Semiconductor Guidestar Laser Development

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and

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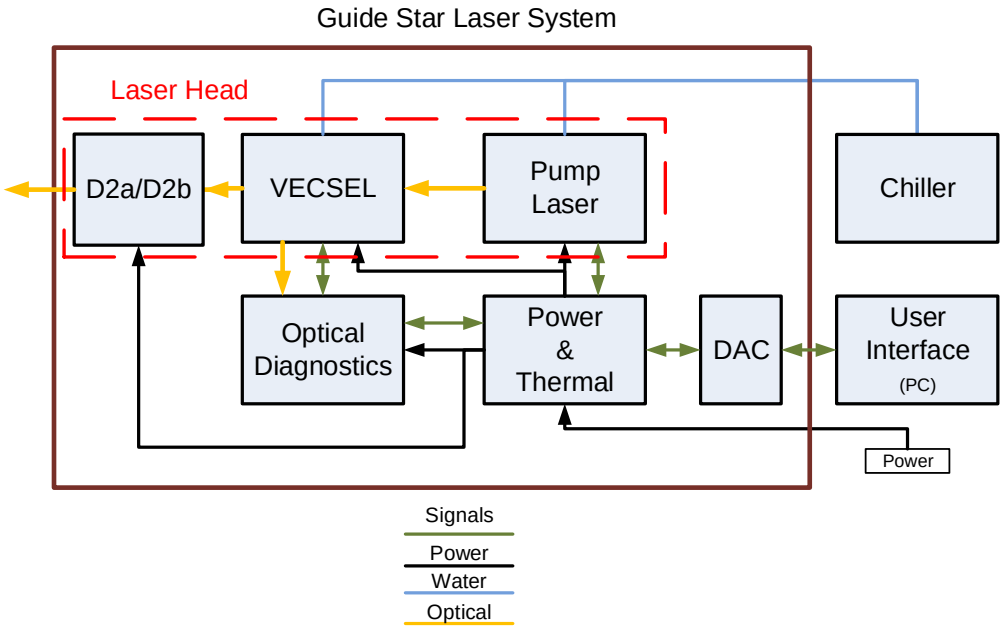
Laser Workshop

Outline

- Performance Objectives
- Current Programs
- System Design
- Power 1178 and 589 nm
- Beam Quality
- Laser Mode Selection Principles
- Single Frequency Power
- Locking to Na Resonance
- Summary and Next Steps

Areté's VECSEL GSL System



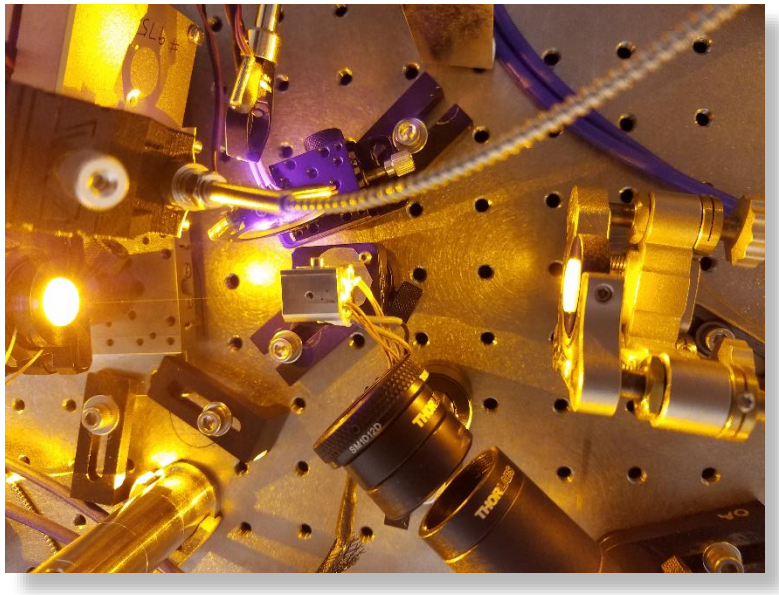
Goal: Design a system that:

- Demonstrates the viability of VECSELs for Guidestar applications
- Serves as a foundational prototype on which to build future units
- Lowers acquisition and maintenance costs of GSLs
- Provides utility to astronomy, space situational awareness, communications, and other applications

Characteristic	Values and Rationale
Primary λ and Power	8-20 W locked to Na(D_{2a}) ~589 nm
Secondary λ and Power	Tunable and lockable at D_{2b} $\Delta\lambda$= 1.7 GHz from D_{2a}
Waveform	Continuous Wave
Linewidth	5-50 MHz
Fine Tuning	~1 GHz, continuous *Scan sodium transition to enable line locking*
Gross Tuning	~5 GHz, does not need to be continuous *Allow capture of Rayleigh backscatter*
Beam Quality	M^2 < 1.2 *Near Diffraction Limited*
Polarization	Well defined polarization, contrast ratio >20 *Circular polarization is broadcast*
User Interface	PC Based GUI
Diagnostics	Wavelength and power
Power	110-240 V AC
Water	4-8 slpm flow of *cool* water

ANU Program Snapshot

- Areté is supplying a prototype VECSEL sodium guidestar laser to Australian National University (Celine D'Orgeville).
- ANU is the lead organization of a consortium consisting of:
  - Australian Astronomical Observatory (AAO)
  - University of New South Wales (UNSW),
  - The Giant Magellan Telescope Organization
  - EOS Space Systems
  - Lockheed Martin Space Systems
- The laser will be installed and tested on the sky at the Mt Stromlo Observatory near Canberra AUS
- **Will represent the first on sky VECSEL GSL demonstration in the world!**

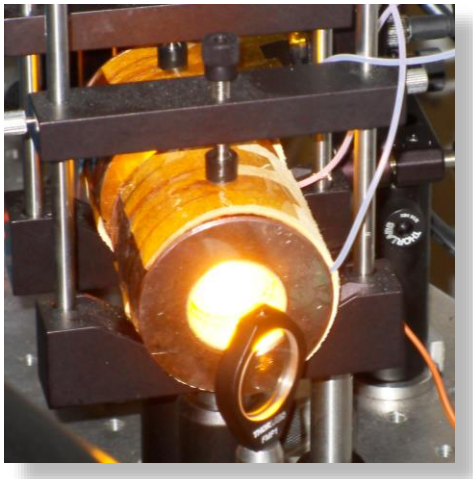


	2018				2019			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Tech Demonstrator								
Design								
Procure and Fab								
Integration & Test								
Delivery								
On-Sky								

Areté's Air Force STTR Program

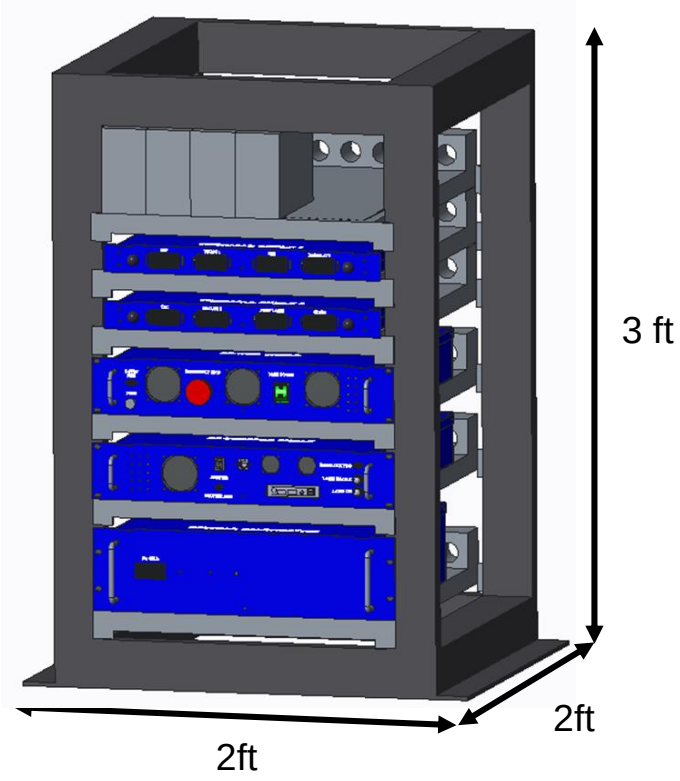
- Continue to increase 589 nm VECSEL output powers to greater than 20W
- Produce a proof-of-concept system capable of installation at an observatory for an on-sky test at 589 nm wavelength
- Deliver a second VECSEL GSL to an observatory (Starfire Optical Range)
- Measure on-sky returns from a VECSEL SGSL at SOR

Sodium Cell Excitation



	2019				2020			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Power Scaling								
Procure and Fab								
Integration & Test								
Delivery								
On-Sky								

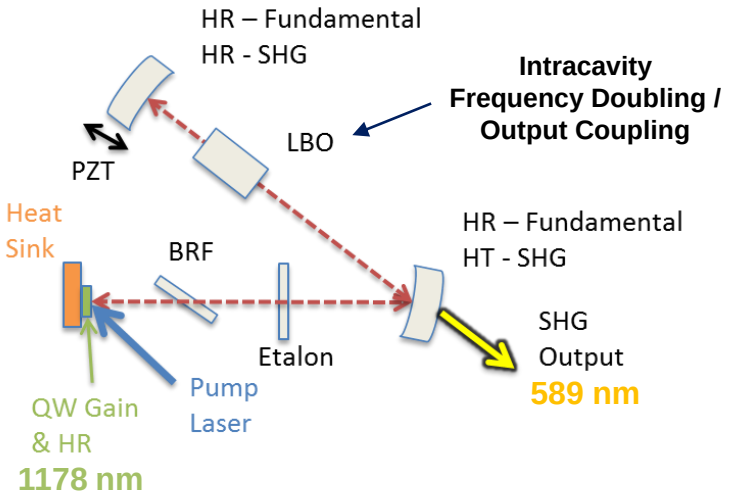
VECSEL System for On-Sky Demonstration



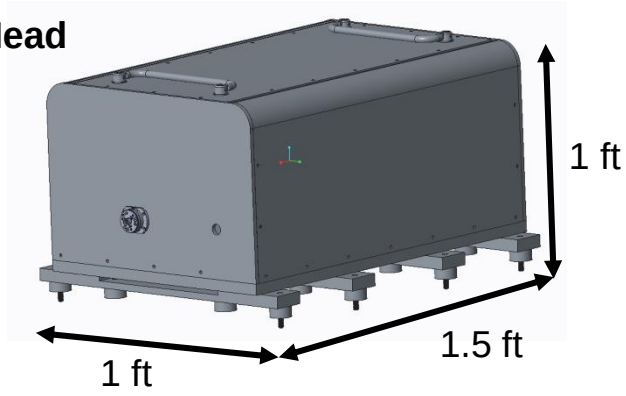
System Rack

Weight ~200-250 lbs

Electrical Power ~ 1kW



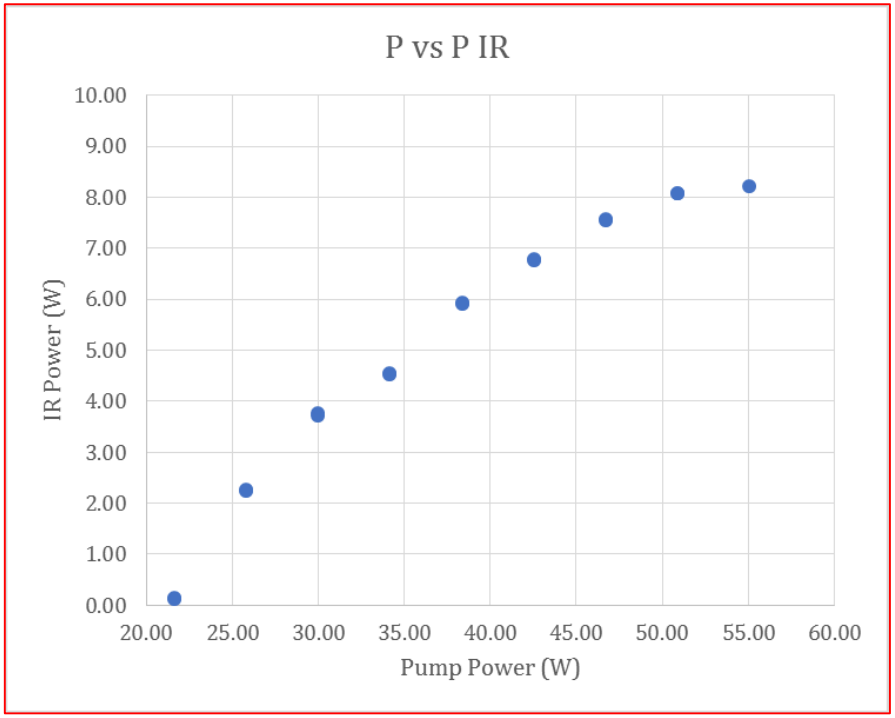
Laser Head



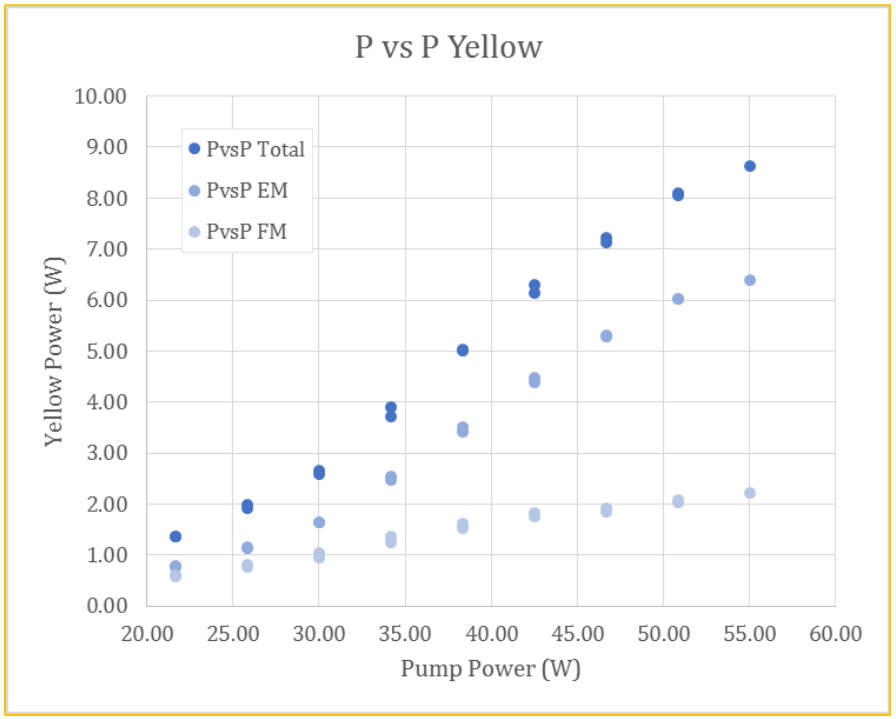
Weight ~ 30-40 lbs

High Extraction Efficiency Achieved with Intracavity Doubling

1178 nm

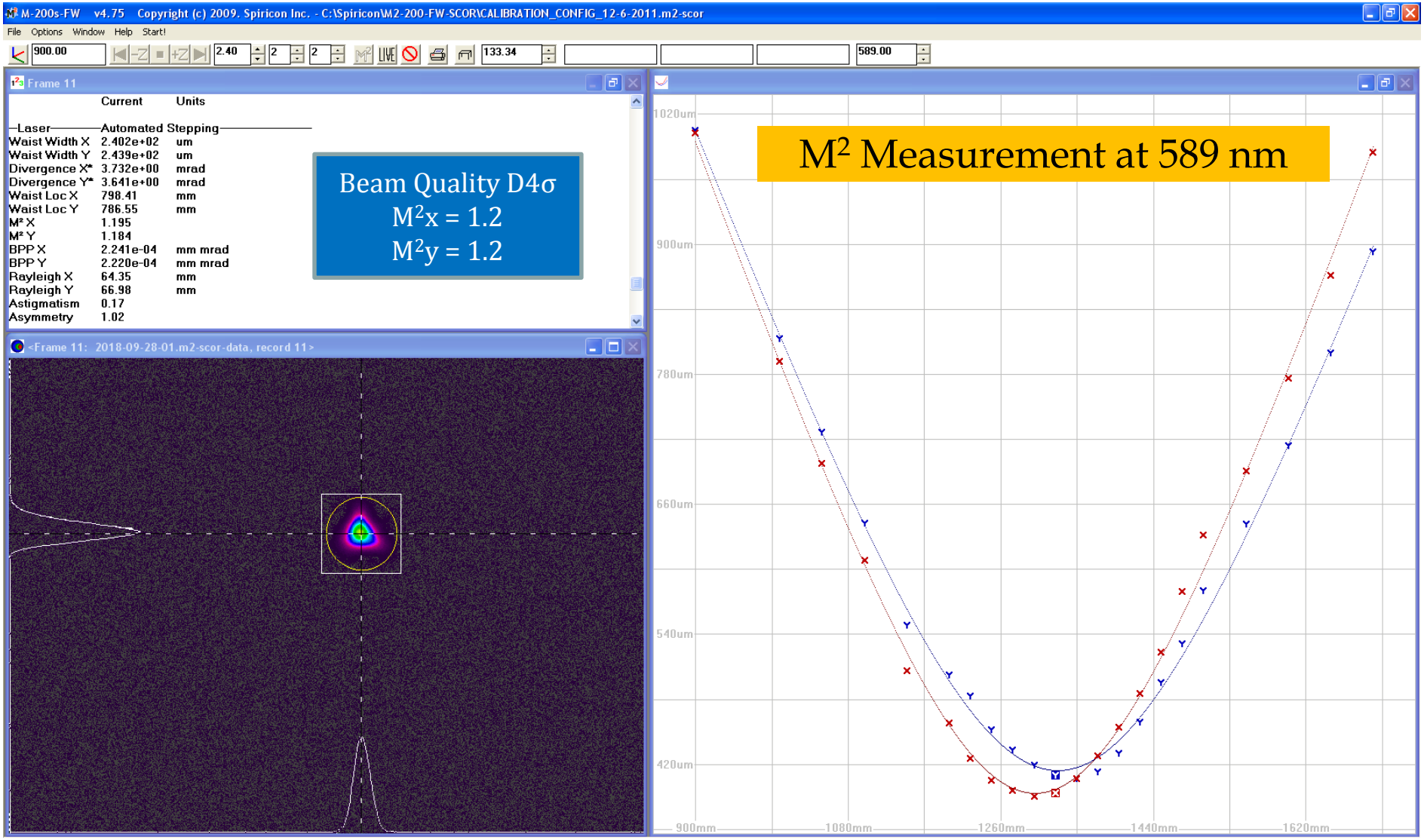


589 nm

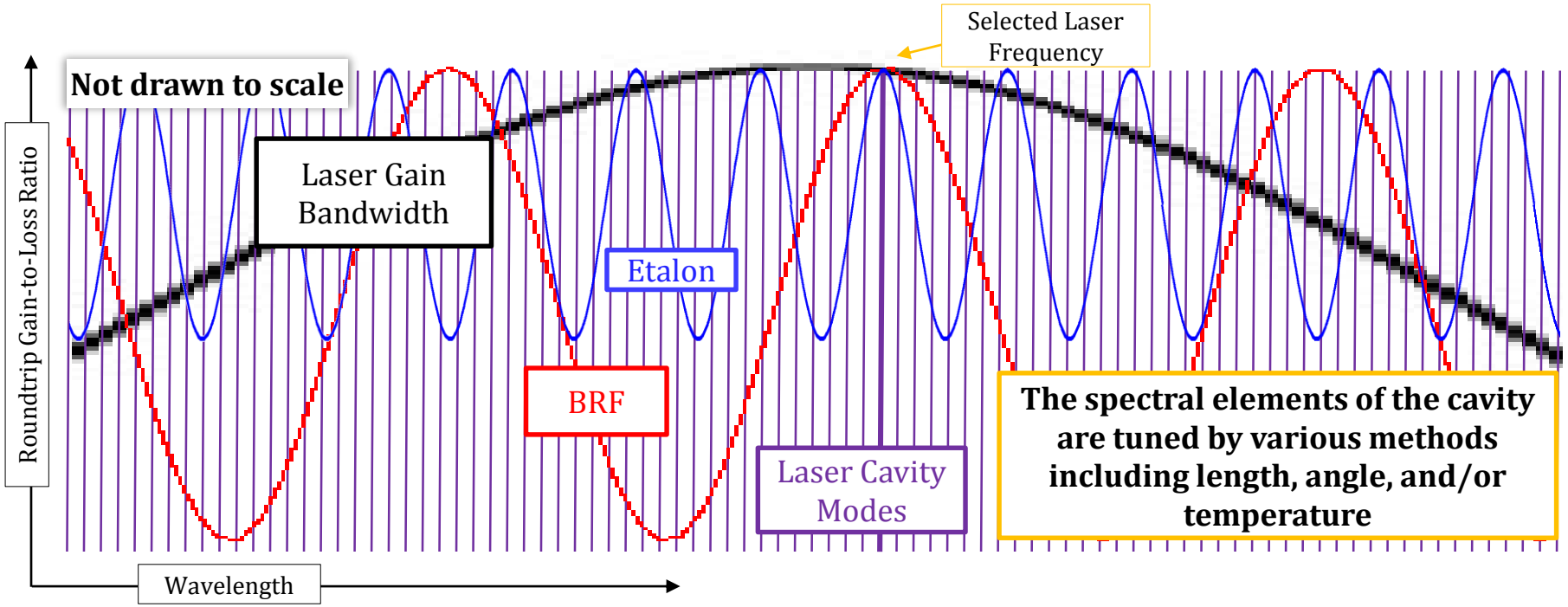


- Intracavity doubling is a highly attractive method of converting from the fundamental wavelength to 589 nm
- Low complexity
- Highly efficient

Good Beam Quality at 589 nm

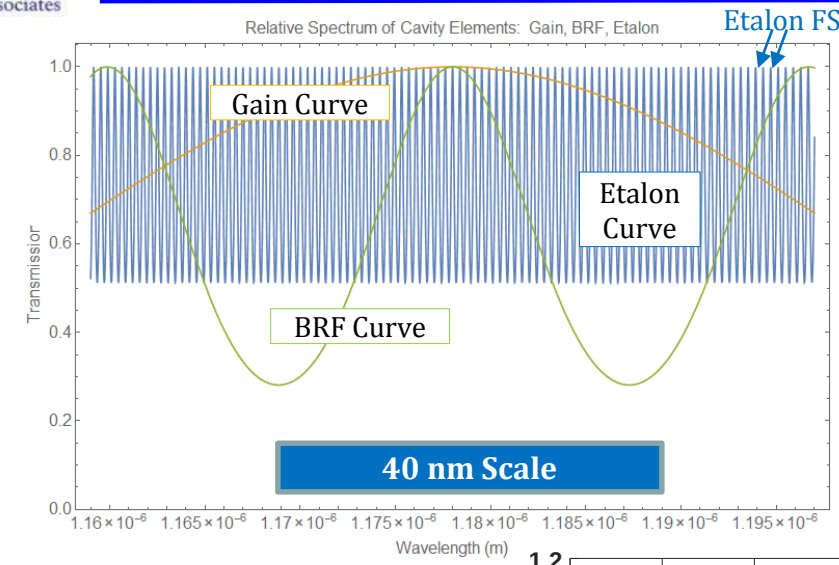


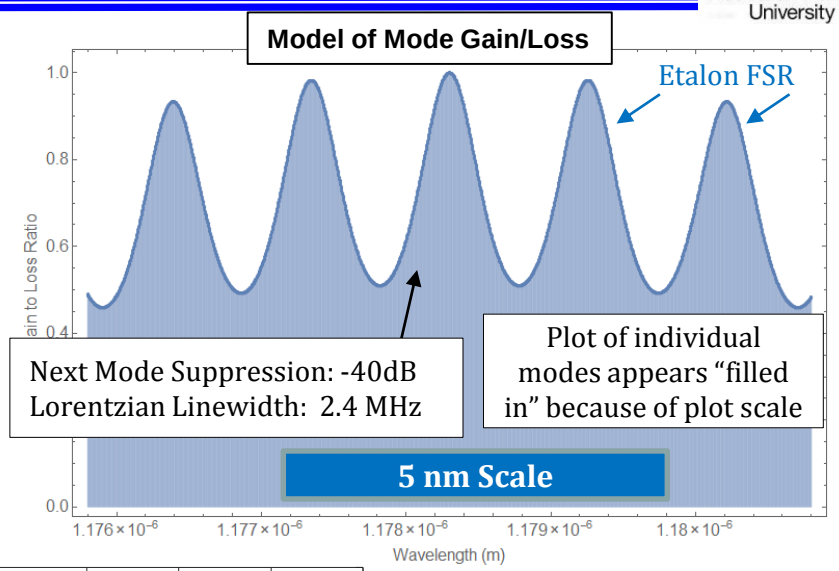
Tuning and Frequency Selection

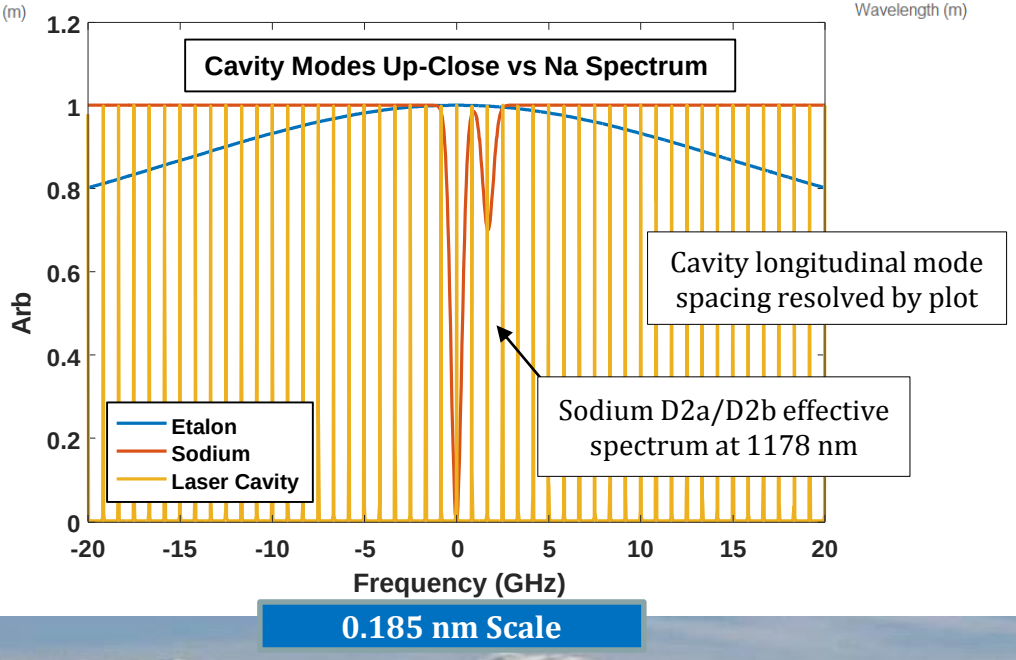


Gain Bandwidth supports lasing over broad range of frequencies, allowing large number of longitudinal **Laser Cavity Modes.**
BRF provides tunability of center wavelength and coarse frequency selection.
Etalon provides fine frequency selection of single cavity mode.
Piezo shifts laser modes in wavelength for extra-fine tuning on resonance
NLO not shown but has strong impact on frequency selection

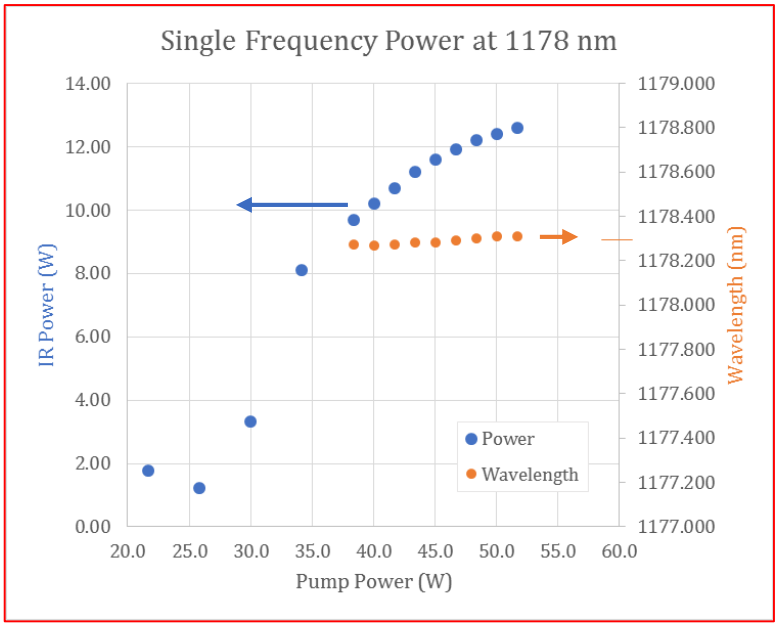
Frequency Selection on a Few Scales

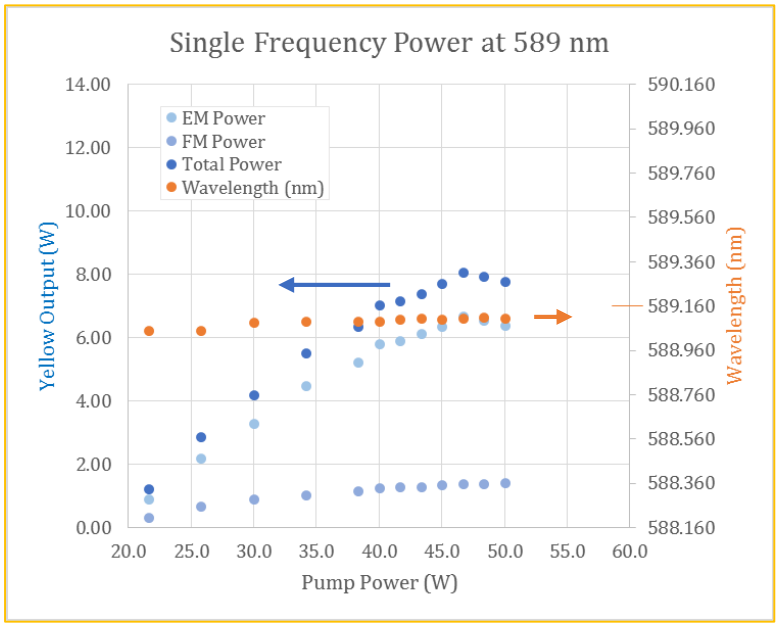






Single Frequency Operation





In the IR, laser “prefers” to run single-frequency.

The lasing mode steals gain from other modes and tends to be a stable equilibrium.

When intracavity doubling, achieving single-frequency is a delicate balance.

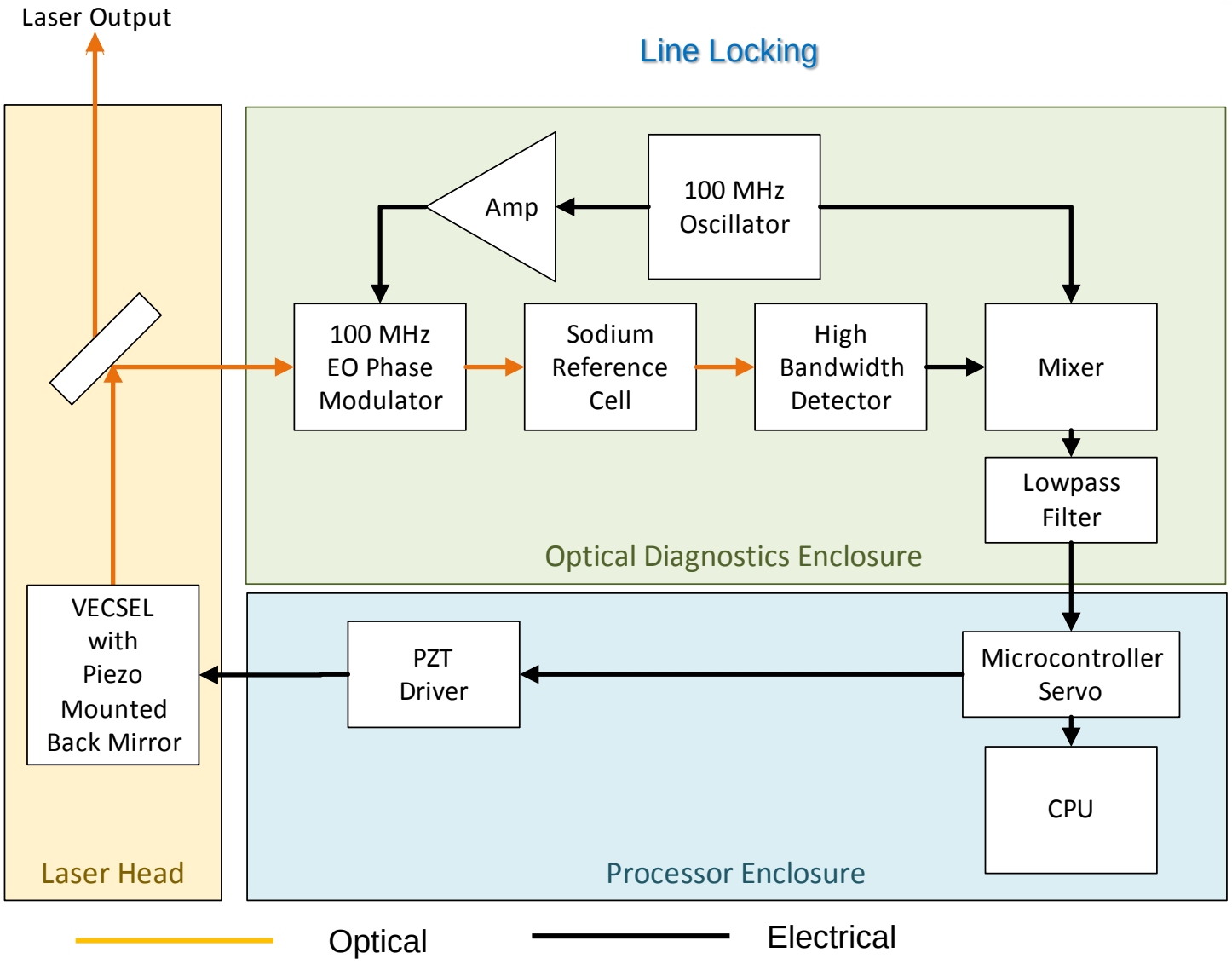
The lasing mode steals gain from other modes, but also incurs more intracavity loss due to nonlinear output coupling.

Despite challenges, reasonable output powers at 589 nm single-frequency on sodium resonance are presently achievable

Performance can an be improved with careful optimization

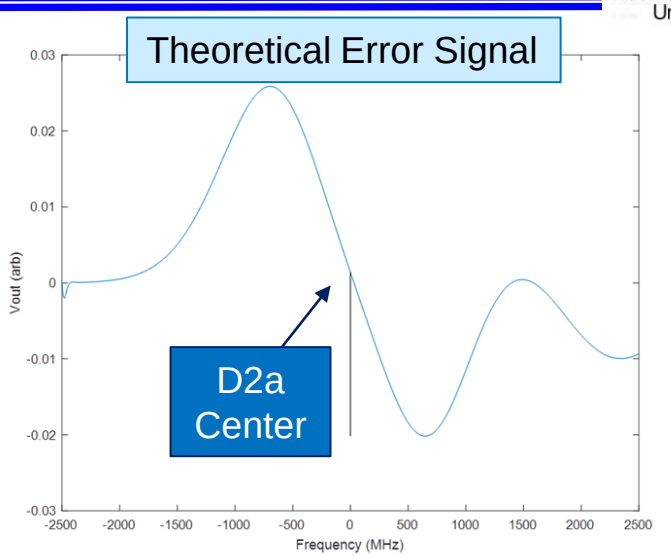
Work is underway to stabilize frequency while improving extraction efficiency

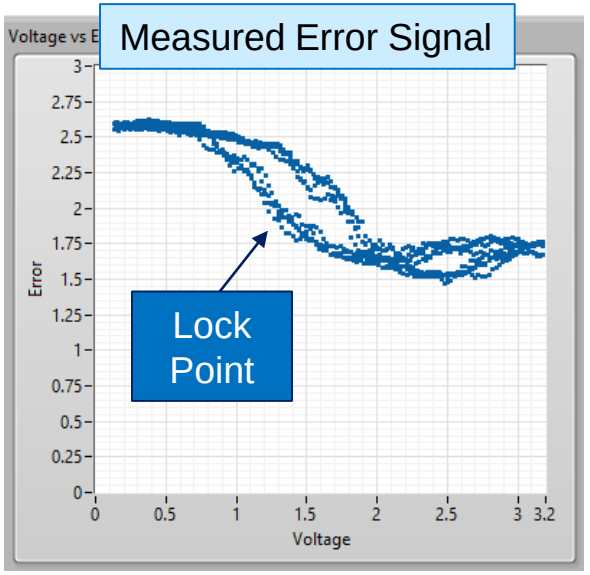
Wavelength Control Scheme

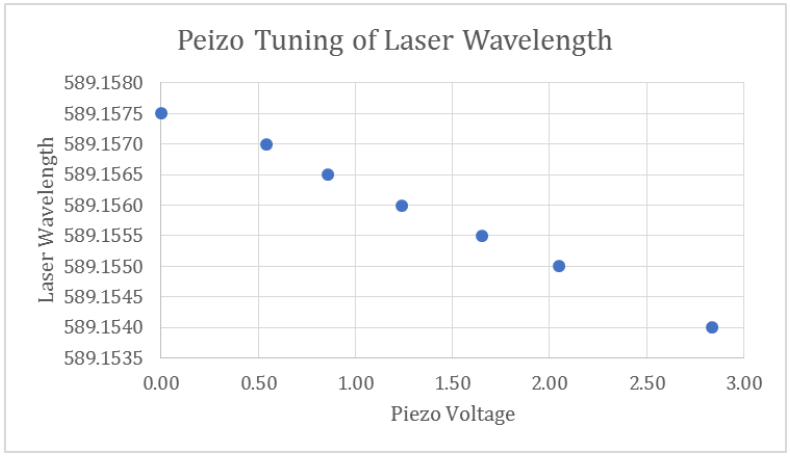


Line Locking

- IR wavelength measured while operating at 589 nm and tuning to resonance
- Mode-hop-free tuning over sodium resonance demonstrated
- System can be locked to D2a or D2b line center or offset from line centers







Summary & Next Steps

- SSGSLs are capable of achieving performance characteristics (power, frequency tuning/locking) sufficient for on-sky demonstration
- Presently implementing measures to improve frequency stability and power
- In coming months will begin prototype integration and test
  - Line locking refinement
  - Packaging
  - Testing
- Scheduled for Installation 2019 Q3 at Mt. Stromlo, Canberra Australia