



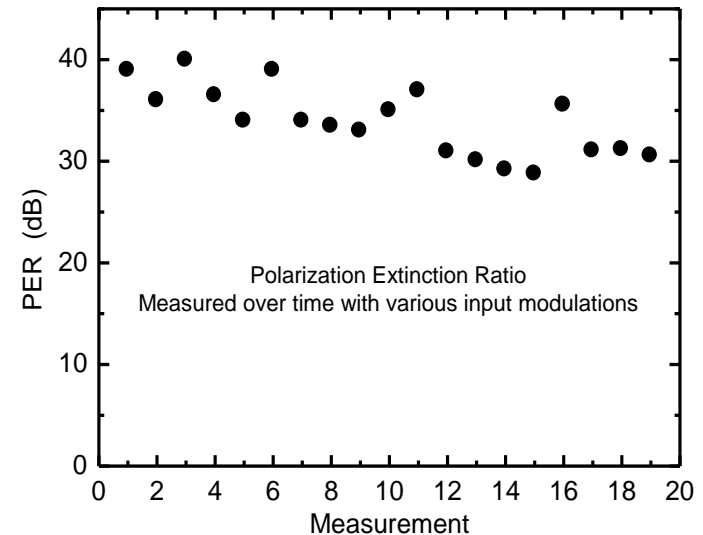
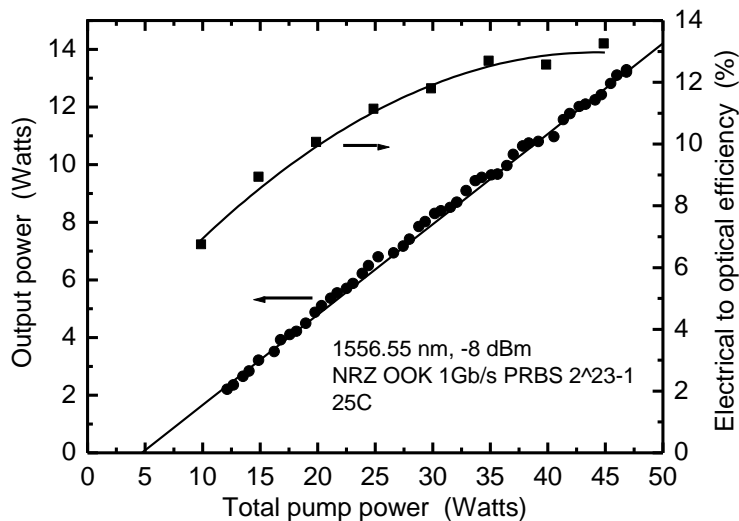
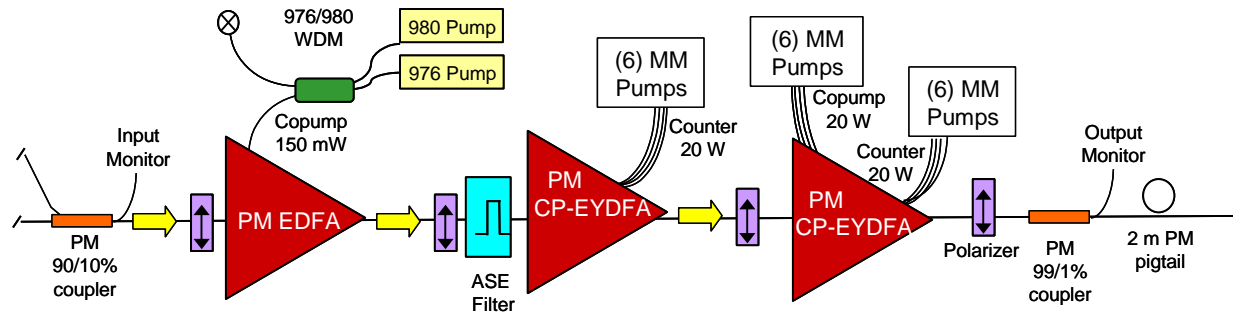
Lasercom in Space and in the Air

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High Power Optical Amplifiers (HPOAs) for Space

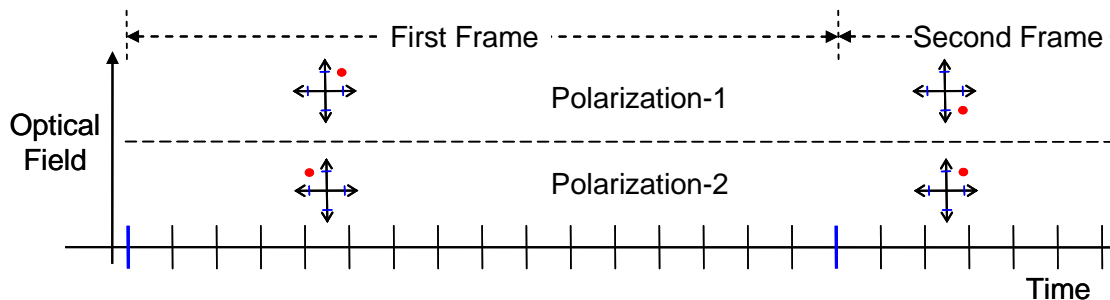
- LGS built a brassboard HPOA for Boeing on the Air Force's TSAT program. It supported up to 40 Gb/s links and was declared TRL 6 for space
- LGS built a 13 W PM-HPOA for potential use for Mars lasercom:



High reliability HPOAs demonstrated for space applications. Record efficiency and PER

New Optical Modulation Format for High-Sensitivity Receivers

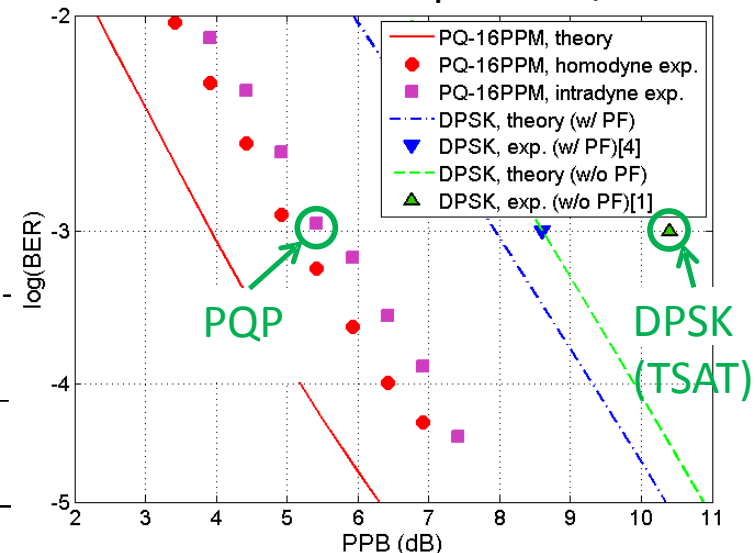
- PPM can get to (arbitrarily) low Photons Per Bit (PPB) sensitivity, by increasing frame size (M). Unfortunately, data rate goes down. It starts out at the OOK receiver sensitivity
- QPSK provides 2 bits/symbol, and starts out 3 dB more sensitive than OOK
- Polarization multiplexing (putting two data streams on the two independent polarizations) can double data rate at same PPB
- We can combine
 - Polarization Multiplexing (PM)
 - Quadrature Phase Shift Keying (QPSK)
 - Pulse Position Modulation (PPM)



- This combination (PQP) can get to reasonable bits/symbol at acceptable symbol rate, permitting Gigabit/sec highly-sensitive transmission

PQP was shown to require ~ 5 dB lower PPB than DPSK @ 2.5 Gb/s

Measured BER vs. photons/bit



Liu, Wood, Tkach, Chandrasekhar, "Demonstration of record sensitivities in optically preamplified receivers by combining PDM-QPSK and M-ary pulse-position modulation," J. Lightwave Technol. 30, 406 (2012)

Proven Lasercom Modem Capabilities

Successfully used in various terrestrial and airborne lasercom systems. Include WDM, multi-mode receivers, and custom FEC for FSO

10G TX/RX w/ FEC
ATCA Pack



-5 to 50 C

2.5G TX/RX
VME Pack



-45 to 71 C

100Mbit Ethernet Modem



- GbE Ethernet transport
- 100Mbit optical bandwidth. Architecture supports higher rates to 1Gbit
- Wide dynamic range (>50 dB)
- Fade Tolerant Forward Error Correction (FEC)
- PPPoE Link Management

10Gbps

2.5Gbps

100Mbps

Line Rate

Sensitivity

DARPA Inter-Satellite Communication Link (ISCL)

- LGS is currently executing on the DARPA ISCL program
- Designing and building broadband lasercom terminals for 100 lbs.-class small satellites in Low Earth Orbit (LEO)
- Terminals will enable jam-resistant, high data-rate, low-latency communication within a network of hundreds of small satellites
- Target terminal parameters:
 - 2 lbs. weight
 - 3 W orbit-averaged bus power draw
- **LGS' solution is CICADA: Compact Inter-satellite Communications and Data Link**



Distribution A: Approved for Public Release, Distribution Unlimited

Photonic Manufacturing and Test

- LGS has manufacturing space dedicated to the production of high reliability photonic subsystems
 - Class 10,000 clean room (~ 950 sq ft)
 - Controlled temperature and humidity
 - ESD compliant
 - All high strength fiber splicing is conducted in clean room environment
 - Expanding to a second (~450 sq ft) clean room
 - Clean rooms and lab areas are controlled access
 - Database for storage of all manufacturing & test data
- LGS has developed high strength optical fiber splicing processes for many fiber types
 - Used for all high reliability photonic subsystems
 - Splices proof tested, inspected, verified
- Developed proprietary rad-hard doped fibers and high-reliability components for space
- On-site facilities for performance, thermal-vac, environmental testing

