SWIFT Frequency-Tunable CW Single Frequency 2-micron Laser

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SWIFT Laser Characteristics

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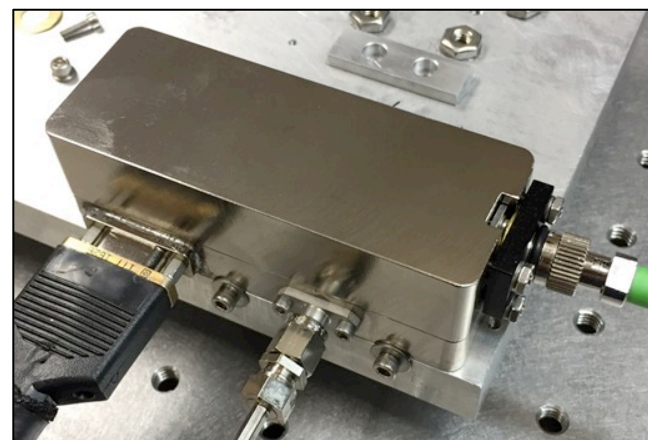
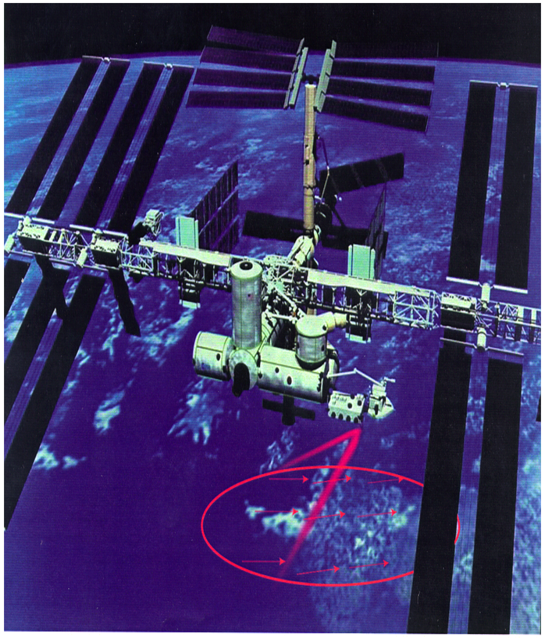
Laser developed jointly with Beyond Photonics IRAD and NASA Phase I SBIR

- Tm,Ho:YLF operating near 2.05 um
- Single-frequency, TEM_{oo}; PM-fiber-coupled output >30 mW
- Integral dual-stage Faraday isolation and fiber-coupling optics
- Very compact, laser head, 3.2”L x 1.2”W x 1.1”H
- Wavelength / Frequency Tuning
  - Broadly tunable over 2050 – 2060 nm using intracavity piezo tuning element
  - Thermal tuning over ~1.4 nm
  - PZT fast mode-hop-free tuning up to 50 GHz
- Frequency Stability
  - Jitter & short term drift <10 kHz/ms (with low-noise piezo voltage)
  - Long-term drift less than 5 GHz



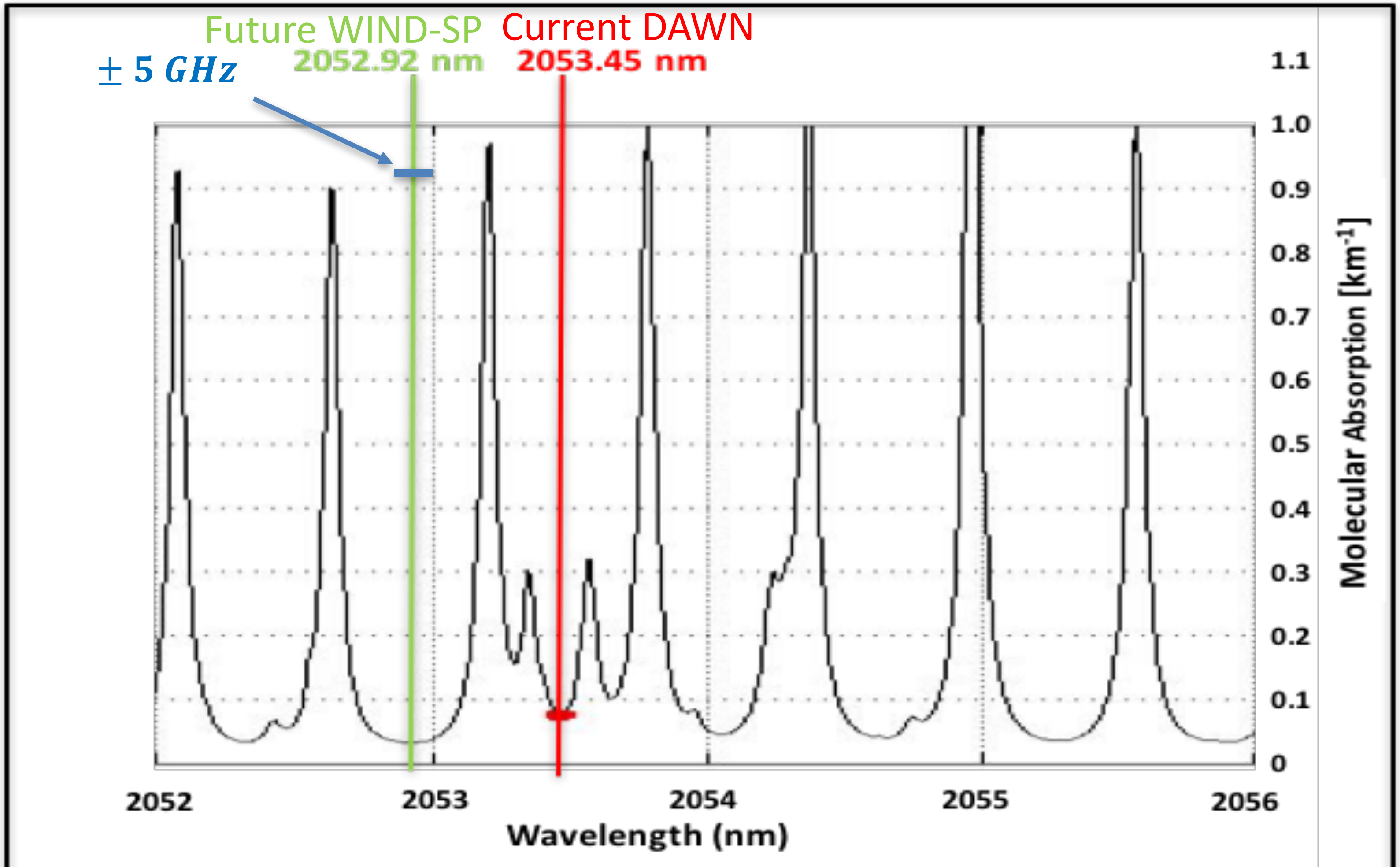
Atmospheric Winds from Space

- System efficiency is critical
- Doppler shifts from space platforms exceed COTS high efficiency 2 um detector bandwidths
  - Typical **high-QE** extended wavelength InGaAs BW ~ 1GHz
  - Typical platform velocities demand +/- 5 GHz
- Solutions
  - Development of improved coherent detector/receiver bandwidth while maintaining high QE
    - High risk detector development
    - Expensive RF electronics with higher noise figure
  - Offset locked frequency MO/LO lasers
    - +/- 5 GHz offset-lock optical servo to cover all look angles with up to 45 degree from nadir viewing
    - Options:
      - Single tunable offset locked laser with fast tuning and settling time
      - Multiple offset lasers, one for each look direction (reasonable solution if only 2-3 look directions)



Wind Measurement

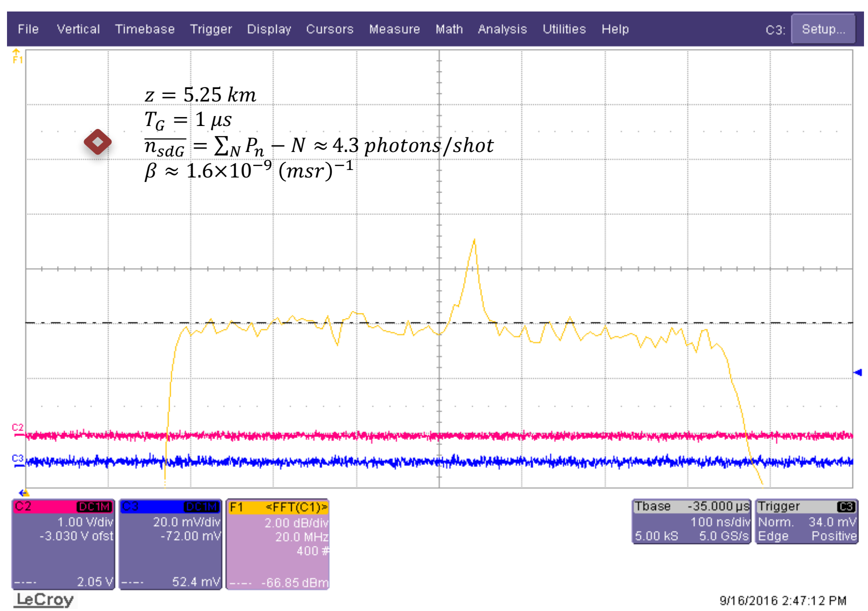
- 2-micron Wind Measurement



Space Wind Measurement Lidar

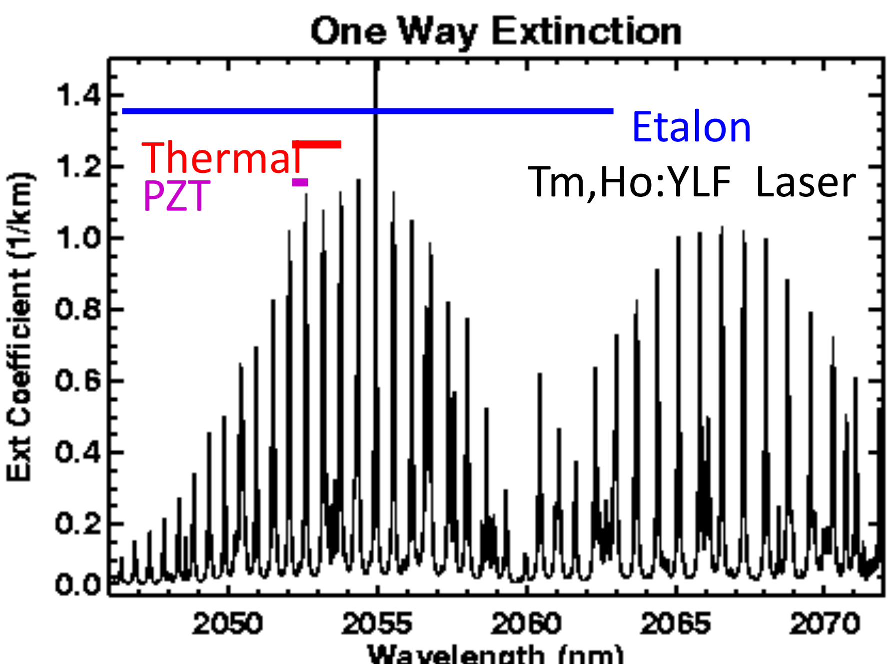
Local Oscillator Frequency Stability Requirement

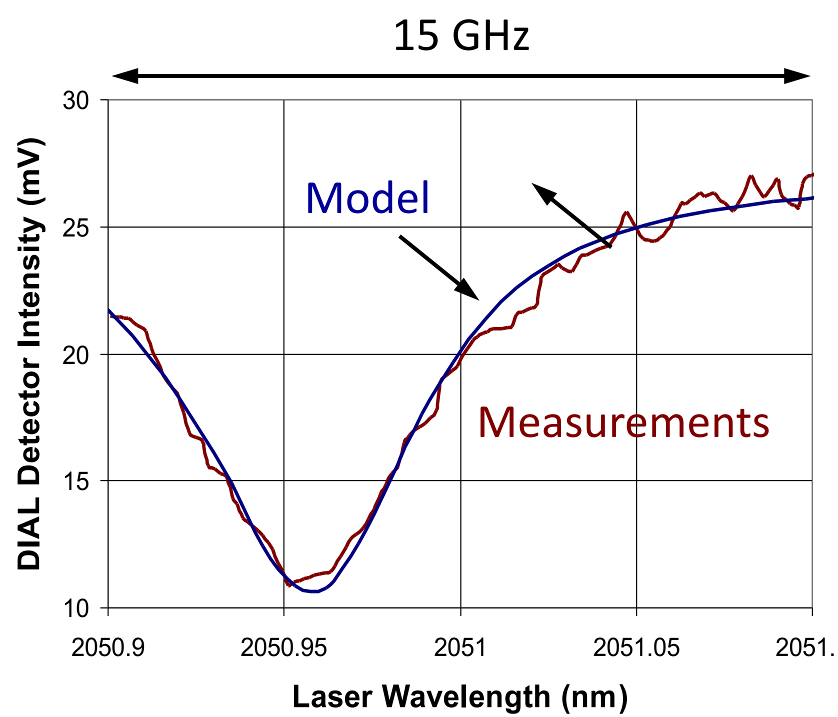
- LO Frequency Variation over round trip time must be small compared to frequency shift associated required velocity accuracy
  - e.g., $1\ m/s\ \ at\ 2\ \mu m\ \ \Longrightarrow \delta(\Delta t) \ll 1\ MHz,\ \ e.g.,\delta\nu = 0.1\ MHz\ okay$
- Bandwidth of signal return in absence of wind variation is determined by transmitted pulse duration
  - Since we almost always accumulate many pulses for a wind measurement requirement is that frequency variation over pulse duration is small compared
- First requirement usually dominates for long range lidar measurements



Differential Absorption Lidar IPDA and DIAL

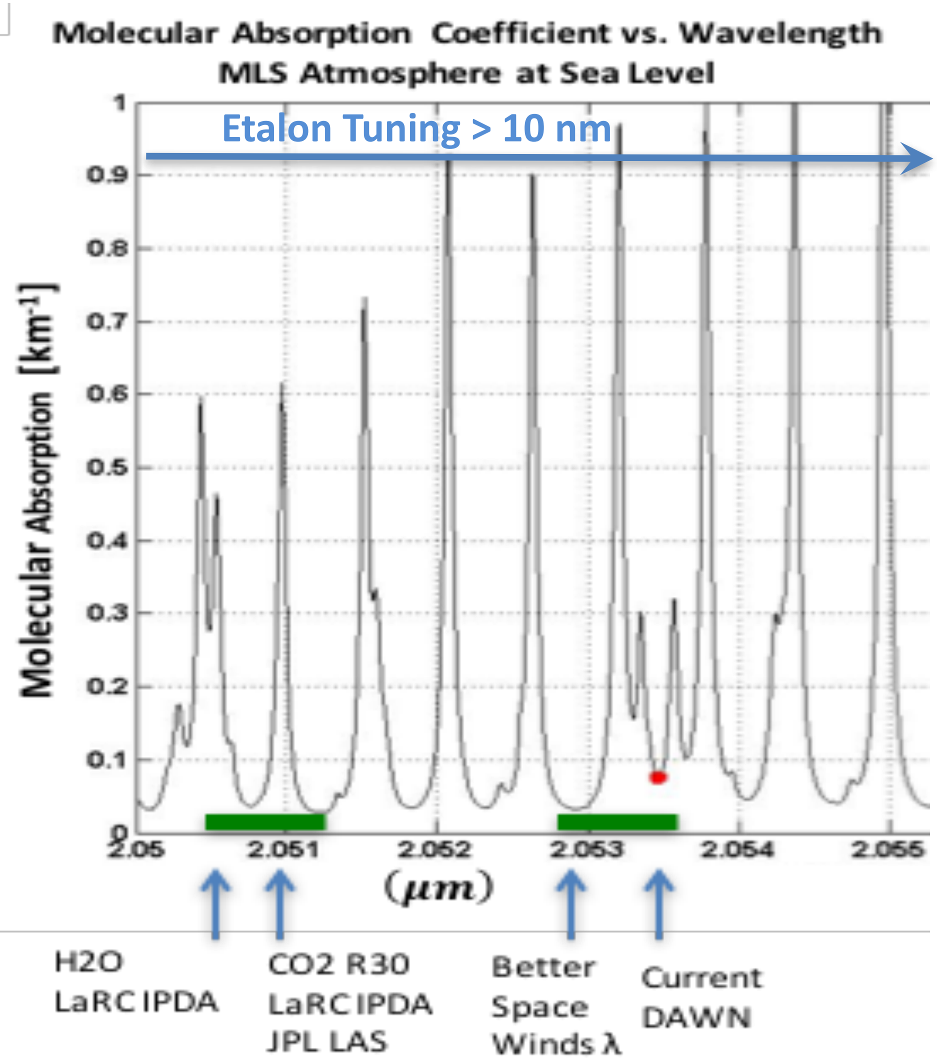
- Tm,Ho:YLF SWIFT tunable over CO2 and H20-vapor Absorption Lines
  - Etalon Tuning over 10+ nm allows Frequency to be set to general region of interest – set during manufacture
  - Thermal tuning over 100+GHz allows centering of PZT tuning range
  - PZT tuning up to 50 GHz allows fast mode-hop free
  - Tuning over Absorption Features





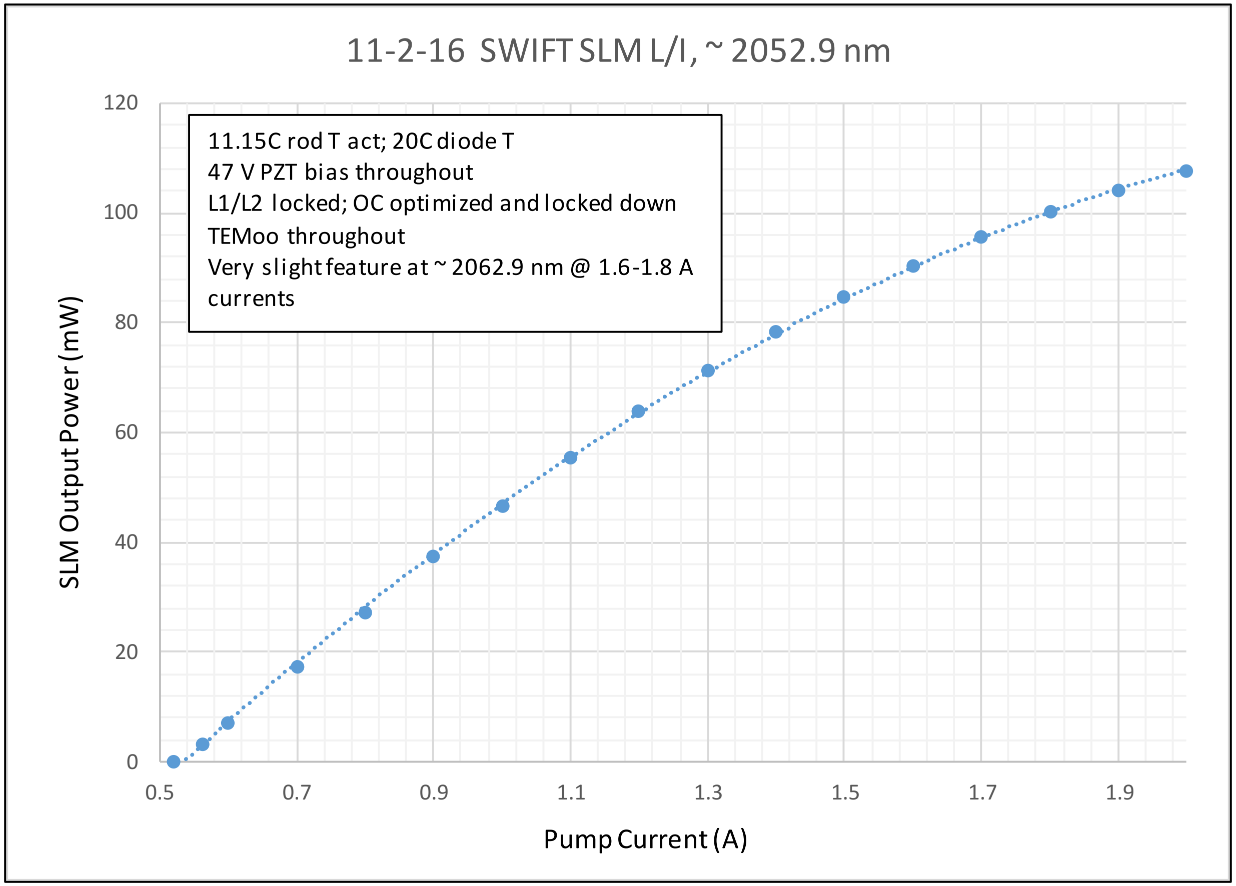
2-Micron Wavelengths of Interest

- Wind Measurements:
  - NASA DAWN operating at 2053.472 nm for atmospheric winds
  - Improved Wavelength at 2052.92 nm in Future
- CO_2 and H20 Vapor IPDA
  - R30 CO_2 absorption line at 2050.967 nm is one of most suitable for measurements of CO_2 concentrations from space (JPL and NASA LaRC)
    - Low level of interference from other molecules
    - Weighting function peaks in lower atmosphere
- SWIFT Wavelength/Frequency tuning
  - Factory center wavelength selection using Intracavity Etalon – 2050 – 2070 nm
  - Temp./Current tuning – >100 GHz (1.40 nm)
  - Fast Mode Hop Free SLM Tuning using PZT up to 50 GHz



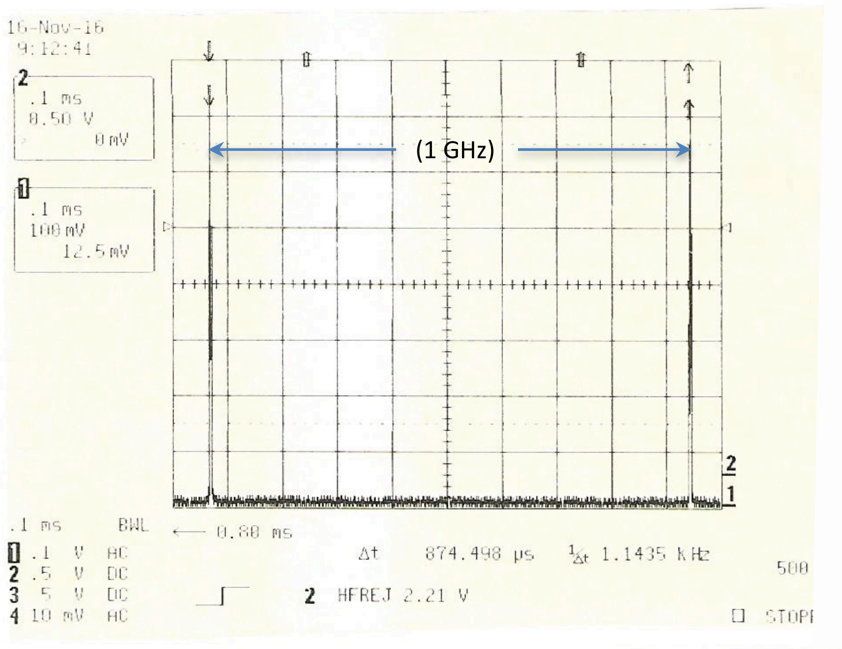
SWIFT Laser Produces over 100 mW of SLM Output Power

- When frequency selective etalon was introduced into the cavity, single longitudinal mode operation near 2052.9 nm was obtained

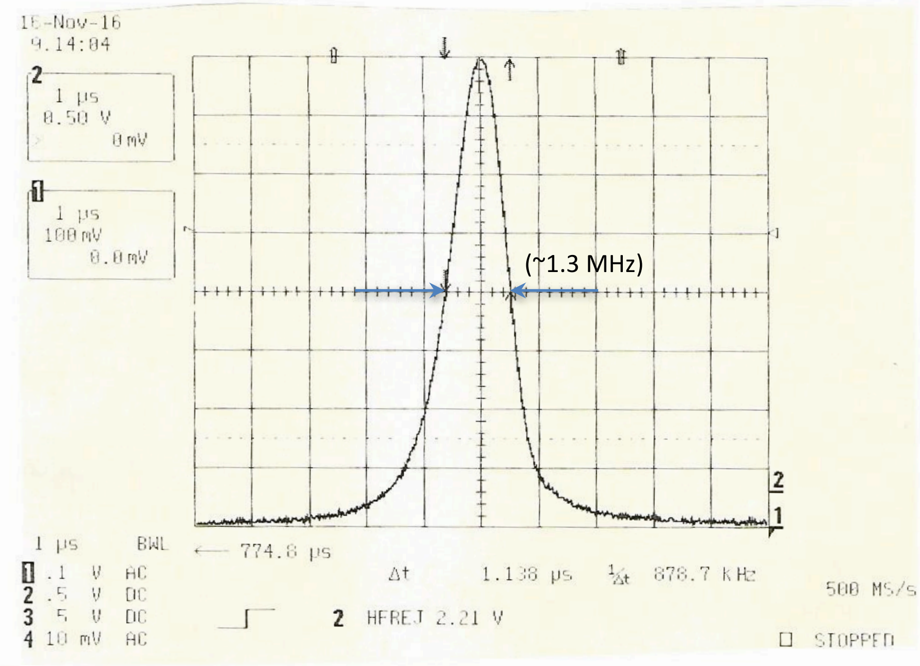


SWIFT SLM Diagnostics

- Single-frequency diagnostics include a Burleigh wavemeter, and Burleigh TL-15 75 GHz FSR scanning Fabry-Perot and Toptica 1 GHz FSR scanning confocal Fabry-Perot interferometers
- Frequency jitter and short term drift < 10 kHz/ms
- Long term frequency stability <5 GHz



Resolution limit of Interferometer



Fast Wide Frequency Tuning Demonstrated

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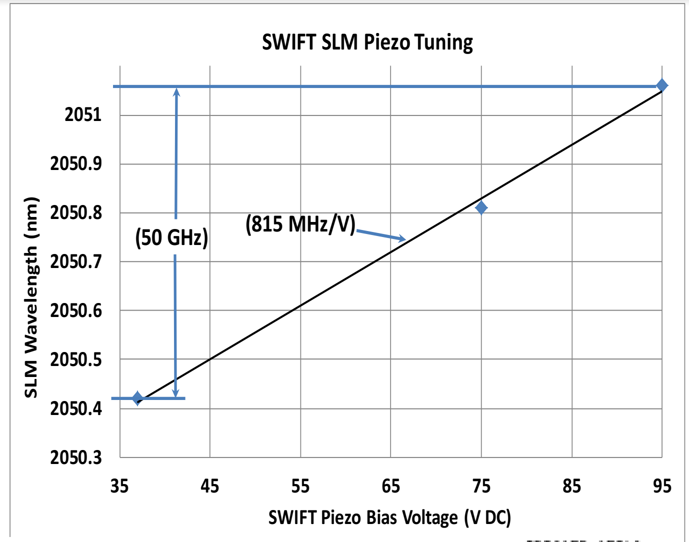
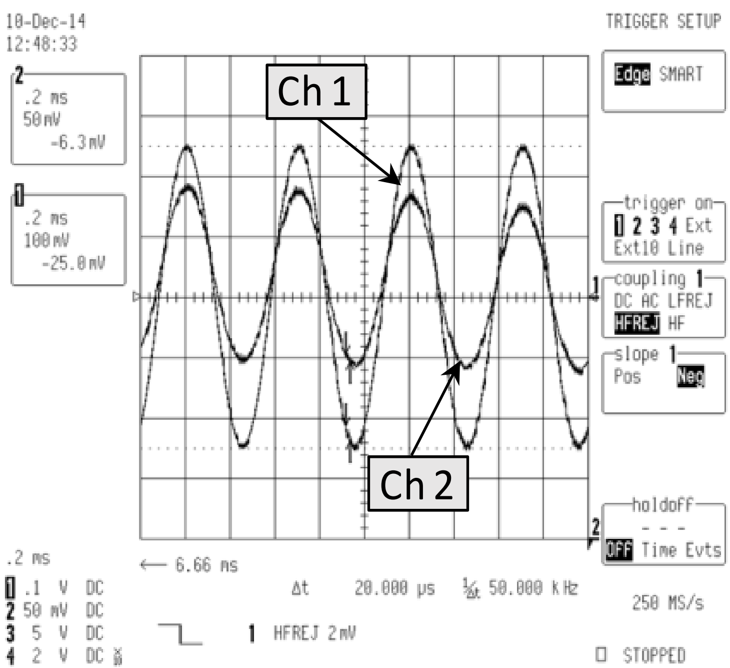
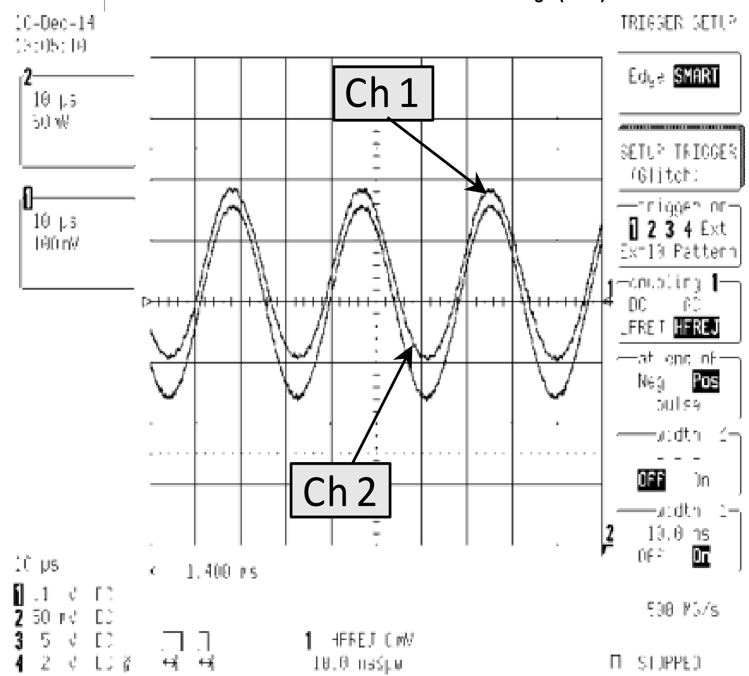
- Mode hop free frequency tuning of 50 GHz demonstrated in short-cavity SWIFT
- Tuning rate > 200 MHz / us

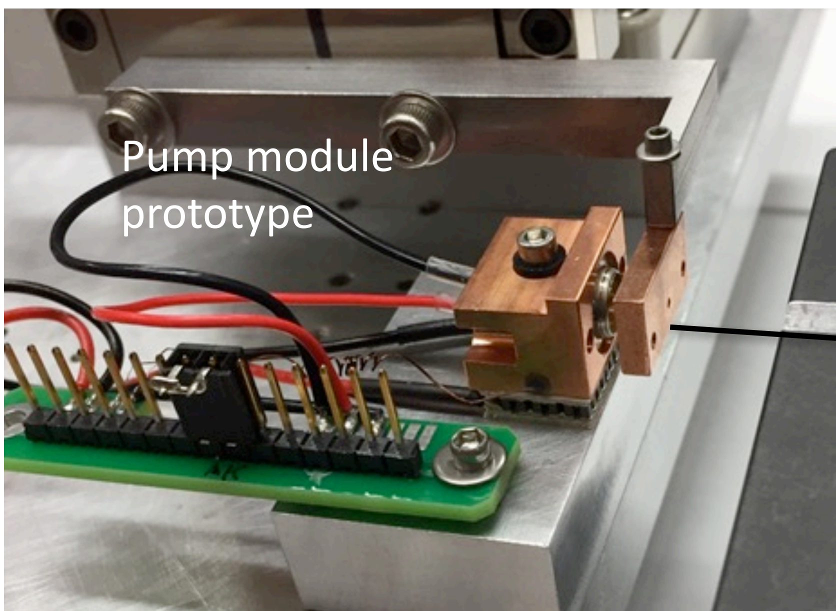


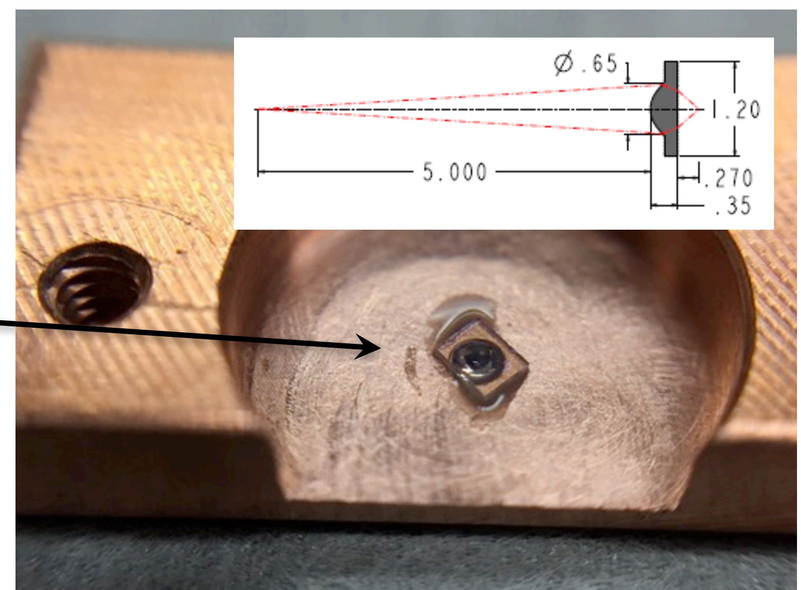




Nano-SWIFT R&D Shows Feasibility of an Even More Compact and Efficient SWIFT

- In parallel with standard-design SWIFT laser, we also began development of a “nano-SWIFT” design that further compacts the laser head, reduces prime power required and heat load, and lowers design complexity
  - Uses 400 mW cw, 792 nm single-transverse mode diode pump source
  - Single very short focal length, high numerical aperture pump lens collects and projects magnified image of pump source in laser rod





SWIFT Summary

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- The initial fully-packaged SWIFT laser is performing well
  - ~ 100 mW SLM TEM_{oo} out of PM fiber
  - PZT Tunable
  - Delivered Prototyp to NASA which is Tunable around 2052.9 nm with PZT and/or resonator temperature with more than adequate power
- Future improvements include
  - Better optimization of prototype controller for lowest possible noise and frequency drift operation
  - Suppression of sporadic higher-wavelength lasing with higher-transmission output coupler
  - Mechanical improvements identified during fabrication
  - More compact flight-hardened controller
  - Full nano-SWIFT prototype