GLOBAL WIND MEASUREMENT WITH A PULSED, COHERENT-DETECTION LIDAR SYSTEM

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ESTO WIND-SP

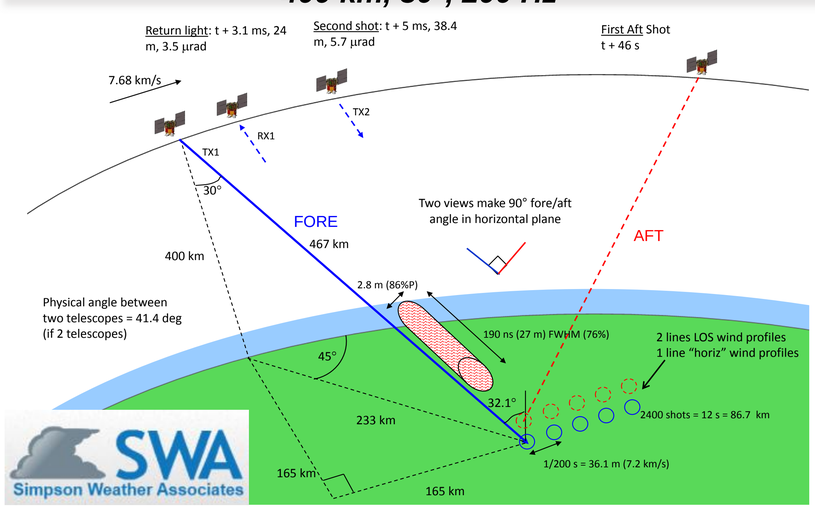
Coherent 2-Micron Wind Lidar Technology Advancement for Space

- NASA ESTO supported 3-year effort (2017 – 2020)
- Deliverables
  - Conceptual design of a space mission and instrument that proves the feasibility of returning wind science from space
  - Operational ground-based coherent detection lidar demonstrator instrument focusing on undemonstrated coherent-detection Doppler wind lidar components required for space
  - Roadmap going forward that shows an understanding of the current design gaps and a logical progression towards a space mission

Why Coherent Detection is Important

- **Accurate Velocity Measurement**
  - Aerosols much heavier than molecules; less Brownian motion
  - Long laser pulse for narrow spectral width; Atmosphere dominated signal spectral width; Full signal spectrum captured
  - Processing in software more flexible than using optical elements
  - Frequency estimation; not intensity estimation
  - Result: LOS velocity error ~ 10 – 100% of signal spectral width
    - Shot averaging, surface return, contextual information, etc. further reduces LOS error
- **High Photon Efficiency**
  - Heterodyne detection with LO provides immunity to background light and Sufficient LO power on detector effectively eliminates all noise except quantum noise; Spectral processing in software permits narrow effective receiver bandwidth
  - Frequency estimation more photon efficient than intensity estimation
  - Result: Excellent horizontal & vertical resolution, Equal day/night operation
- **Multiple Data Processing Options & Additional Data Products**
  - Multiple trades of resolution, aerosol sensitivity, probability of outliers, velocity search space, etc.
  - Wind turbulence (second moment)

Base Doppler Wind Lidar Measurement Geometry: 400 km, 30°, 200 Hz



Project Team

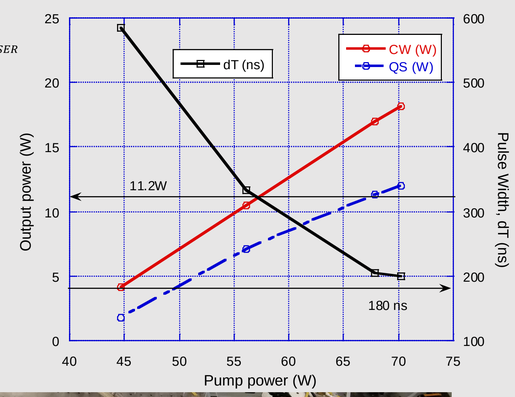
- **NASA Langley Research Center, Lead – Pulsed transmitter laser, electronics, structure, computer control, data processing**
- **Beyond Photonics – CW lasers, optical bench, transceiver enclosure, electronics**
- **Simpson Weather Associates, Science Lead – mission concept, Lidar parameter trades, advanced processing algorithms**
- **Fibertek – Tm fiber pump laser**

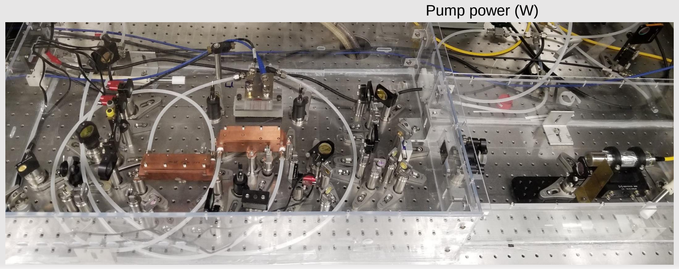
SP Laser Requirement and system performance

	Threshold	Goal	Achieved
FOM	2.22 (1.33 CPEX)	3.14	**3.48**
Energy (mJ)	42 @200 Hz	56 @200 Hz	**60@200 Hz**
Pulse Width (ns)	≥150	≥180	**200**
Power (W)	8.4	11.2	**12.02**

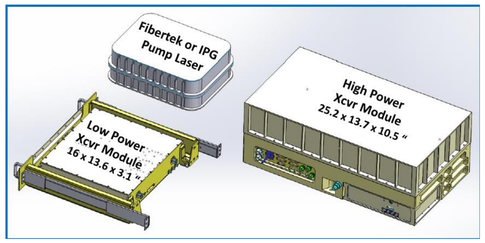
$$\frac{1}{\beta_{MINIMUM}} \propto Figure\ of\ Merit\ (FOM)_{LASER} = \frac{E_{LASER}\sqrt{PRF_{LASER}}\,\tau_{LASER}^{0.285}\cdot 2}{1+\left(M^2_{LASER}\right)^2}$$

- **A major technical challenge for the SP laser is the pulse width requirement.**
- **MOPA architecture found to be efficient to achieve the goal.**

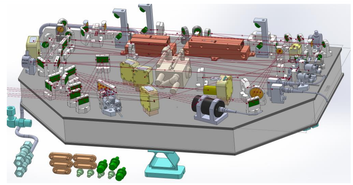


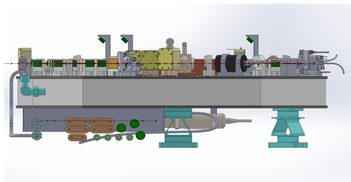


Wind-SP transceiver / high power module

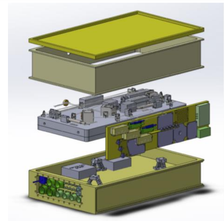


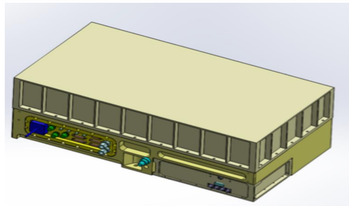
- **Two major sub-assemblies**
  - **Slave Oscillator (SO) high power unit**
  - **Master oscillator Local oscillator (MOLO) lower power unit**
- **IPG laser will be initially used.**

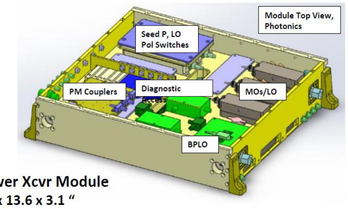




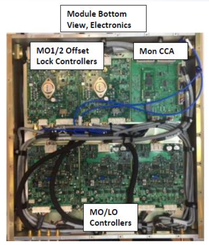
High power / Low Power Module







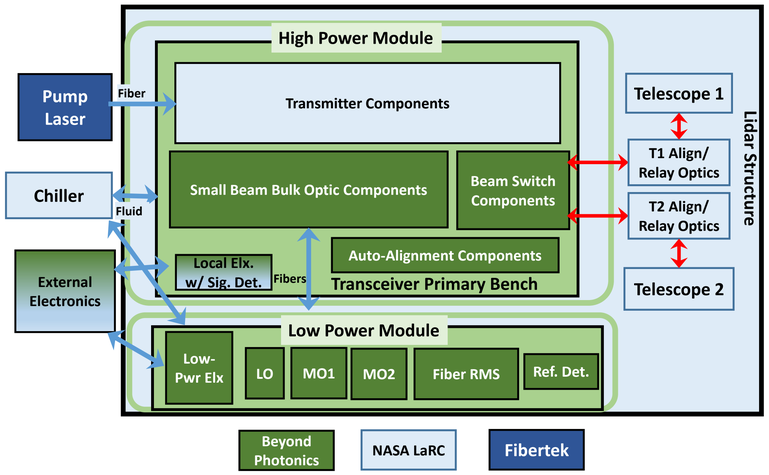
Low Power Xcvr Module
16 x 13.6 x 3.1 "



Auto-Alignment BPLO WDM Fiber Coupler

- Receiver auto-alignment approach uses a small low power continuously present back propagated local oscillator (BPLO) laser that is well offset in wavelength from the Lidar transmitter to prevent interference with transmitter/LO, but still perfectly represents single mode RCVR pointing in space
- A low loss WDM fiber coupler is required to inject the BPLO light into the receiver.

Wind-SP Transceiver Assembly



Summary

- The SP laser performance has been demonstrated that exceeds the design goals. The detail design is nearly completed.
- Completed the Swift MO/LO lasers laboratory test and associated control electronics
- Auto-Alignment subsystem procure and fab schedule consistent with Wind-SP build schedule
- Completed the build of Low-Power Module enclosure & bench
- Completed the SP transceiver detail design

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