International collaboration to develop Optically-Pumped Solid-state Laser (OPSL) for LGS AO applications

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Outline

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- Sodium laser state of the art and rationale to develop the next generation source
- Guidestar OPSL R&D state of the art
- International collaboration
  - NSF ATI proposal (submitted 3 Nov. 2014)
  - ARC LIEF proposal (to be submitted April 2015)
  - Prospective Partners in Astronomy and Satellite/ Space Debris Tracking applications

Sodium Lasers in *Routine* Operation at Astronomical and Tracking Telescopes

- Old generation (~2000-2014)
  - Dye lasers (already or soon to be decommissioned e.g. ESO VLT, Keck II)
  - Solid-state lasers (in operation e.g. Starfire Optical Range, Subaru, Gemini North, Keck I, Gemini South)
- Current generation (~2014+)
  - Fiber-based lasers (being, or to be, commissioned soon e.g. ESO VLT, Keck II, Stromlo)

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Sodium Laser State of the Art: Toptica SodiumStar[1]

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- Specifications[2]:
  - 589nm CW, 20W at Na D2a + 2W at Na D2b (re-pumping), 5MHz linewidth, near diffraction-limited
  - Laser head can be mounted on telescope, no further than 30m from electronics cabinet
- Only fully-engineered, commercially available source for the foreseeable future…with very high availability risk:
  - Production line will stop shortly after 5 first units (4 ESO + Keck II lasers) are/ have been delivered these days
  - Budget and schedule programmatic risks inherent to sole-source supplier e.g.
    - The need to resurrect the production line will add to future unit cost
    - Service agreements may not be enough to maintain company interest in this line of business for years to come
- Still relatively large (90x70x40cm^3 head + 90x91x173 cabinet) and demanding system (e.g. heat exchangers)
- Too expensive (>$1M)[3] for most would-be sodium LGS AO users/upgrades

Next Generation Sodium Laser Source

- ANU and Arete Associates propose to demonstrate a guidestar OPSL for LGS AO applications in Astronomy and Satellite/Space Debris Tracking applications
  - Arete Associates-led NSF Advanced Technologies and Instrumentation (ATI) proposal submitted Nov 3, 2014
  - ANU-led ARC Linkage Infrastructure, Equipment and Facilities (LIEF) proposal to be submitted in April 2015
- If proposed development successful, opens route to alternative, competitive, commercial sodium laser source option
  - Same performance specifications as Toptica SodiumStar
  - Lower complexity (no seed laser, no extra resonant doubling cavity and associated control electronics)
  - Smaller package (shoe-box size laser head)
  - Higher efficiency (less cooling)
  - Cheaper price (factor 2 or more cheaper than Toptica SodiumStar)

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Laboratory 589 nm OPSL

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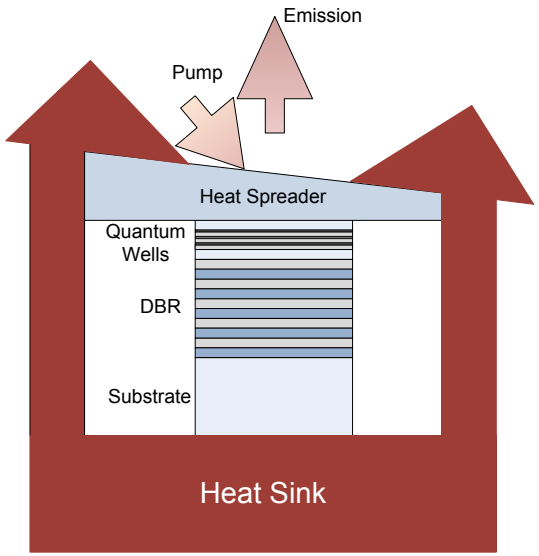
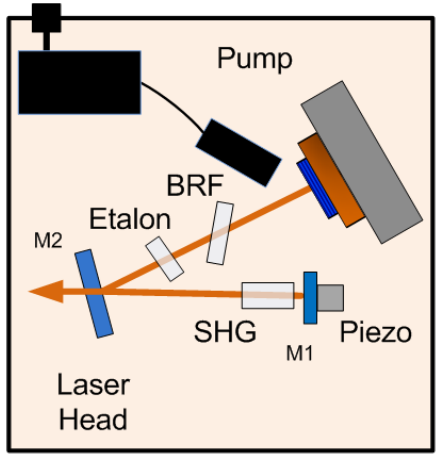
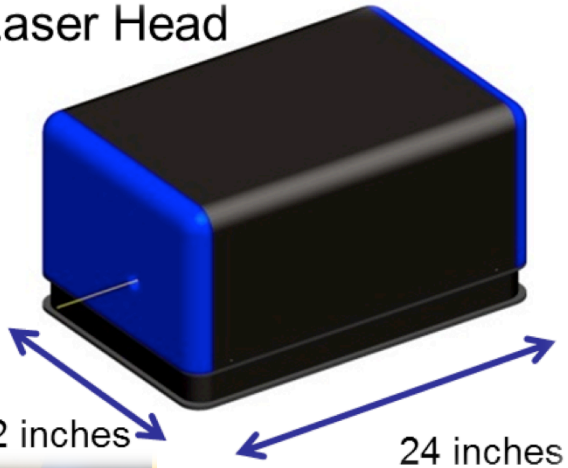
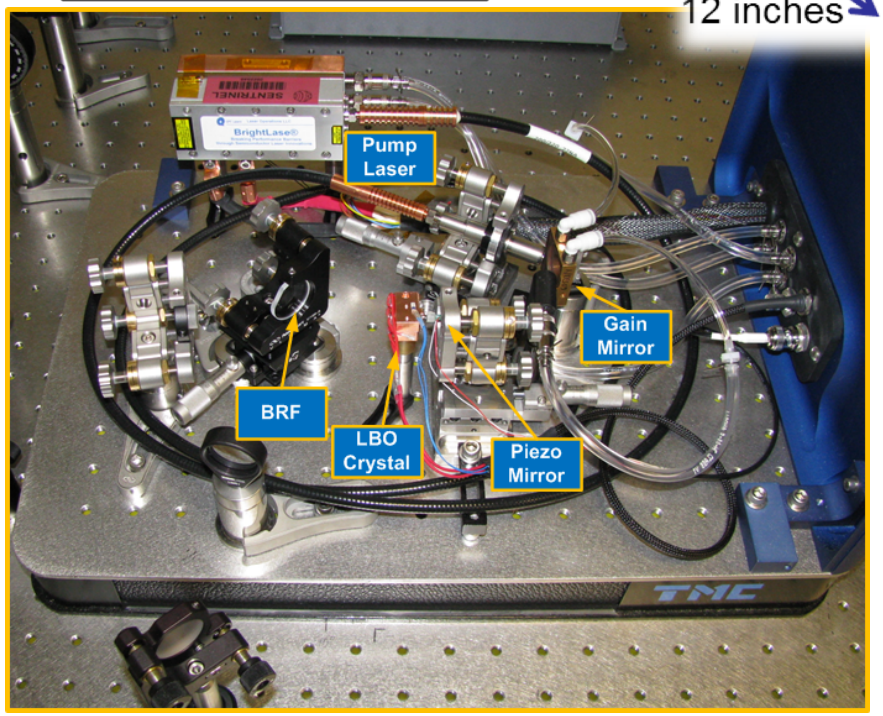
OPSL Gain Mirror





Laser Head





System produced in 2009-2012 under SBIR funding from NSF

Details reported at CfAO in 2012

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589 nm Single Frequency OPSL

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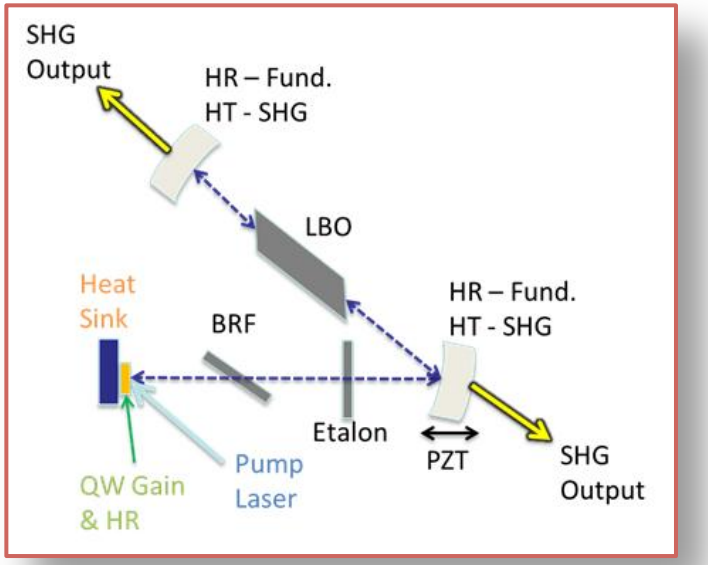

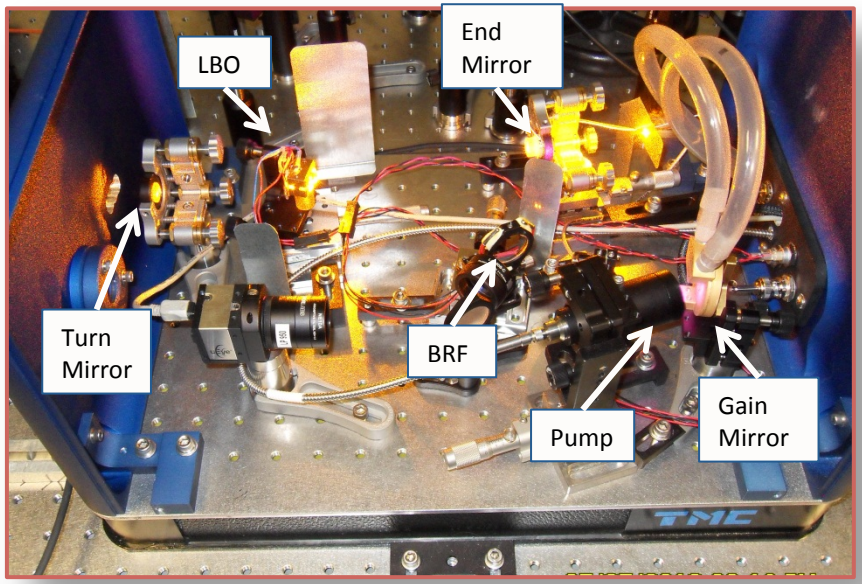

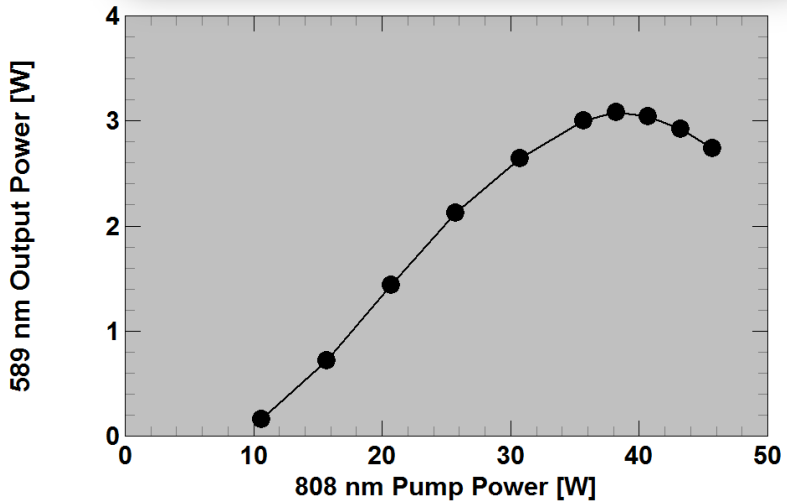

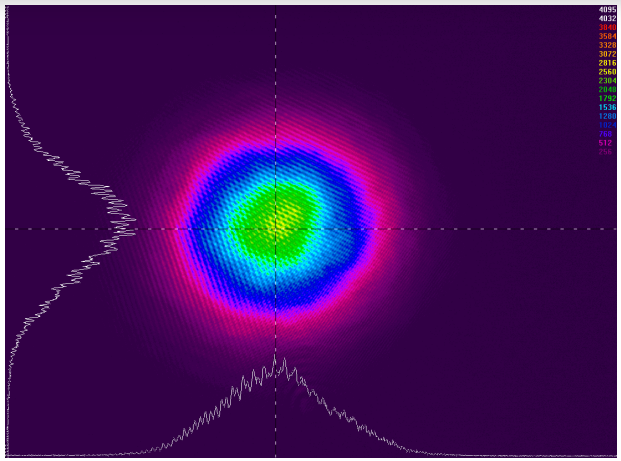

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Spectral Linewidth

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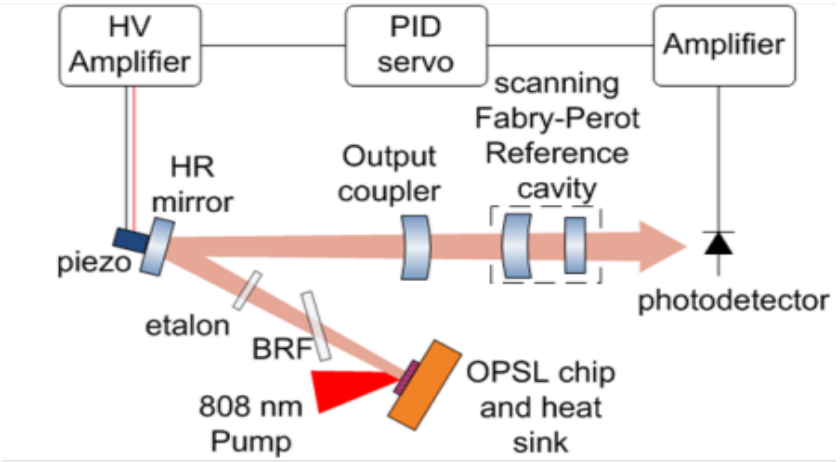
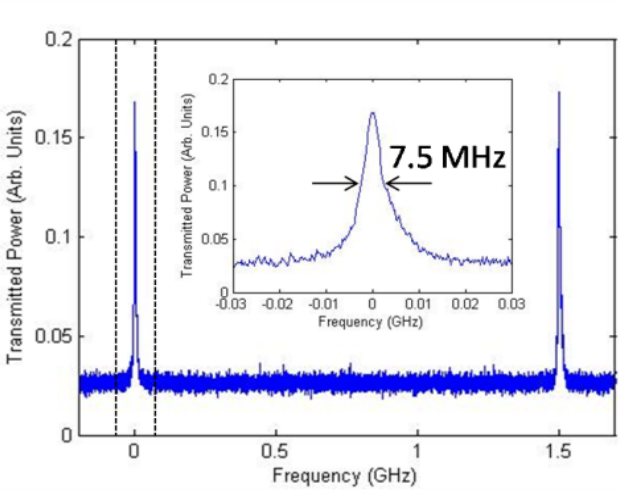
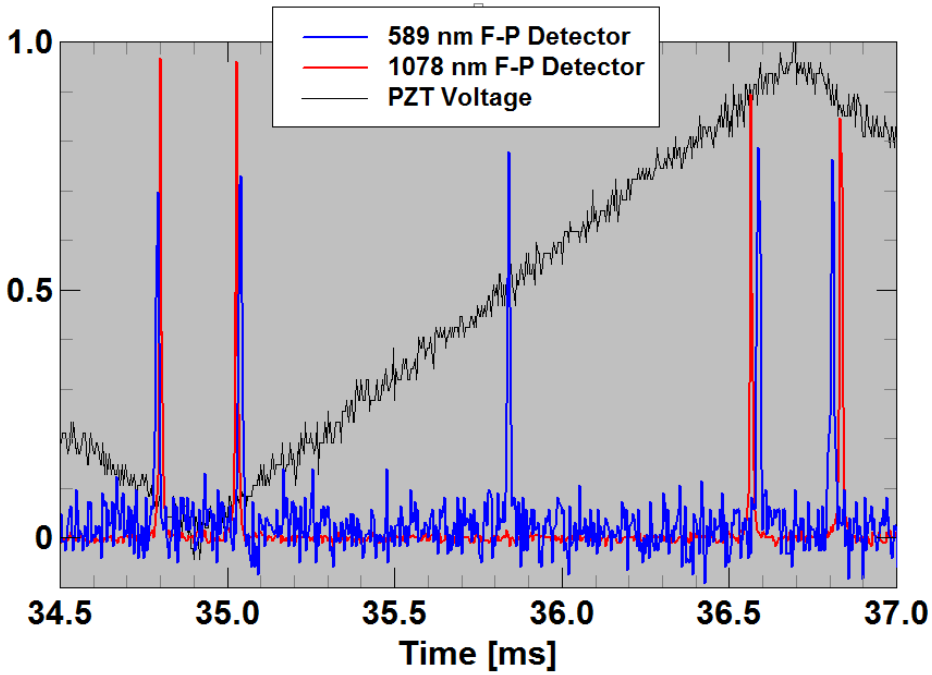


1178nm Linewidth Estimate





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Tunability

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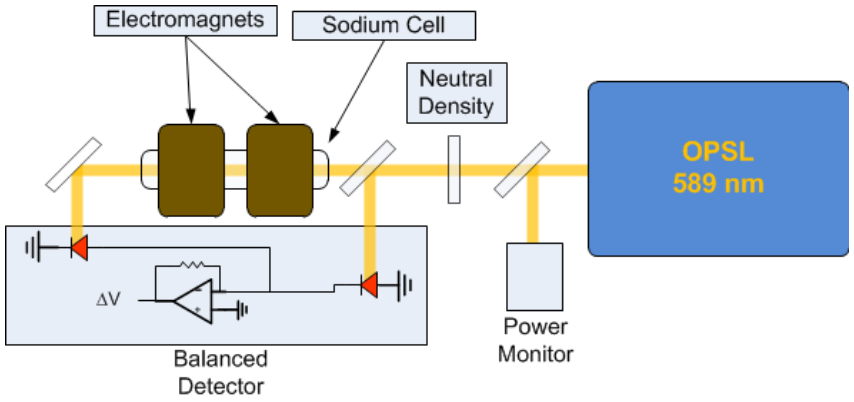
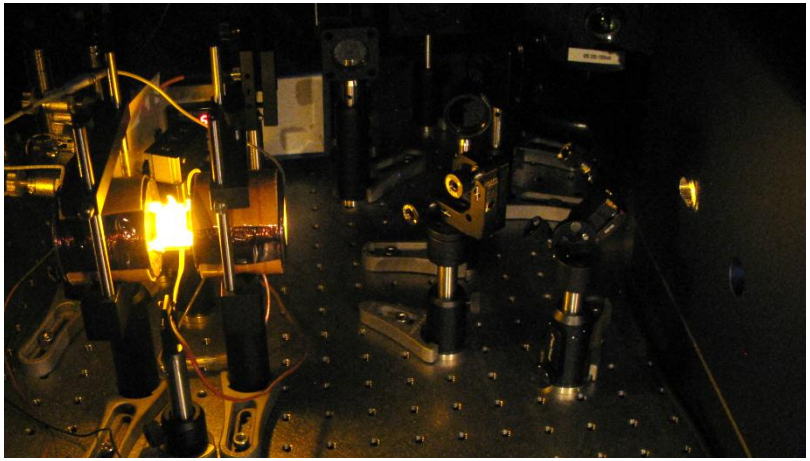
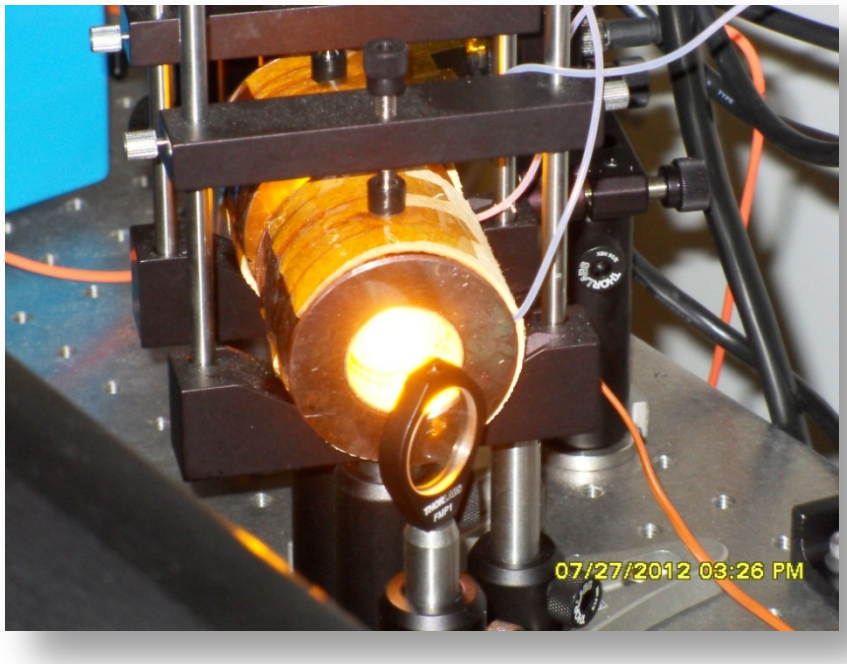
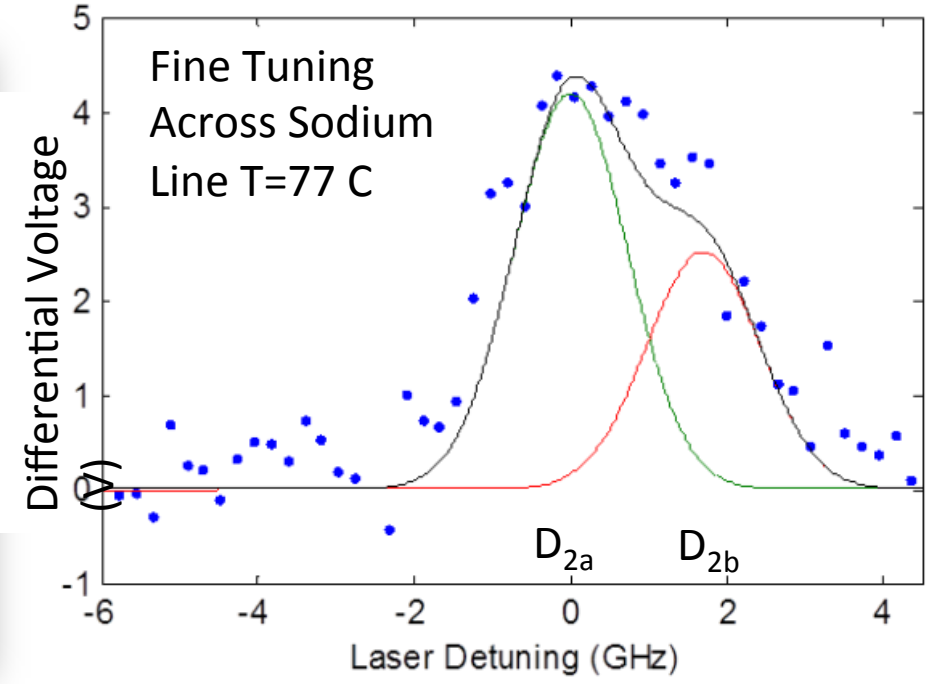


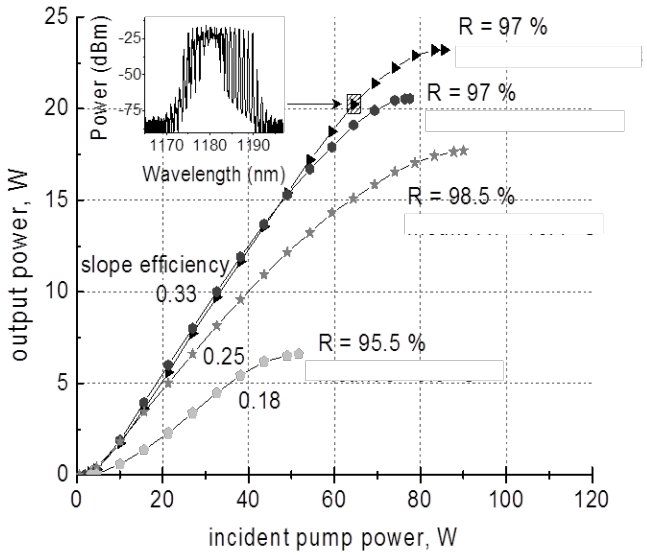




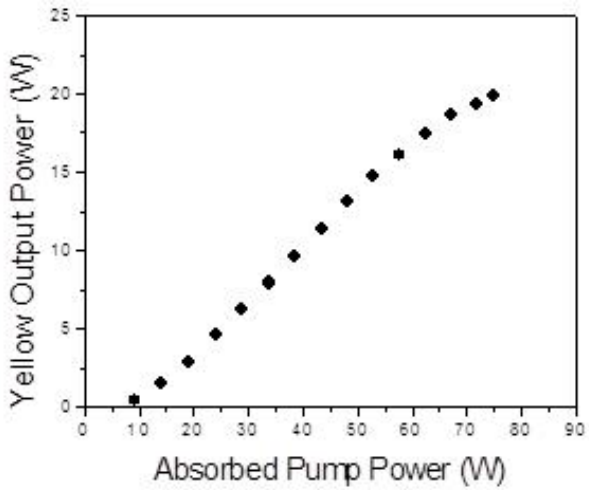


Power Scaling

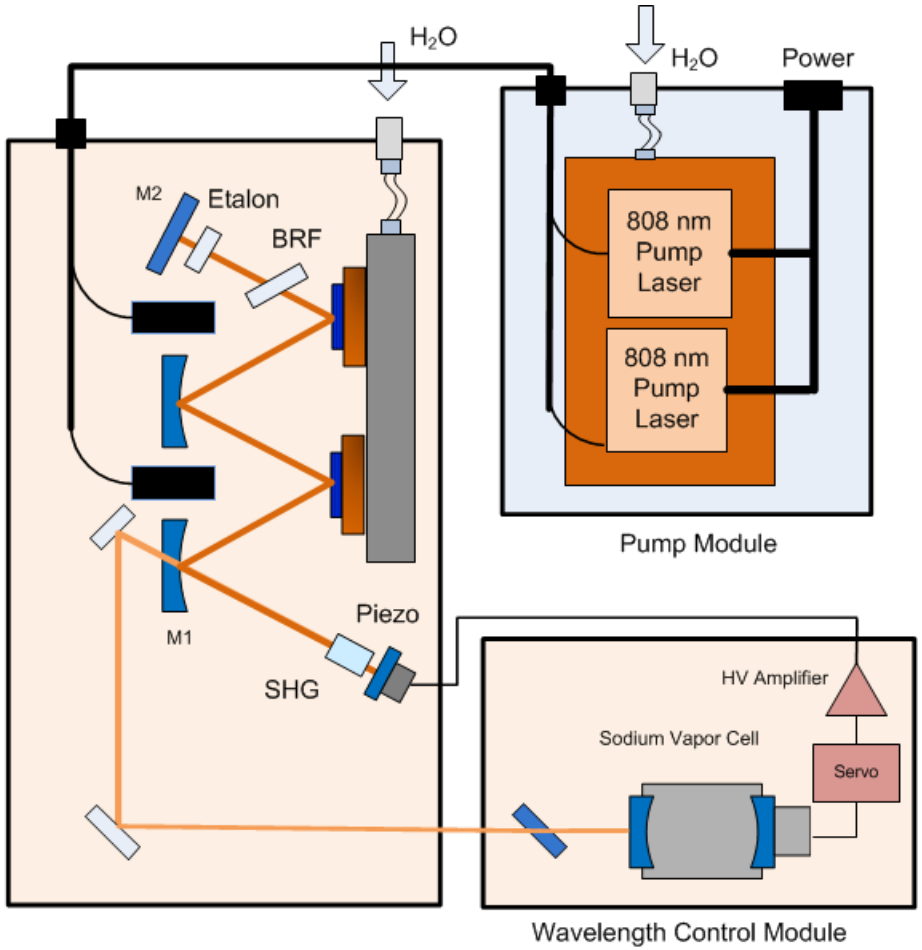
1178nm



588 nm



Multiple Gain Mirrors Can Be Used to Further Scale Power



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D_{2a} and D_{2b}

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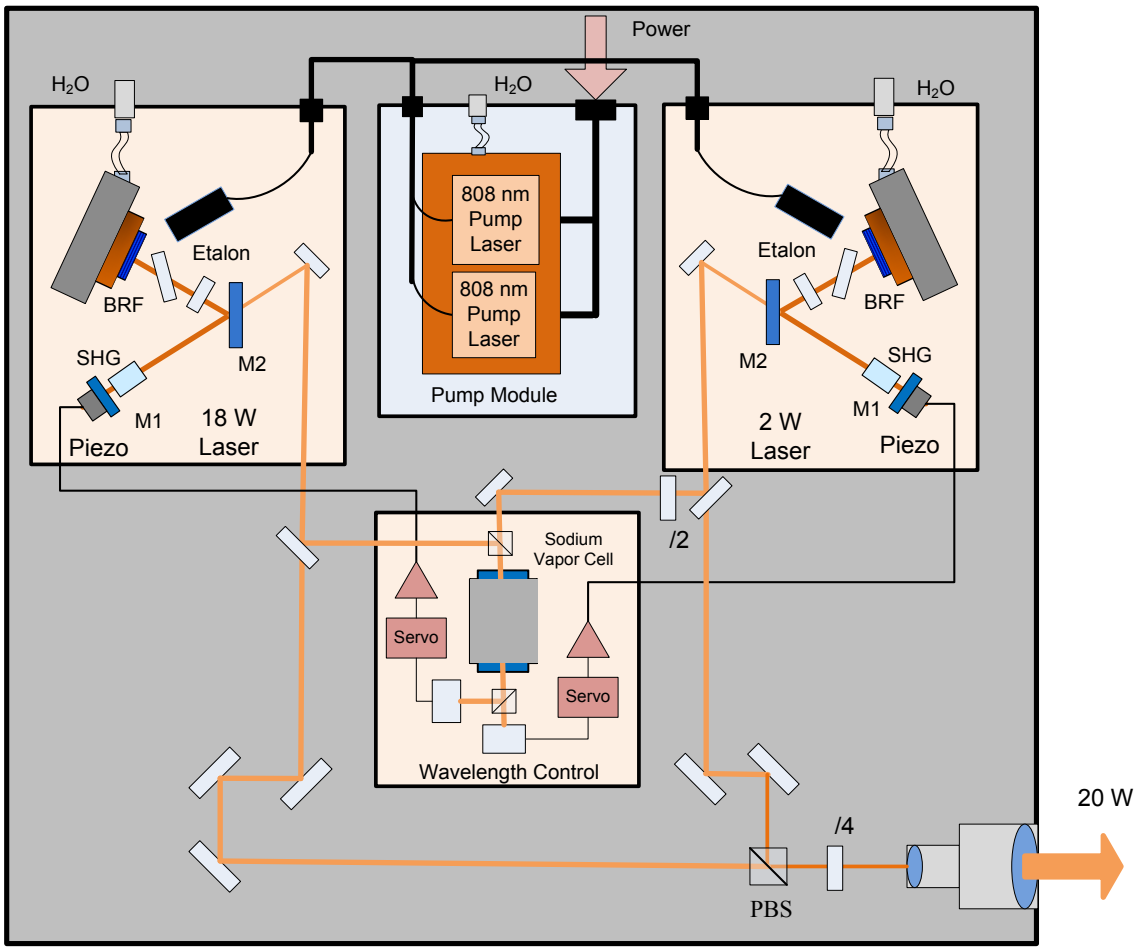
Multiple approaches to generating both wavelengths

- Polarization beam combining
- Sideband generation using EOM
- Coherent beam combining



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NSF ATI Proposal

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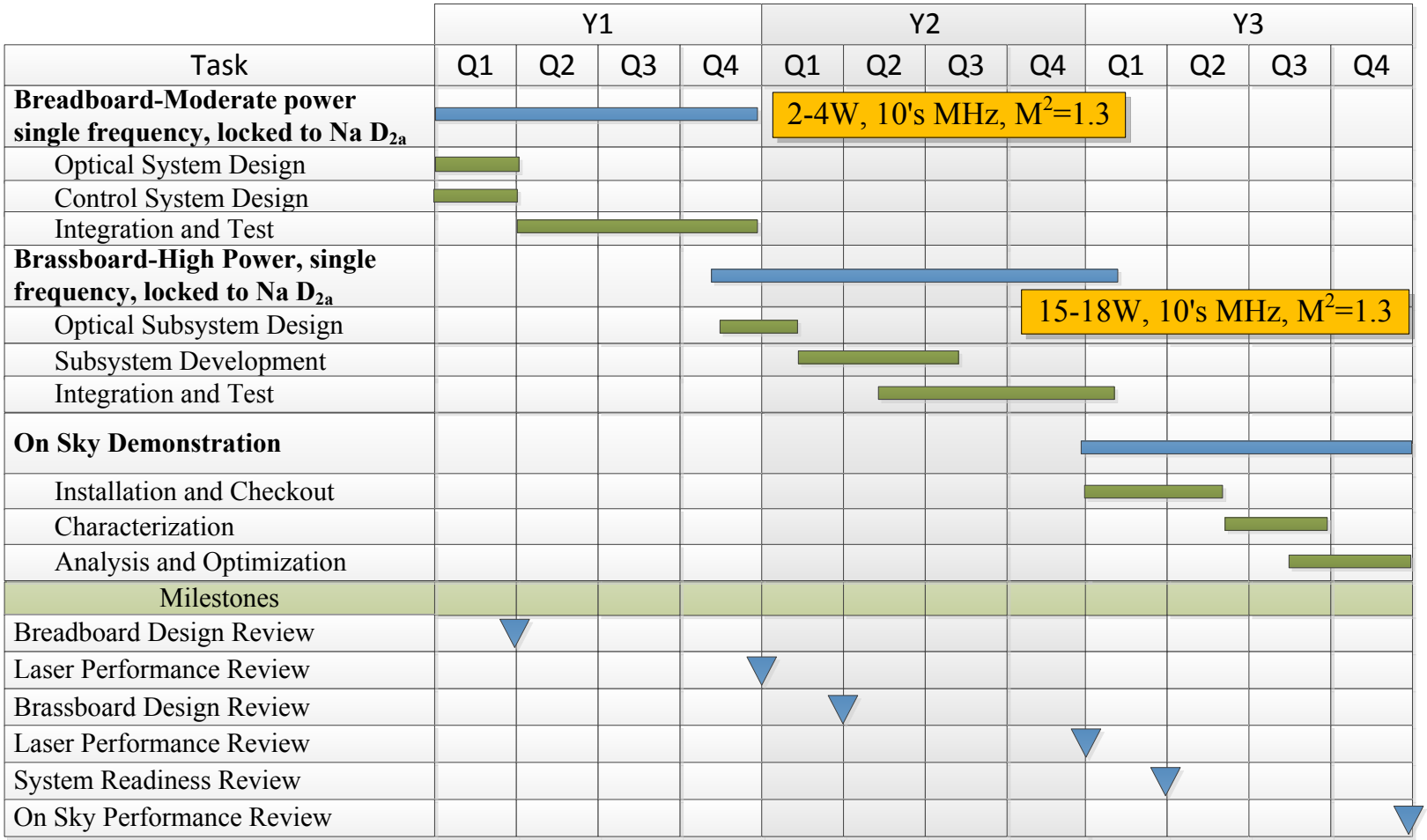
- Scope - Develop a 589 nm single frequency, high power OPSL and demonstrate it on-sky at the Kuiper telescope near Tucson, AZ
- Schedule - 3 Year Program
- Budget - ~$1.3M
- NSF ATI proposal
- Submitted Nov 3, 2014

NSF ATI Program Objectives and Team

Objectives
• Develop OPSL design for operation on the Kuiper telescope at the Steward Observatory on Mt. Bigelow near Tucson, Arizona • Build laser guide star system brassboard • Characterize and optimize laser performance with respect to sodium returns. • Transition guide star laser system to Steward Observatory

Team			
Organization	**PI**	**Role**	**Location**
Areté Associates	Dr. G. J. Fetzer	Laser Development	Longmont, CO
Steward Observatory	Dr. M. Hart	Beam Delivery Optics Telescope Installation On Sky Demonstration	Kuiper 61” Telescope Tucson, AZ
Australian National University	Ms. C. D’Orgeville	Guide Star Laser Expertise Program Oversight	Canberra, AU

NSF ATI Program Plan



ARC LIEF Proposal

DISCLAIMER: The material contained herein is only preliminary and the ARC LIEF proposal will evolve depending on eventual partner interest and contribution levels…

ARC LIEF Project: Technical Objectives

- Laser system architecture
  - 1178nm OPSL with intra-cavity doubling to produce 589nm
  - Single-frequency operation, locked to sodium D2a line
  - D2b repumping [*optional depending on final budget*]
- Laboratory demonstrations
  - ✓ High power, broadband operation[4, 5]
  - ✓ Low power, single frequency operation[6, 7]
  - ❑ High power, single frequency operation
  - ❑ Guidestar OPSL prototype performing at specifications
- On-sky demonstrations [*either or both depending on partners*]
  - ❑ At partner astronomical telescope
  - ❑ At partner satellite/space debris laser tracking station

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ARC LIEF Project: Schedule & Budget

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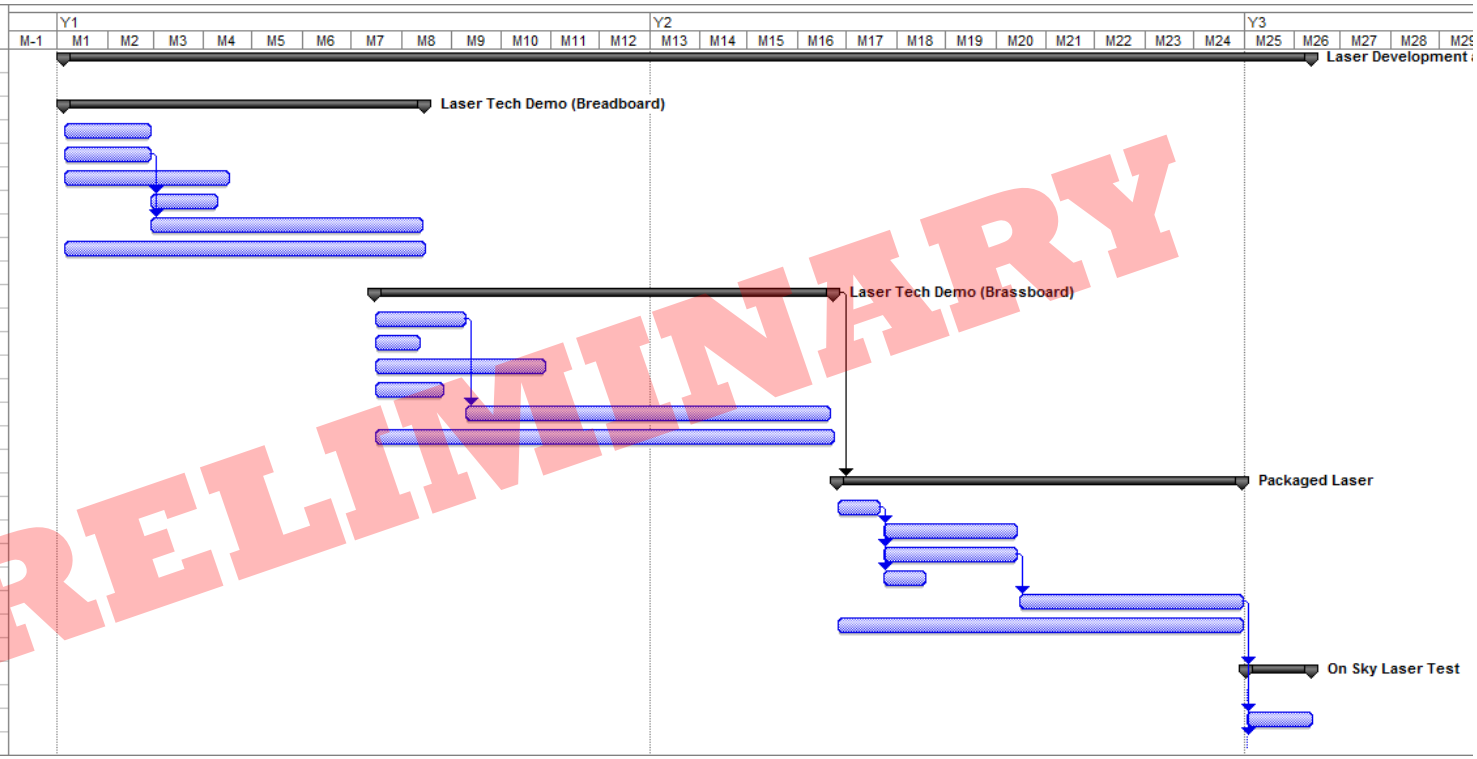
- 3-year program with early/mid 2016 start
  - Year 1: Laboratory demonstrations
  - Year 2: Prototype development
  - Year 3: On-sky demonstration
- Total funding ~$2M (AUD) including:
  - ~$1.2M to be requested from ARC over 3 years
  - ~$500k to be provided by ANU over 3 years
    - LIEF requires that partner cash contribution be >25% of requested ARC funds
    - ANU typically supports 25% of ANU-led ARC LIEF bids
  - Remaining ~$300k to be provided by ANU and other Partners (cash and/or in-kind) over 3 years

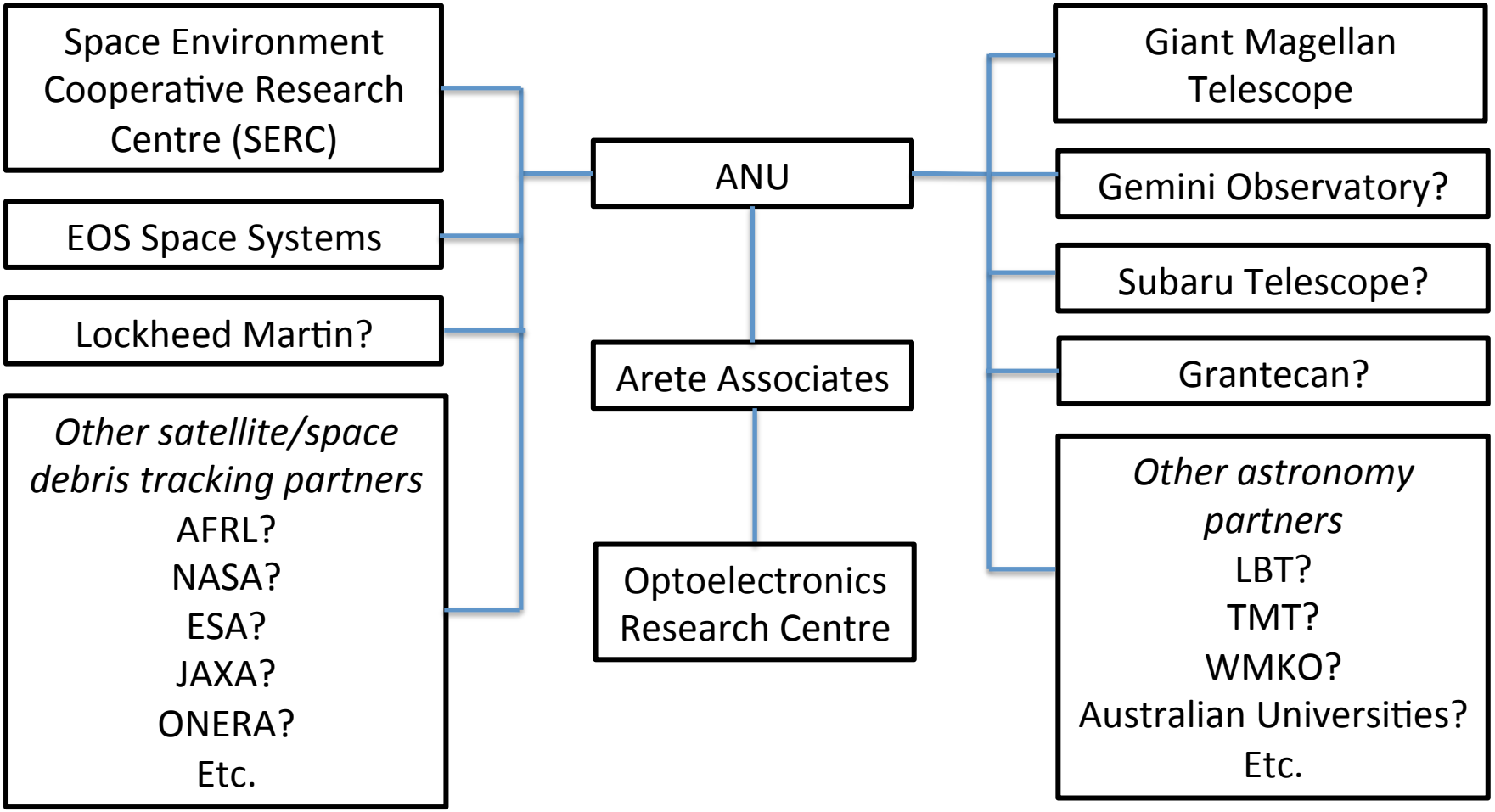
ARC LIEF Project: Work Plan

- ANU: Project management; system engineering; laser system packaging; controls; assembly; laboratory and on-site testing
- Arete Associates: Laser head development
- Other partners: User requirements; on-site testing; other contributions depending on interest/opportunities

ID	WBS	Task Name
1	1	**Laser Development and Demonstration**
2		
3	1.1	**Laser Tech Demo (Breadboard)**
4	1.1.1	Optical Subsystem Design
5	1.1.2	Control System Design
6	1.1.3	Chip Procurement
7	1.1.4	Materials
8	1.1.5	Integration and Test
9	1.1.6	Management
10		
11	1.2	**Laser Tech Demo (Brassboard)**
12	1.2.1	Optical Subsystem Design
13	1.2.2	Control System Adaptation
14	1.2.3	Chip Fabrication
15	1.2.4	Materials
16	1.2.5	Integration and Test
17	1.2.6	Management
18		
19	1.3	**Packaged Laser**
20	1.3.1	Requirements Flowdown
21	1.3.2	Software
22	1.3.3	Mechanical
23	1.3.4	Thermal Control
24	1.3.5	Integration and Test
25	1.3.6	Management
26		
27	1.4	**On Sky Laser Test**
28	1.4.1	Travel
29	1.4.2	Install and Operate
30	1.4.3	Shipping



ARC LIEF Proposal: Partner Organizations



ARC LIEF Proposal: Important Dates

2014

- November/December: Build partnership

2015

- January/February: Finalize project scope and budget based on partner cash and in-kind contributions
- February/March: Write proposal
- April: Submit proposal
- October-November: Award announcements

2016

- January + 3-6 months: Project start (once partner agreements are signed)

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Guidestar OPSL: Future Plans

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- If prototype demonstration successful, plan is to seek additional funding to develop commercial product in Years 4-5
  - IP generated by ARC LIEF will be shared with contributing Partners
  - Commercialisation avenue discussion already initiated
- Guidestar OPSL R&D overall program will be updated depending on success of NSF ATI and ARC LIEF proposals
  - ARC LIEF project scope independent of NSF ATI proposal outcome
  - Scope may increase if both proposals receive funding
- Future research avenues:
  - Increase output power
  - Coherently combine multiple 589nm beams using optical phased array technique being developed by ANU and EOS under existing, on-going ARC Linkage Project

References

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