Herbert Wertheim College of Engineering
UNIVERSITY of FLORIDA

POWERING THE NEW ENGINEER TO TRANSFORM THE FUTURE

Precision Space Systems Lab
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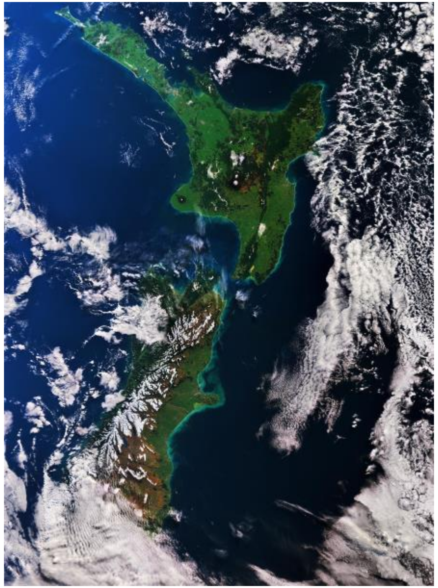
A Miniature Optical Communication Transceiver for Deep Space CubeSats

Background

- Advancements in technology increasing the need for high bandwidth communication
- CubeSats are becoming increasingly cost effective as well as complex
  - CLICK
  - Hypercube
  - HORUS
- Optical frequencies diverge less than radio frequencies and can therefore maintain similar intensities at lower power and weight costs



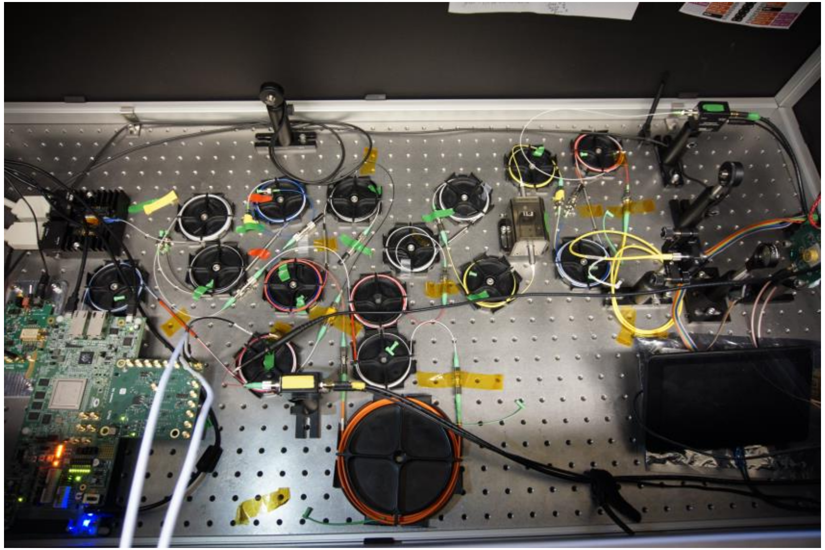
High resolution image taken from ESA's Sentinel 3, sent via laser comm [1]

PSSL

A Solution

MOCT

- The Miniature Optical Communications Transceiver
  - Pulsed optical communication in a CubeSat package aimed at lunar distances and closer
  - ~10 W power consumption
  - Minimal adjustments needed for longer or shorter communication distances



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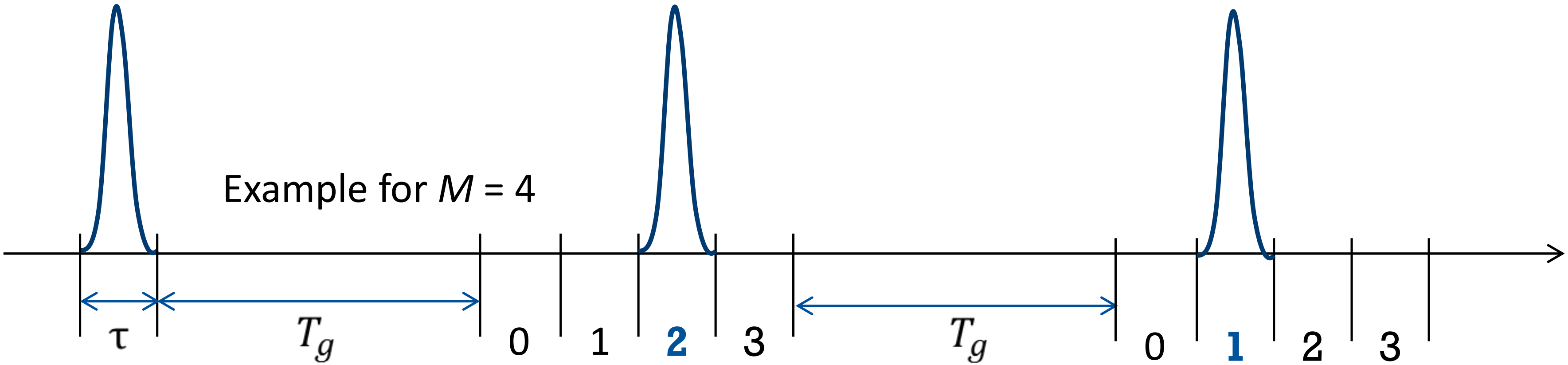
Communication Scheme

PPM

- MOCT minimum slot width is 400 ps
- Wide variation of repetition rate supported

τ = slot width
T_g = guard time

$$Data\ Rate_{PPM} = \frac{data\ per\ pulse}{time\ per\ pulse} = \frac{\log_2 M}{M\tau + T_g}$$



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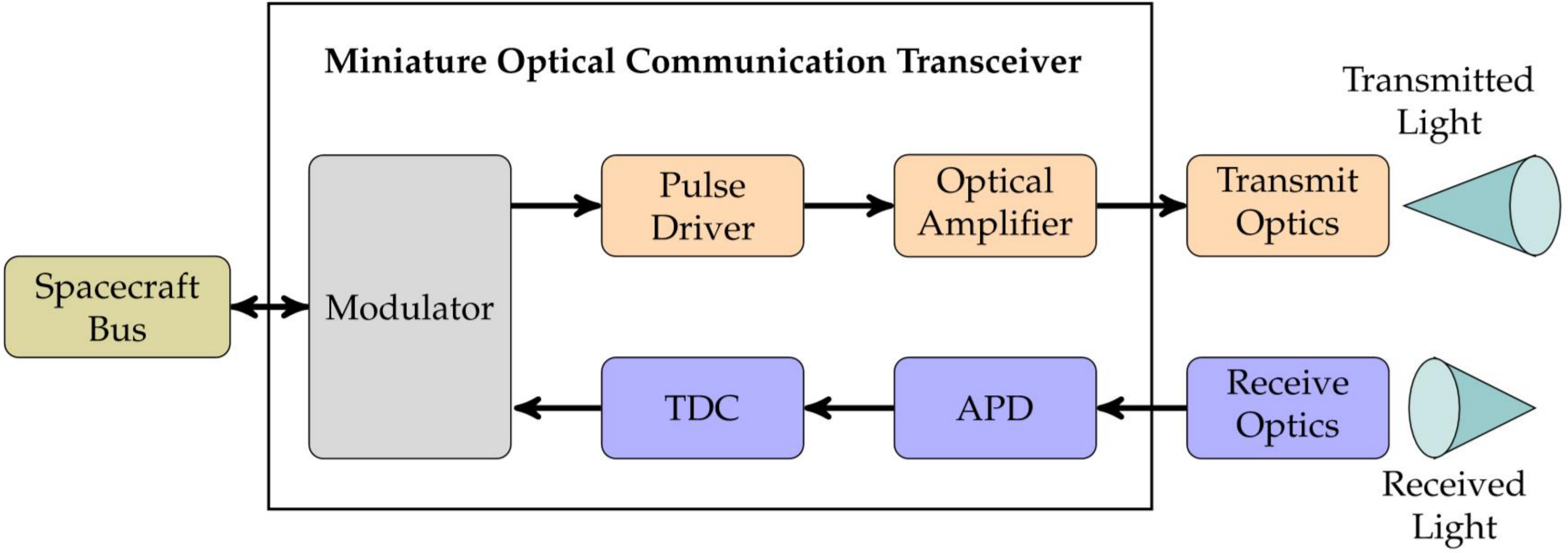
Setup Overview

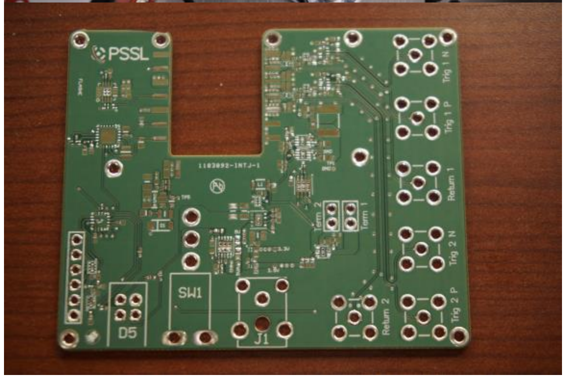
- 10 MHz reference oscillator (CSAC)
- Software defined pulse modulator
- Gain switched seed laser



Key Technologies

FLASHE Laser Driver

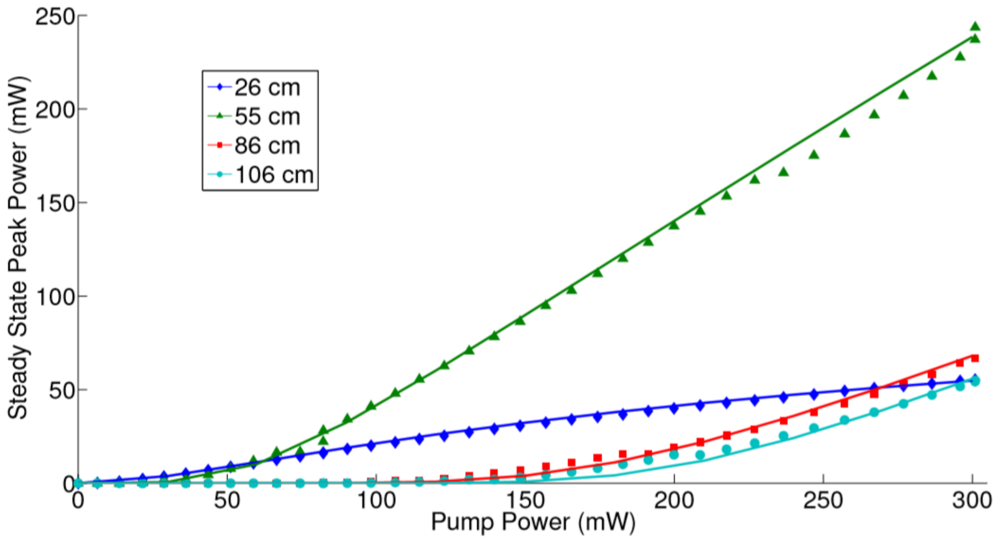
- Uses high speed FETs and a differential input to control laser output
  - Sharp rising and falling pulse edges
  - High pulse repetition rate
- Phase shift in input determines optical pulse width (≥ 100 ps)
- Software controlled TEC for laser on board
- Output current monitoring



Fiber Amplifier

EDFA

- Erbium Doped Fiber Amplifier testbed created by Nathan Barnwell
  - Stores energy from a pump laser to release at seed laser wavelength
  - Various lengths of Erbium doped fiber categorized and interchangeable
  - Modelled to amplify optical power up to 1 kW peak



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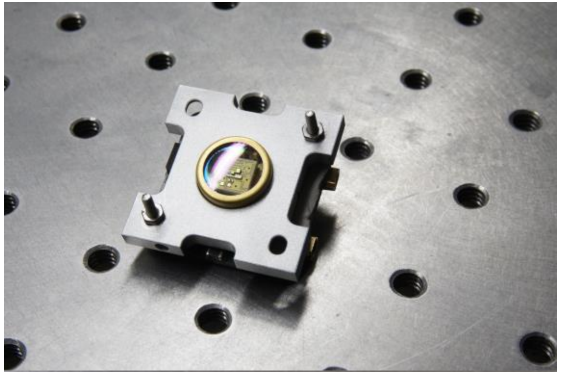
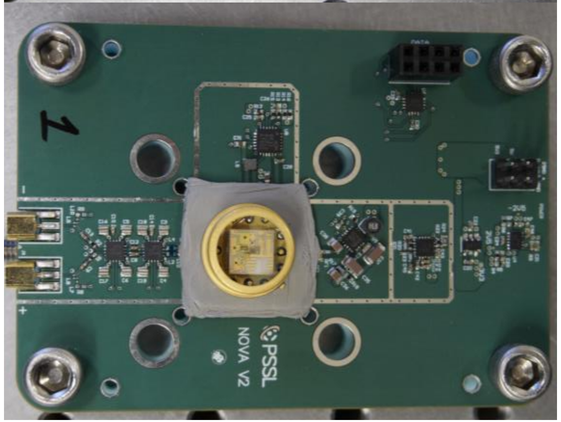
Key Technologies

GHz APD-based receiver

- Designed for wide dynamic range of optical powers
  - Adjustable APD gain via reverse bias chip
- High speed programmable gain amplifiers on output chain
- Software defined PID for TEC controller
- APD current monitoring for average optical power calculations

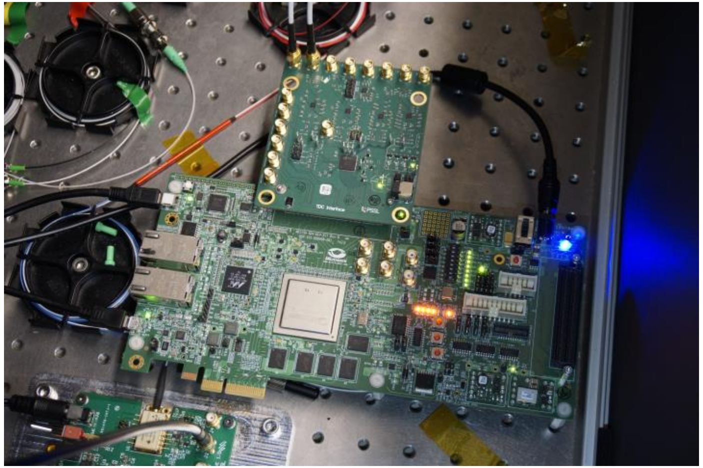




Key Technologies

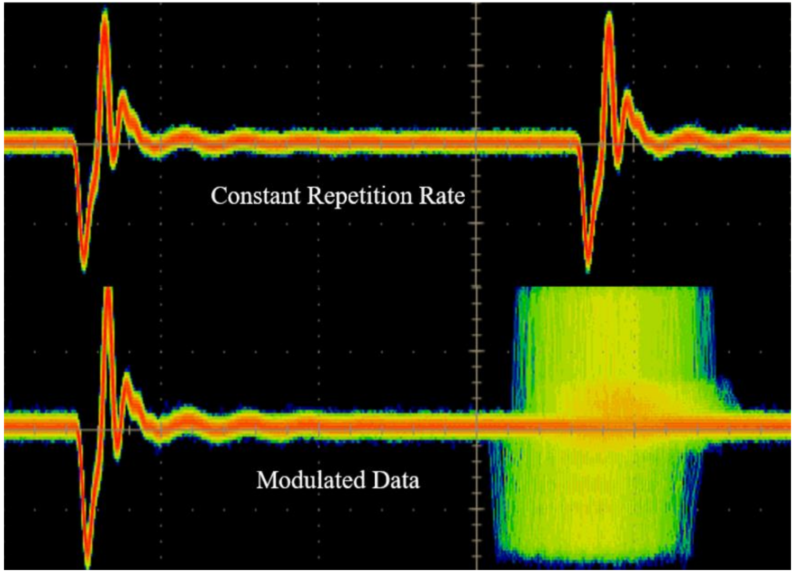
FPGA and Time-to-Digital Converter

- FPGA based controller board supports control for each of the key technologies listed
- FPGA handles all modulation and demodulation of data
- In house timing board allows for continuous timestamping at up to 4 MHz repetition rate



Conclusions and Future Work

- Achieved raw data rate of 78.1 Mbps with optical powers configured for LEO to Earth link
- Bit Error Ratio of 0.257% measured at <200 nW optical power received
  - 2.5 ns pulses at ~15.625 MHz
  - While limited to 32 sample increments (hardware limitations)
- Tests to be redone with >4000 sample increments
  - Use second generation hardware to decrease pulse width and increase peak optical power
  - Test CubeSat formfactor FPGA board
- Some elements of MOCT will be demonstrated on the NASA/MIT/UF CLICK CubeSat mission
  - (hope you saw the previous talk!)



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PSSL

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SmallSat Technology Partnerships Cooperative Agreement: NNX16AT13A

References

1. “New Zealand,” *European Space Agency*, 08-Mar-2019. [Online]. Available: https://www.esa.int/spaceinimages/Images/2019/03/New_Zealand. [Accessed: 11-Apr-2019]. contains modified Copernicus Sentinel data (2018)

2. N. Barnwell, T. Ritz, S. Parry, M. Clark, P. Serra, and J. W. Conklin, “The Miniature Optical Communication Transceiver-A Compact, Power-Efficient Lasercom System for Deep Space Nanosatellites,” *MDPI*, 31-Dec-2018. [Online]. Available: https://www.mdpi.com/2226-4310/6/1/2/htm. [Accessed: 11-Apr-2019].