Australian National University

First Laser Guide Star for Space Debris Tracking, Imaging and Manoeuvring in Australia

Celine d'Orgeville[1,2]

Fetzer G.[3] , Rako S.[3] , Webb J.[1,2] , Lingham M.[1,2], Price I.[1] , Brodrick D.[1], Galla A.[1], Hassan Krishna S.[1], Blundell M.[4], Chan A.[4], Smith C.[4]

(1) ANU; (2) Space Environment Research Centre; (3) Arete Associates; (4) EOS Space Systems

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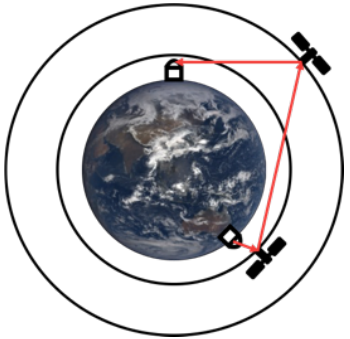
Outline

- LGS AO research @ ANU AITC
  - Astronomy
  - Space Situational Awareness
- ANU **Semiconductor Guidestar Laser** program
  - 4th generation of sodium guidestar laser technologies
  - Testing at Mt Stromlo Observatory, Australia
  - Testing on Subaru 8m Telescope, Hawaii, USA

LGS AO Research @ ANU Advanced Instrumentation and Technology Centre (AITC)

- World-leading AO research and development team
  - 9 AO/laser/RTC instrument scientists
  - 7 postgraduates & 10-20 undergraduates
  - Supported by 20-25 ANU AITC engineering staff



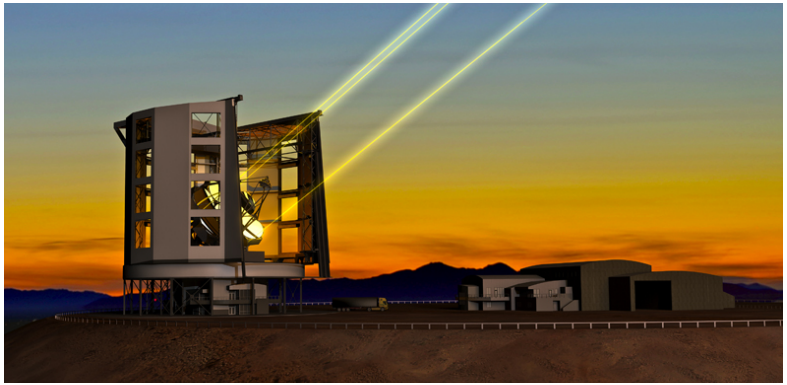
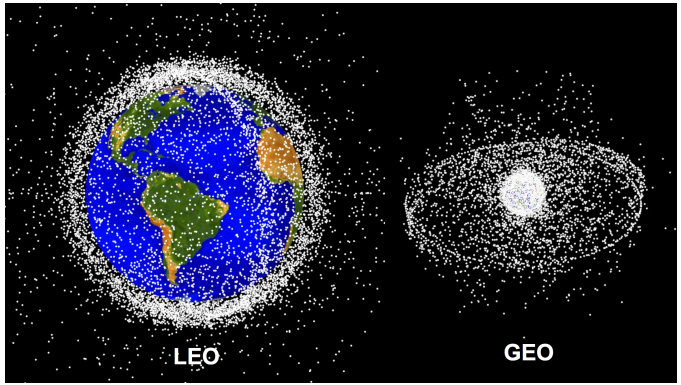


Image Credit: Giant Magellan Telescope Organization



Adaptive Optics for Astronomy

- "Classic" LGS AO as well as multi-mirror, multi-LGS systems
  - SCAO (8m Gemini North, 10m Keck I & II, Hawaii)
  - MCAO-IR (8m Gemini South, Chile) & MCAO-Vis (8m ESO Very Large Telescope, Chile)
  - GLAO (8m Subaru telescope, Hawaii)
  - LTAO (25m Giant Magellan Telescope, Chile)

GeMS 5-LGS constellation (Gemini Observatory)

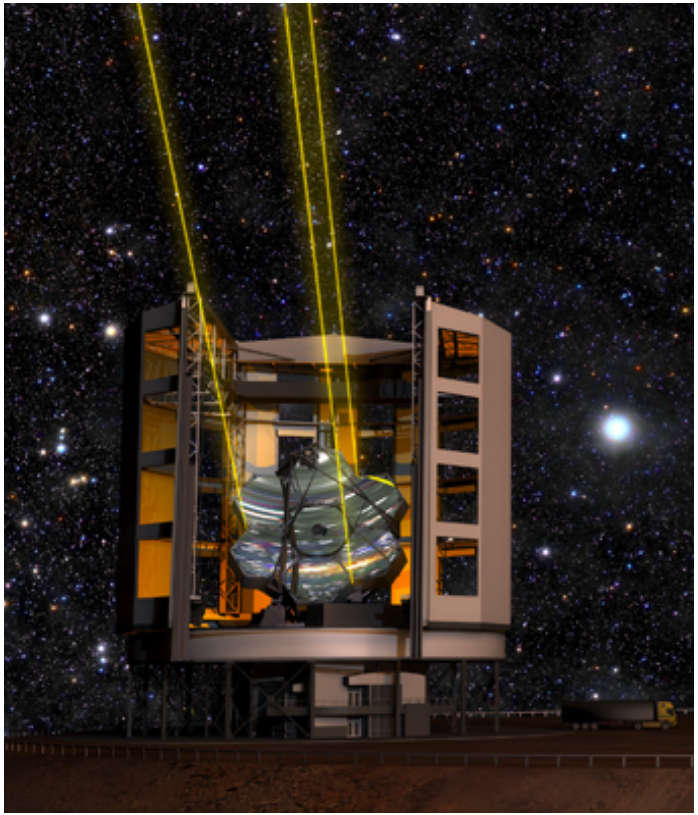
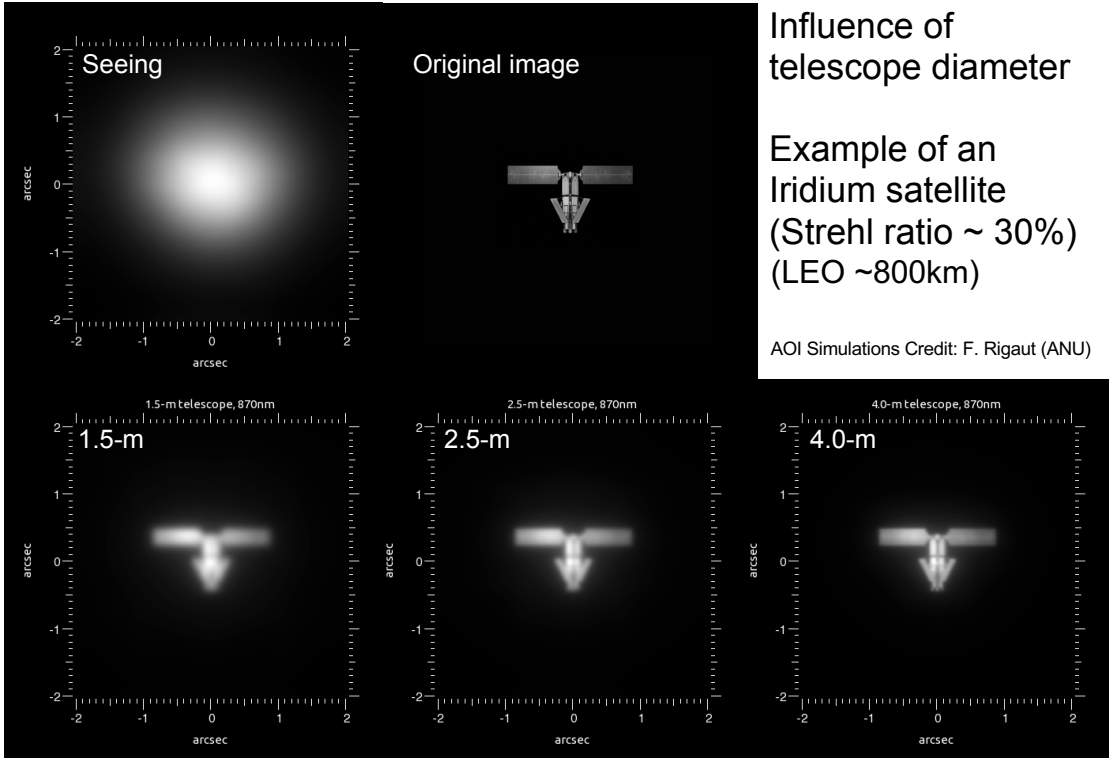


Image Credit: Giant Magellan Telescope Organization

Adaptive Optics for Space Situational Awareness

- NGS AO for Korea Astronomy and Space Science Institute satellite laser tracking station (2017)
- LGS AO for the Space Environment Research Centre (2019)
  - Imaging resolution of satellites at LEO: 0.1” i.e. 50cm @ 1000km
  - Tracking accuracy of space debris at GEO: <2m for mag. 15 object (~1m^2 @ 36,000km)



Influence of telescope diameter

Example of an Iridium satellite (Strehl ratio ~ 30%) (LEO ~800km)

AOI Simulations Credit: F. Rigaut (ANU)

Adaptive Optics for Space Situational Awareness

- SERC objectives:
  - tracking, orbit propagation, collision prediction
  - mitigation of debris to debris collisions using photon pressure from AO-compensated high power IR laser
- Dedicated LGS AO Tracking and Pushing system

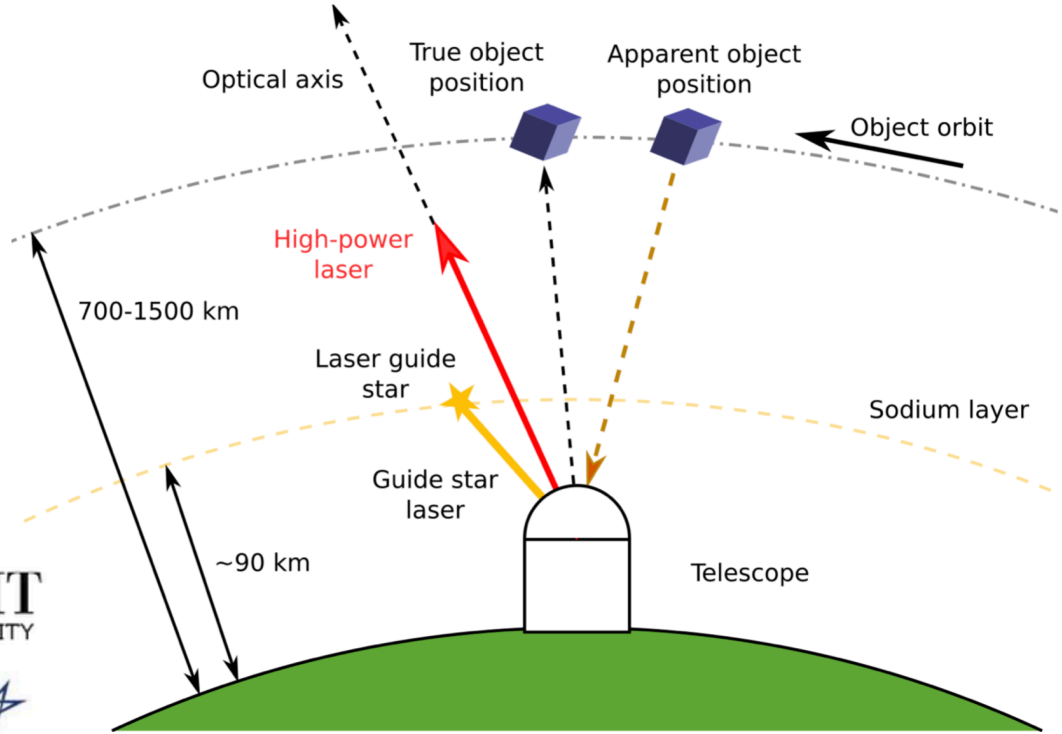
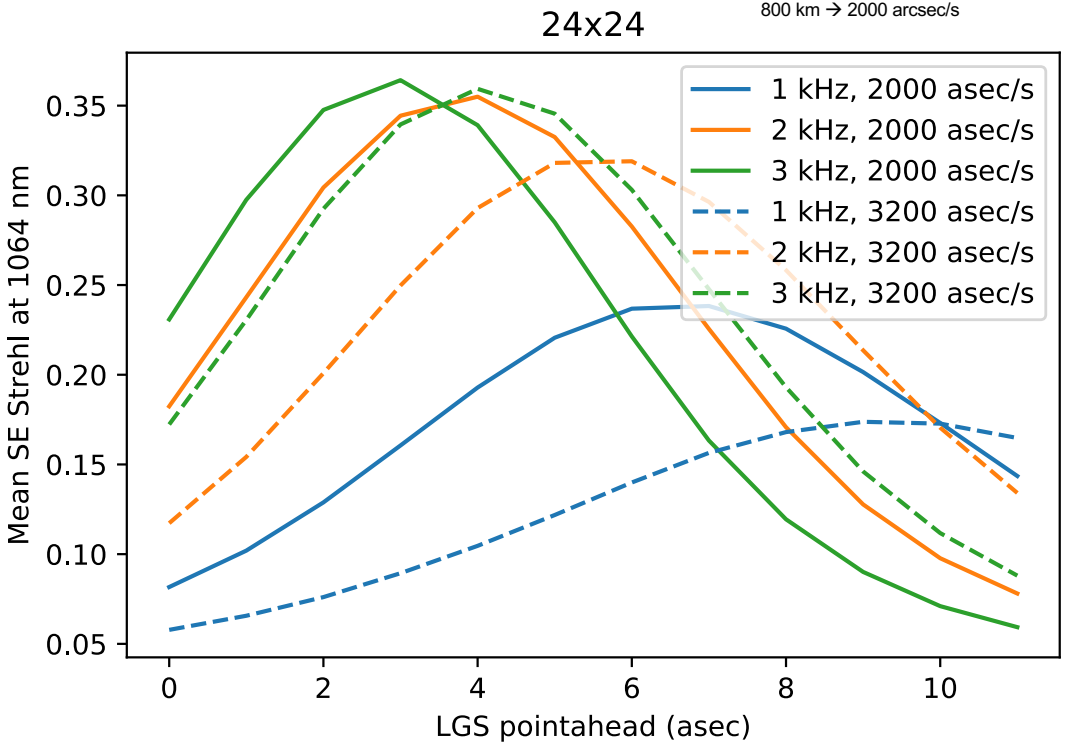


Image credit: D. Grosse (ANU)

Laser Guide Star Point Ahead Angle

- Study performed by Dr Visa Korkiakoski (ANU) for AO on 1064nm laser in 2” seeing
- Optimum LGS point ahead boosts AO performance in all configurations (LEO and GEO) by a factor ~2 to 3
  - 2-10 arcsec typical
- Optimum angle varies with object velocity & AO loop rate
  - Lower altitude → Greater velocity → Larger angle
  - Higher loop rate → Smaller angle

LEO objects:
500 km → 3200 arcsec/s
800 km → 2000 arcsec/s



AO Simulation credit: V. Korkiakoski (ANU)

Sodium Guidestar Laser Technology State of the Art

- Review paper: d'Orgeville & Fetzer, Proc. SPIE 9909, 99090R (also presented @ 2016 LSSE)
- Three generations of sodium guidestar lasers to date:

ALFA CW dye laser @ Calar Alto Observatory (Spain)

1st Gen. (1990s)

50W CW mode-locked solid-state laser @ Gemini South (Chile)

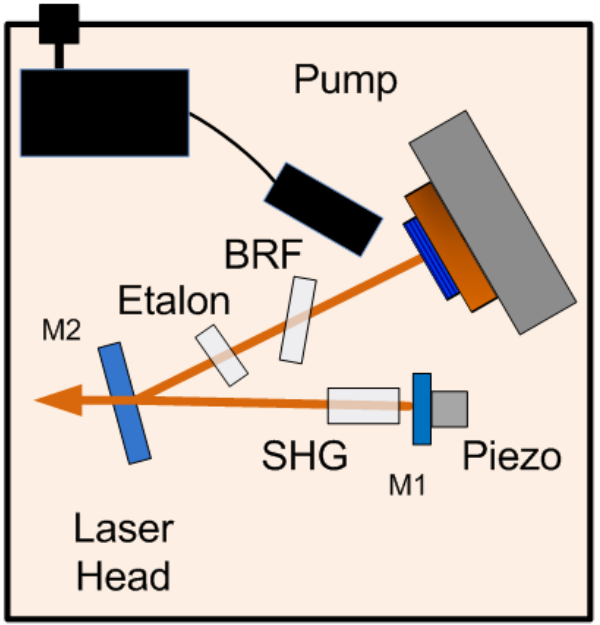
2nd Gen. (2000s)

20W Toptica SodiumStar fibre laser @ Keck Observatory (Hawaii, USA)

3rd Gen. (2010s)

Semiconductor Guidestar Laser (SGL) Program

- 4th gen. sodium guidestar lasers (~2020s)
  - Based on semiconductor laser technology
  - a.k.a Vertical External-Cavity Surface-Emitting Lasers (VECSEL)
  - a.k.a Optically Pumped Semiconductor Lasers (OPSL)
- Technology demonstrated and commercialised at other λ
- Low component count leads to:
  - Small SWaP (Size Weight and Power)
  - Affordable procurement cost
  - Reduced maintenance cost



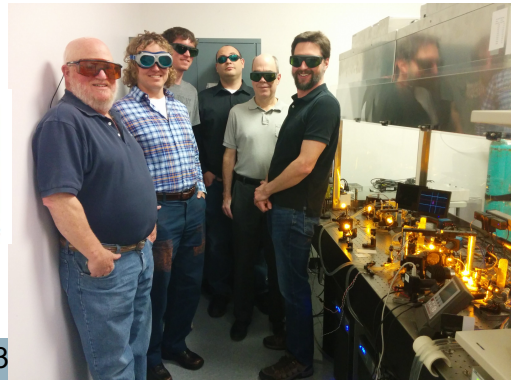
Intra-cavity doubled OPSL

(Image credit: Areté Associates)

Semiconductor Guidestar Laser (SGL) Program

- ANU-led program to build a **prototype** for use in astronomy, space, and laser communications
- Funding to date:
  - Government: Australian Research Council
  - Academia: ANU, UNSW
  - Observatories: AAO, GMT
  - Industry: EOS Space Systems, Lockheed Martin
- Laser vendor:

Areté Associates



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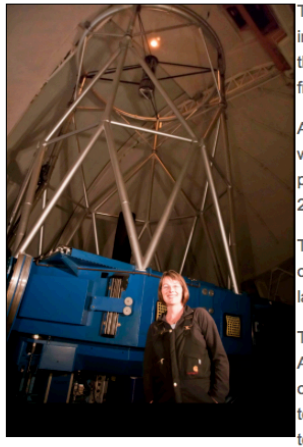


The creation of a new laser system for the first Australian laser guide star that will have important and far-ranging uses in astronomy, satellite tracking and mitigation of the threat of space debris will soon be possible, following the award of a $502,453 grant from the Australian Research Council (ARC).

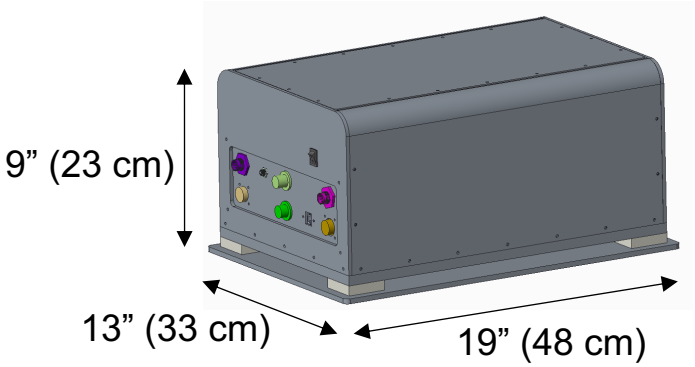
Associate Professor Celine d'Orgeville, from The Australian National University (ANU), will lead the successful ARC Linkage Infrastructure, Equipment and Facilities (LIEF) project announced as part of the ARC Major Grants Announcement on 1 November 2016. The ARC is providing $28.6 million for 48 new LIEF projects.

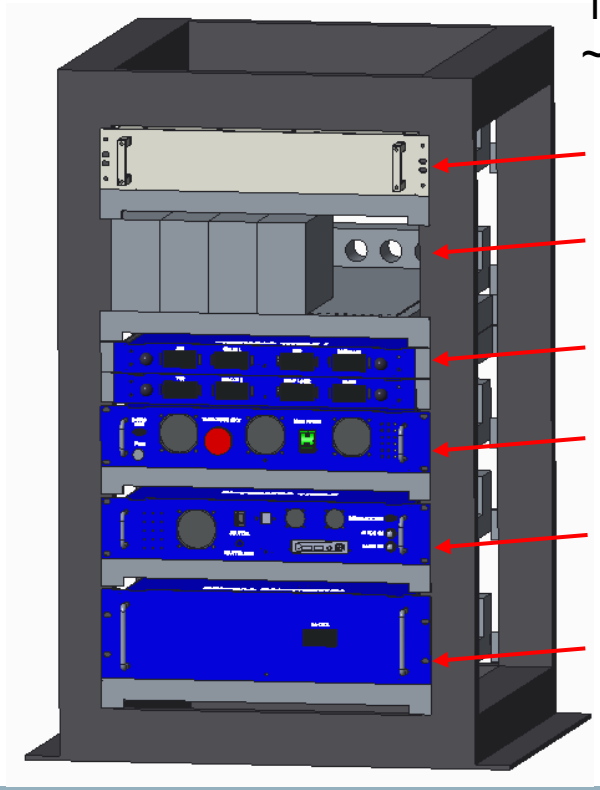
The new project, to commence in 2017, will use semiconductor laser technology as a cost-effective, highly reliable and compact alternative to expensive, inefficient, bulky laser systems that are currently used.

The new infrastructure will enable the production of the first sodium laser guide star in Australian skies, and will secure Australia's position as the premier provider of commercial-grade laser guide star adaptive optics systems for civil and defence telescopes around the world. This laser has wide scientific appeal for research with telescopes in astronomy, and for satellite tracking and mitigation of the threat of space debris.

SGL Prototype Fabrication Status

- Design of Laser Head and Laser Rack is nearly complete
- Detailed design pending final lab results and details of interfaces to EOS telescope
- Delivery to ANU Mount Stromlo Observatory planned in 2019 Q3





SGL Testing @ Mount Stromlo (2019-2020)

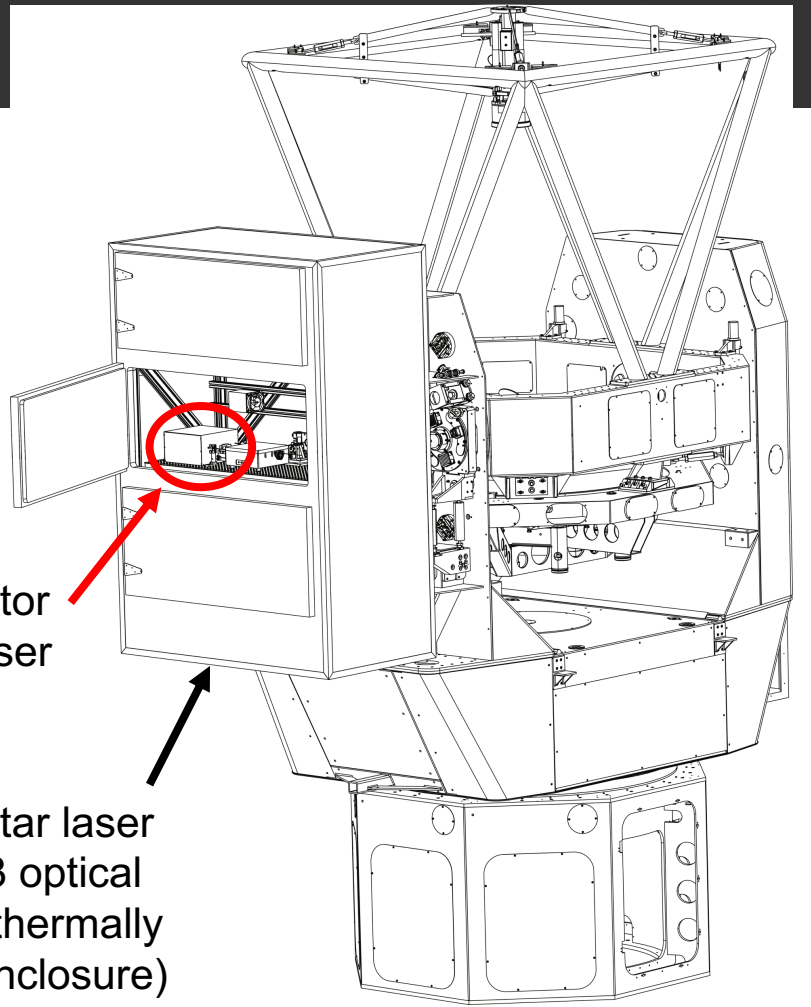
- On-telescope, on-sky testing will bring SGL to Technology Readiness Level (TRL) 6

EOS Space Systems laser tracking station incl. 1.8m telescope, Mount Stromlo Observatory, Canberra, Australia

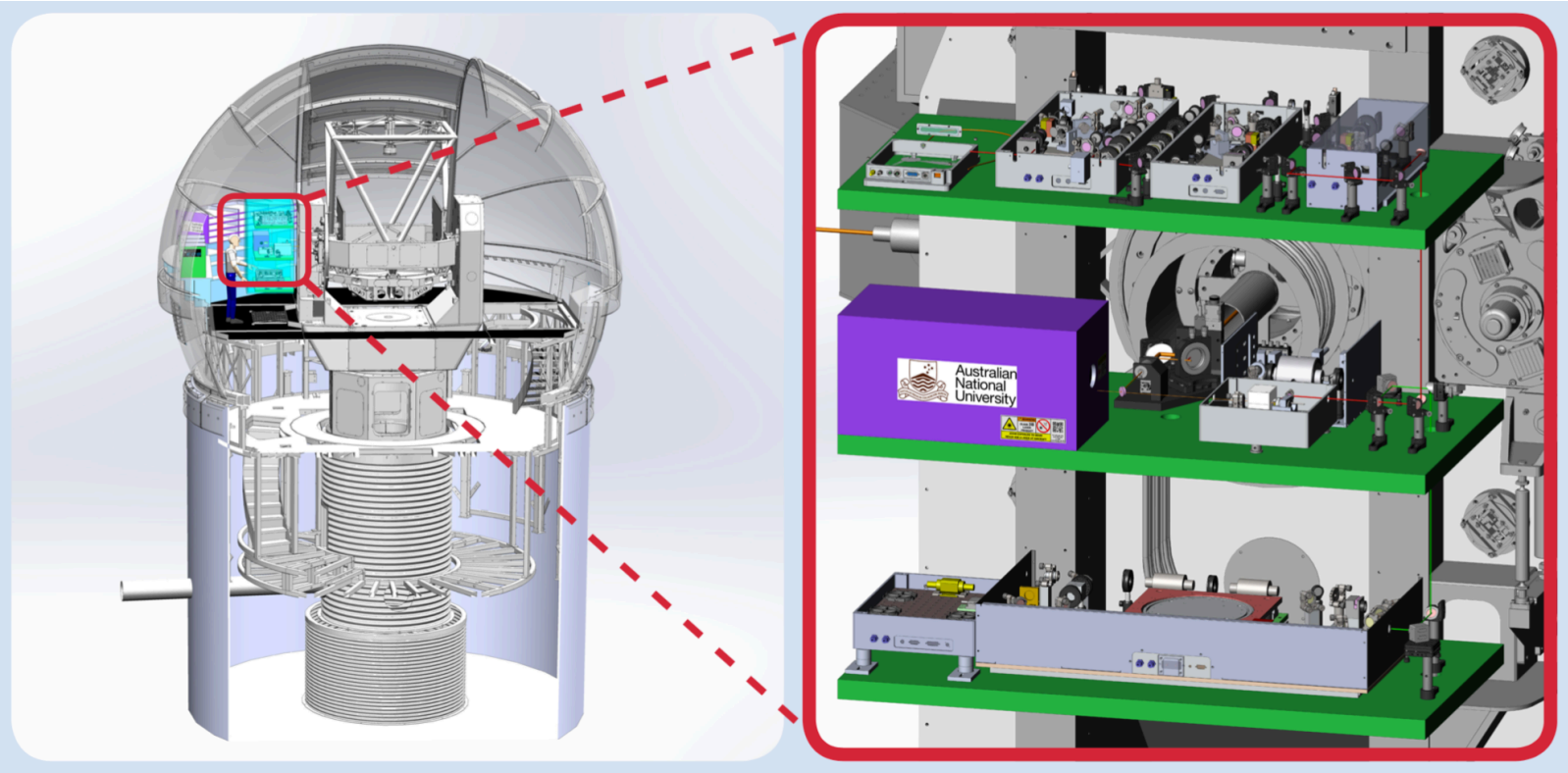
Image credit: EOS Space Systems

SGL Testing @ Mount Stromlo

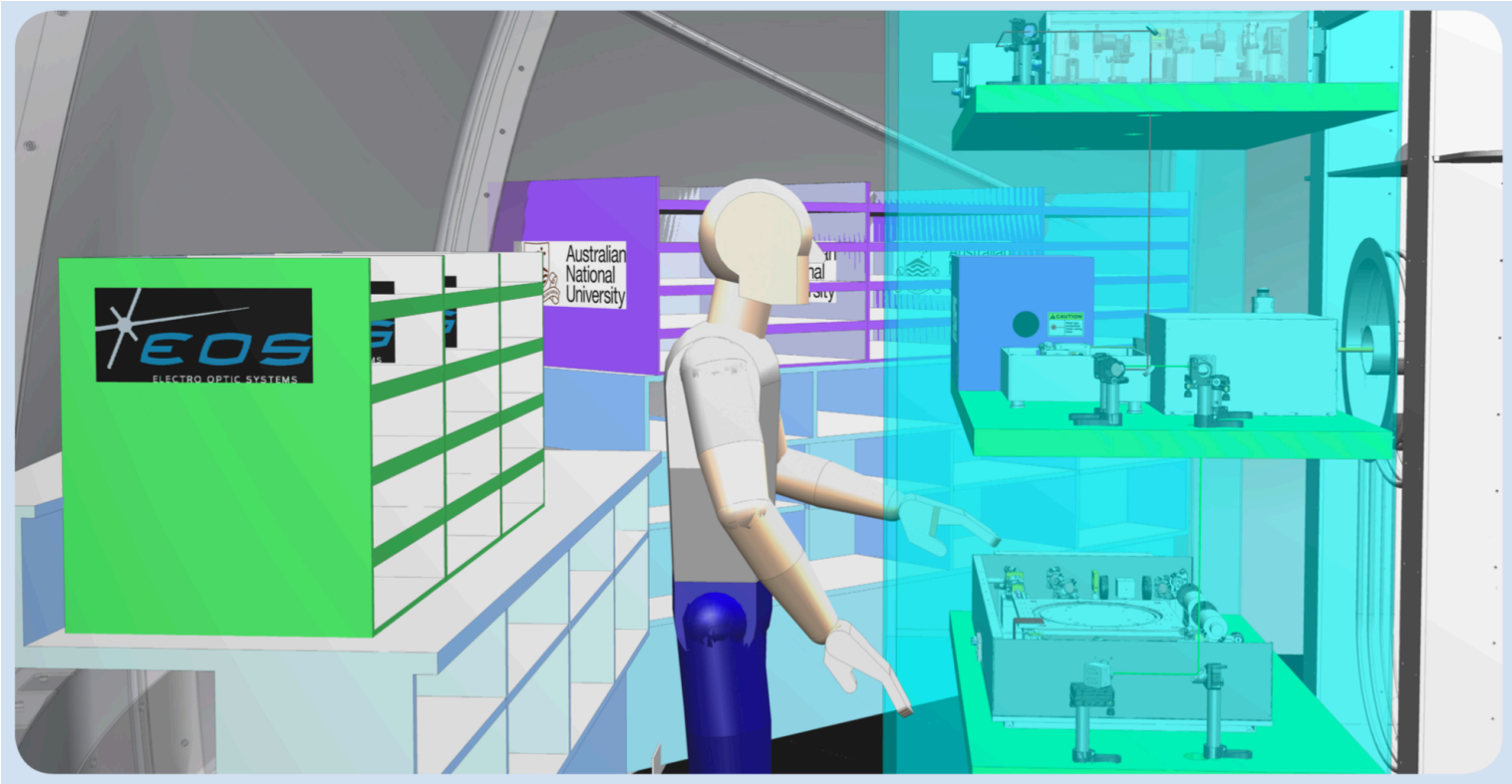
- ~10W ANU/Areté laser beam will be combined with ~10W EOS laser beam
- Will characterize LGS brightness & size and demonstrate SGL robustness
- It will be the first time a LGS is created in Australian skies!



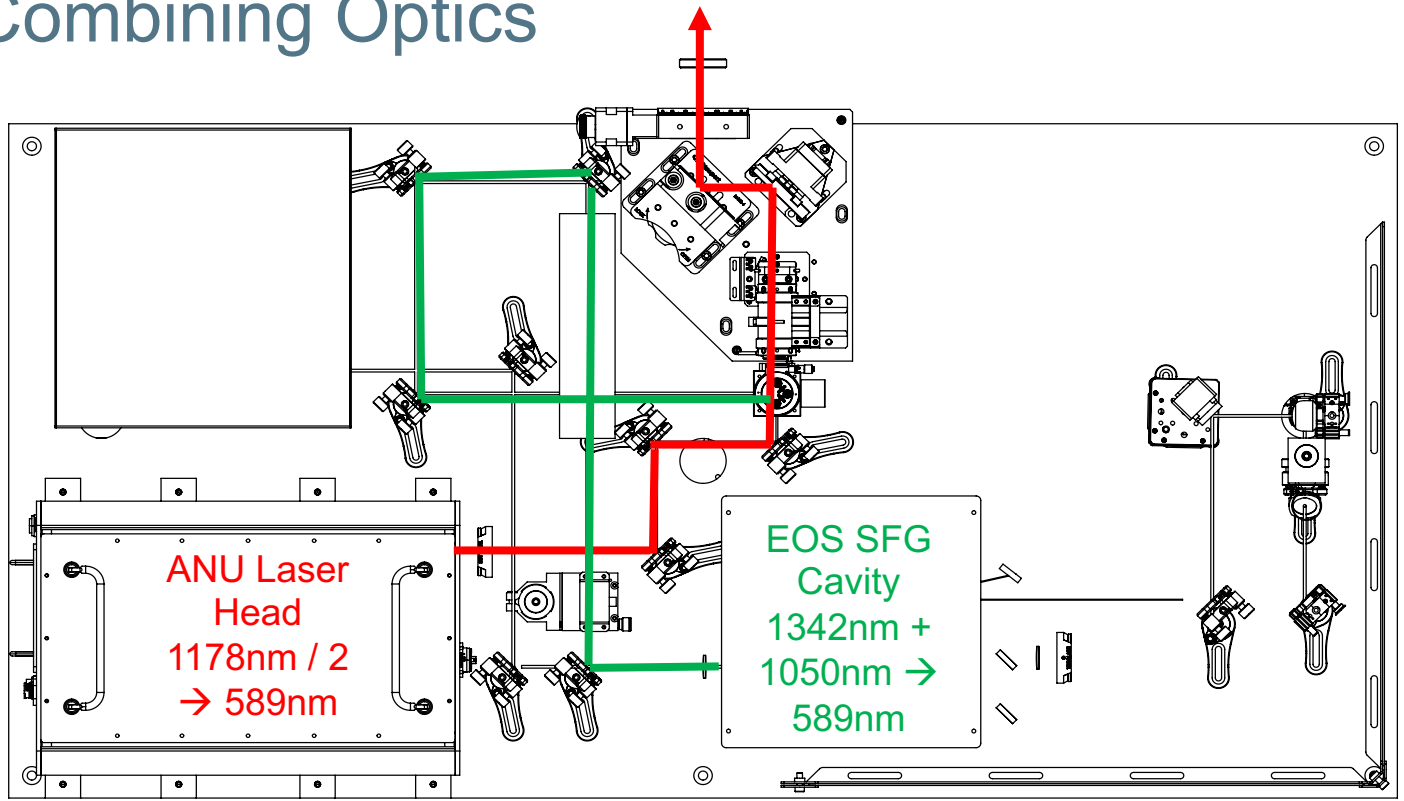
SGL Testing @ Mount Stromlo



SGL Testing @ Mount Stromlo



Beam Combining Optics



SECTION C-C
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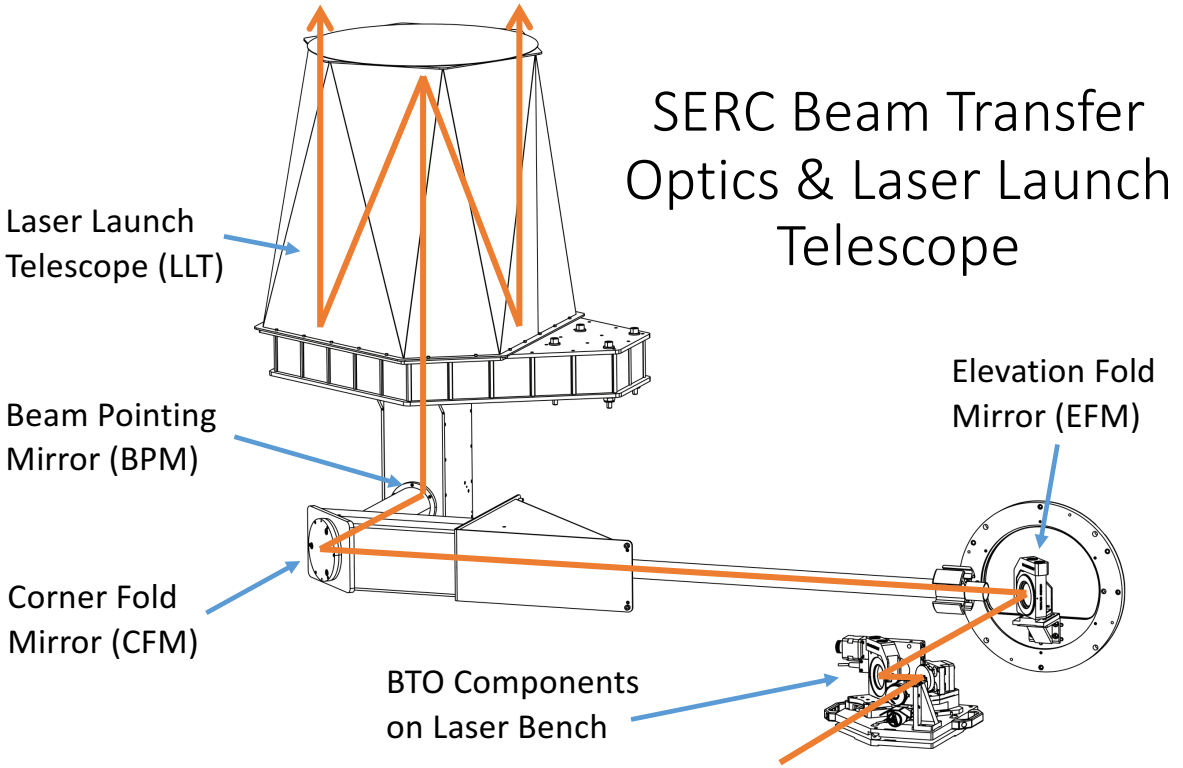
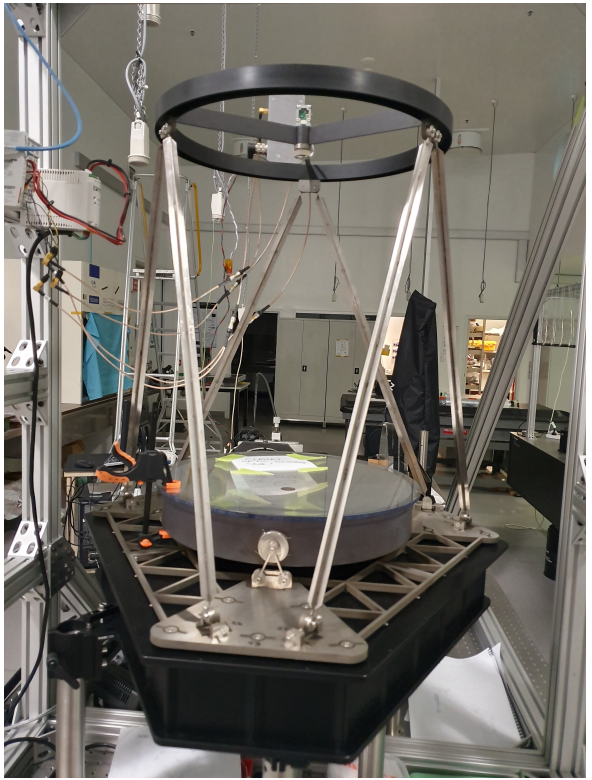
Beam Transfer Optics and Laser Launch Telescope



SERC Beam Transfer Optics & Laser Launch Telescope

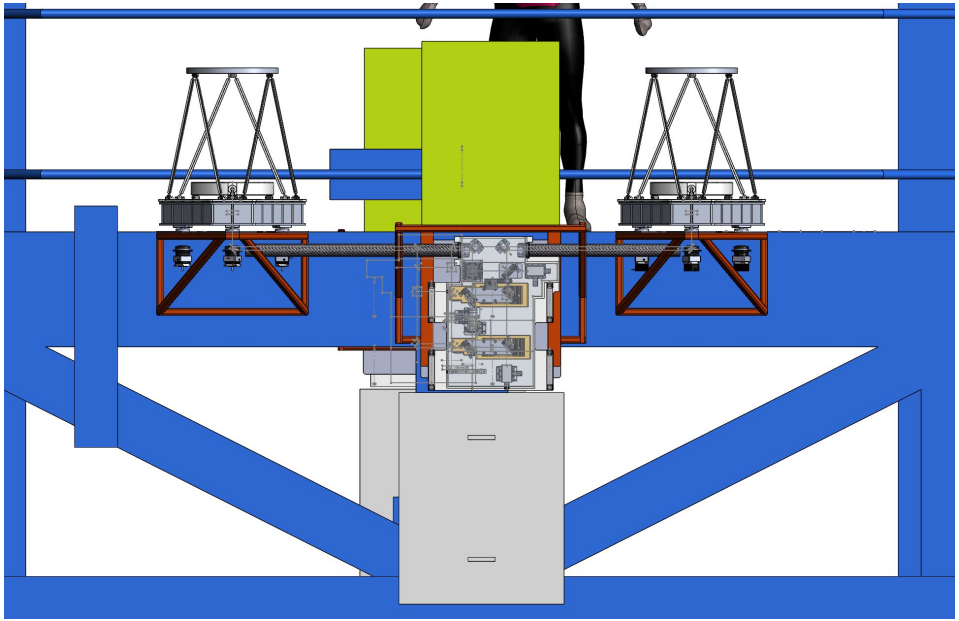


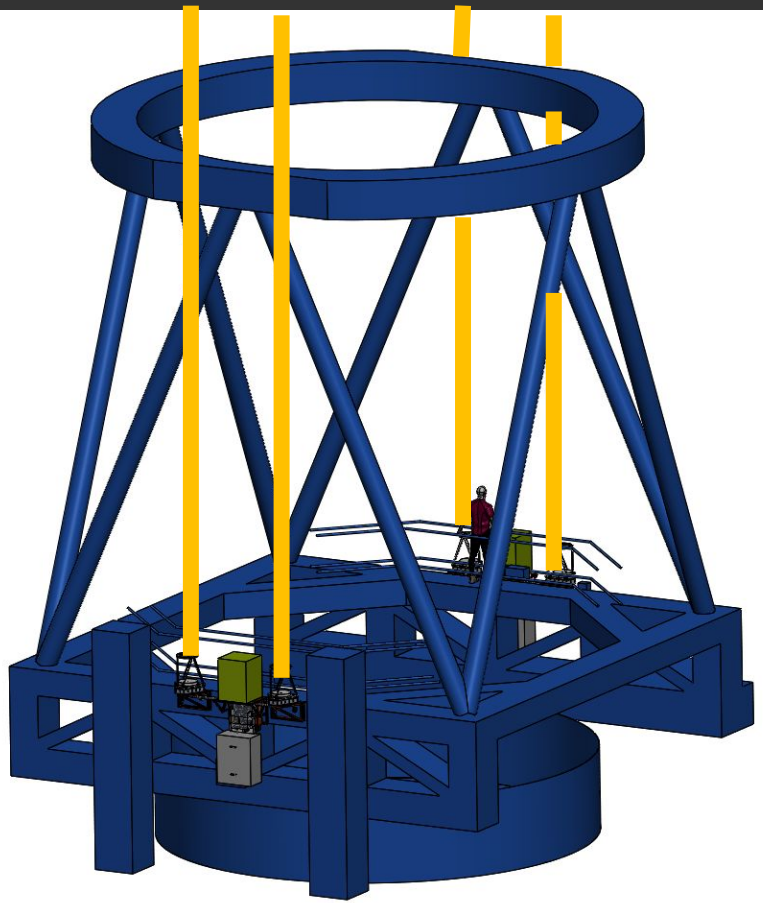
SGL Testing @ Subaru Observatory (2021-2022)

- Context: ANU/Subaru Observatory/ Tohoku University collaboration to demonstrate LTAO on Subaru and advance ULTIMATE GLAO project to Preliminary Design Phase

Image credit: National Astronomical Observatory Japan

Subaru ULTIMATE GLAO LGS Facility Conceptual Design





SGL Testing @ Subaru Observatory (2021-2022)

- 2018 award of ANU Translational Fellowship to A/Prof d'Orgeville
  - Duration: 3 years (2019 start)
  - Objectives: reach 20W output power and bring SGL from TRL 6 to TRL 8/9
- ANU-led 2019 ARC Linkage Project proposal with partners Subaru, Tohoku University & Areté Associates

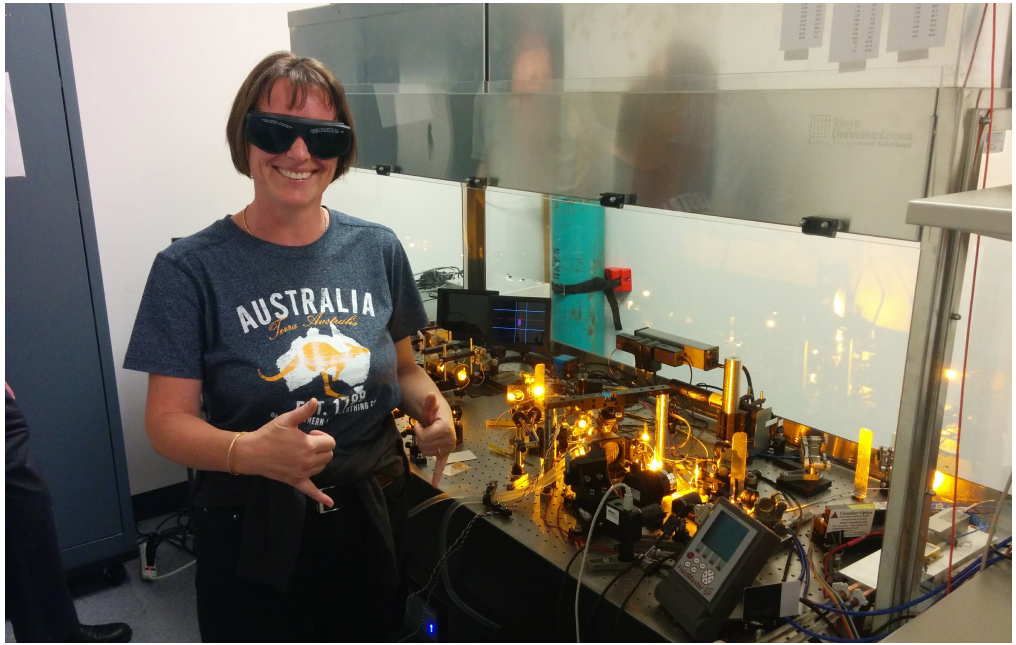


Image credit: Sean Goebel

Thank you!