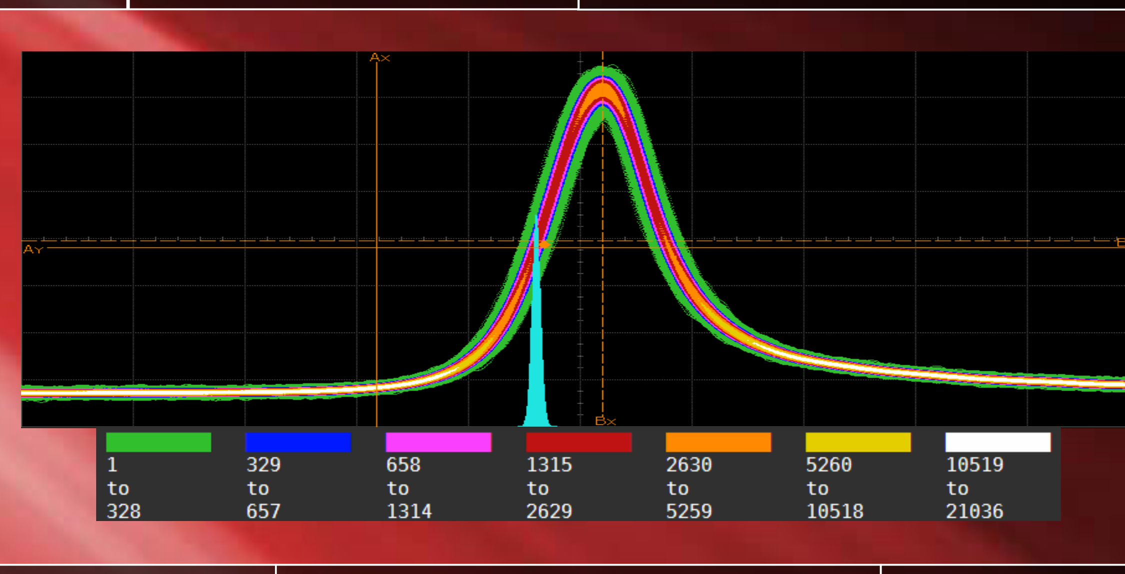
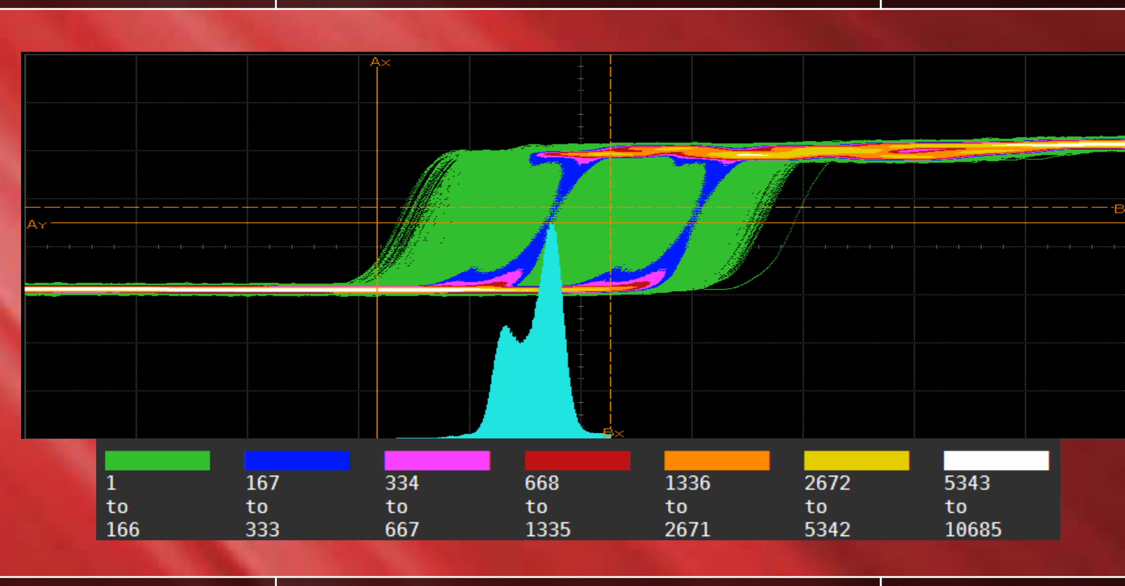
Findings



Voltage (Ay – By)		Rise Time (Ax – Bx)		
mean	1.29500 V	mean	432.374 ps	These markers measure the amplitude of the waveform and the rise time of the pulse. The pulse generator is set for 6V and the DC bias is at 17.6mA.
min	1.27306 V	min	417.198 ps	
max	1.31223 V	max	454.283 ps	



Mean	52.71692 ns	Std Dev	7.89598 ps	µ±1α	73.9%
Median	52.71782 ns	Hits	271.7 khits	µ±2α	96.3%
Mode	52.71560 ns	Peak	30.17 khits	µ±3α	99.9%



Mean	15.89748 ns	Std Dev	46.7736 ps	µ±1α	67.8%
Median	15.90747 ns	Hits	474.6 khits	µ±2α	97.0%
Mode	15.92525 ns	Peak	11.29 khits	µ±3α	99.5%

Conclusion

Since this transponder is only in the proof of concept stage, the most useful conclusions are ones made about the design considerations that either failed or were kept for later stages. This study confirmed that a pump laser could be used for high-speed modulation despite its different intended use. It was found that the type of pump laser that was used can be used without an internal inductor. The project proved that a possibility exists to install an inductor and maintain a 1MHz pulse frequency. A small series capacitor differentiated the leading edge of the signal, resulting in a very clean pulse with short rise time.

The data obtained from the oscilloscope confirmed the usefulness of a pulse generator in cleaning up the original pulse. The pulse generator was configured to produce a sub nanosecond signal by careful changes made to the DC bias and the amplitude of the trigger pulse. The jitter measured between the pulse generator and the output from the detector provided values for delay times and overall accuracy. The measurement for the distance between peaks of the trigger signal and the laser pulse, which was about 52ns, indicated the delay between the pulses. This can accurately be factored out of the final distance calculations for the transponder as a whole. The standard deviation of this measurement is the timing jitter, a value that indicates the accuracy of the system. For the experiment, this jitter was 7.067ps. The jitter of the clock relative to the laser was about 47ps, which is much less accurate than the laser alone. Future research could remedy this problem by eliminating the bimodal nature of the clock jitter. Additionally, the root sum squares of the jitters for each component will be taken to finally determine a jitter measurement of the entire system. If <100ps jitter can be achieved, that results in in a 3cm error range. Higher accuracy transponders result in better mapping and data collection, which in turn improves the extent to which scientists can interpret and use the information they are given.

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