Semiconductor Guidestar Laser for Astronomy, Space, and Laser Communications

C. d'Orgeville[a]*, G. Fetzer[b], F. Bennet[a], A. Bouchez[c], Y. Gao[d], M. Goodwin[e], A. Lambert[f], J. Mason[g], F. Rigaut[a], S. Ryder[e], D. Shaddock[a], R. Sharp[a]

[a]Australian National University, Australia; [b]Areté Associates, USA; [c]Giant Magellan Telescope Organization Corporation, USA; [d]EOS Space Systems, Australia; [e]Australian Astronomical Observatory, Australia; [f]University of New South Wales, Australia; [g]Lockheed Martin Space Systems Company, USA
*E-mail: celine.dorgeville@anu.edu.au

Project Overview

A new type of sodium guidestar laser based on **semiconductor laser technology** (Fig. 1) is being developed by the astronomy, space situational awareness, and laser communication communities in Australia and the United States, in partnership with US laser manufacturer Areté Associates.

Funding has been secured from the Australian Research Council and the Australian National University, with support from the University of New South Wales, astronomy partners at the Australian Astronomical Observatory and Giant Magellan Telescope Organization, and industry partners EOS Space Systems and Lockheed Martin Space Systems.

The consortium, led by the **Australian National University Advanced Instrumentation and Technology Centre** at Mount Stromlo Observatory near Canberra, aims to develop a full scale prototype of the Semiconductor Guidestar Laser.

The laser, to be delivered in late 2018, will be initially installed on the EOS Laser Tracking Station 1.8m telescope at Mount Stromlo Observatory (Fig. 2) where it will be thoroughly tested, on sky and in real operation conditions, to image and track space objects such as satellites and debris at low and geo-stationary earth orbits with Laser Guide Star Adaptive Optics (LGS AO).

This will be the first time that a Laser Guide Star is created in Australian skies.

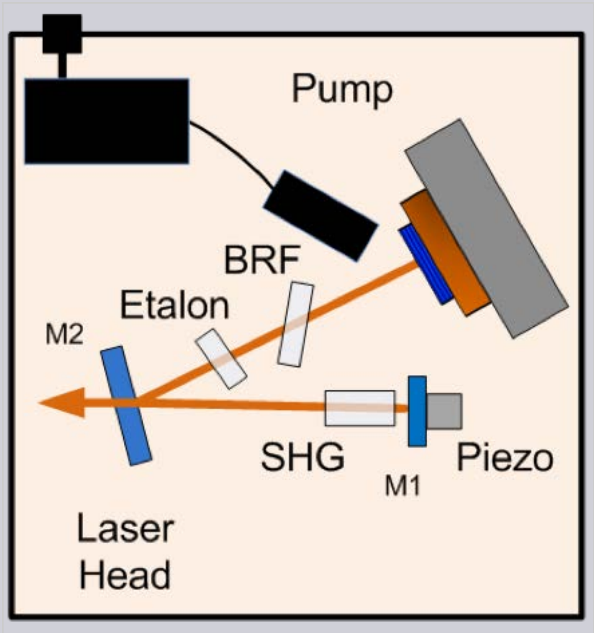

Figure 1: Semiconductor Guidestar Laser Cavity Layout (Credit: Areté Associates)

Figure 2: EOS Laser Tracking Station at Mount Stromlo Observatory (Credit: EOS Space Systems)

Semiconductor Laser Technology

Used in combination with non-linear frequency conversion schemes, semiconductor laser chips (Fig. 3) offer new, efficient, scalable laser architectures to create a wide range of IR and visible wavelengths. The excellent beam quality and multi-Watt powers at fundamental wavelengths provided by Optically-Pumped Semiconductor Lasers (OPSL, Fig. 4) make single-step or sequential frequency conversion processes practical. Single spatial and longitudinal longitudinal mode operation can be achieved with modest optical arrangements, and frequency stabilization is achieved using relatively standard techniques. Early efforts (Fig. 4) to produce 589 nm output with semiconductor laser technology have yielded highly promising results, including:

- 20 W multi-mode operation near 589 nm (sodium resonance wavelength)
- Low power single longitudinal mode operation ($\Delta\nu$ < 50 MHz FWHM)
- Cavity locked to the sodium D2a line resonance feature
- Continuous tuning over sodium D_{2a} and D_{2b} lines

For more details see *d'Orgeville & Fetzer, Proc. SPIE 9909, 99090R, 2016.*

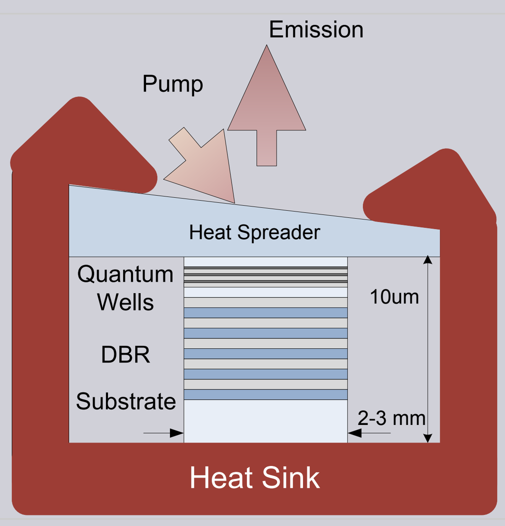

Figure 3: Semiconductor Laser Gain Medium (Credit: Areté Associates)

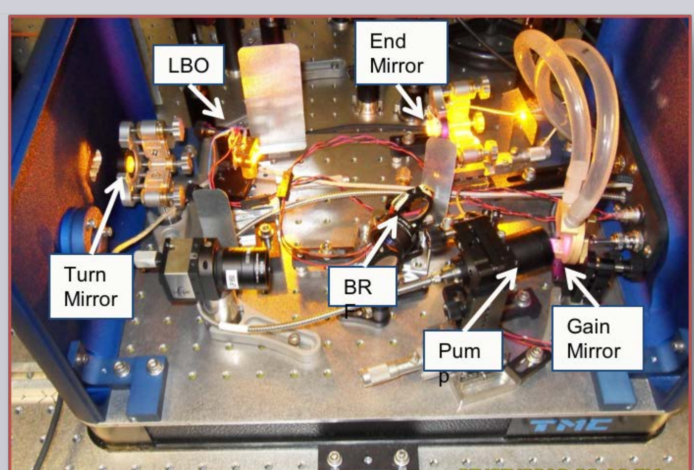

Figure 4: Early Laboratory Demonstrator of a 589nm OPSL (Credit: Areté Associates)

Prototype Performance Objectives

The *Toptica SodiumStar 20/2* laser provides a benchmark for present and future guidestar semiconductor laser developments in terms of spectro-temporal format (CW single frequency), output power at the sodium D2a line (20 W), re-pumping power at the sodium D2b line (2 W), spectral linewidth (5 MHz), and near-diffraction-limited beam quality.

Our goal is to develop a semiconductor guidestar laser with comparable or better performance characteristics than the Toptica laser, **in a significantly smaller package and at a significantly lower acquisition and operational** costs for the astronomy, space situational awareness, and laser communication communities. The advantages of semiconductor laser technology over past and present guidestar laser technologies (e.g. dye-, solid-state-, and fiber-based systems) are highlighted in the table below.

Characteristic	Description	Guidestar Laser Implications
Low Acquisition Cost	20-40 kU$/W	Affordable to large and small observatories Spare laser is a realistic option
Low Complexity	Low parts count Impervious to gravity orientation	Small number of failure points Reduced maintenance time
Small Size	Laser Head ~2 ft^3 Electronics Head ~ 2 ft^3	Flexible mounting on telescope structure is enabled
Serviceability	Routine maintenance by technician Laser head is field replaceable	Minimizes system downtime and repair costs
Supply Chain	Components are commonly available Multiple vendor options Standard semiconductor growth means multiple vendors exist for OPSL chips	High likelihood Areté will be able to continue production well into the future for the limited guide star laser market

Applications in Astronomy, Space Situational Awareness, and Laser Communications

Following its successful demonstration at Mount Stromlo Observatory in late 2018/early 2019, the Semiconductor Guidestar Laser prototype will become available for use by ANU and their academic and industry partners for LGS AO research projects in astronomy (Fig. 5, 6), space situational awareness (Fig. 7), and ground-to-satellite laser communications (Fig. 8).

Commercialisation of the Semiconductor Guidestar Laser technology by US and/or Australian vendors is expected in the longer term.

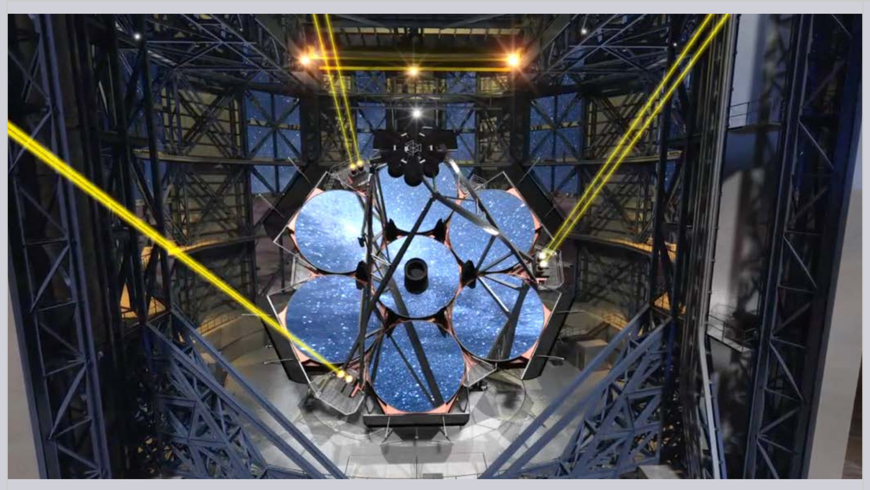

Figure 5: The 25m Giant Magellan Telescope will be equipped with six guidestar lasers (Credit: GMTO)

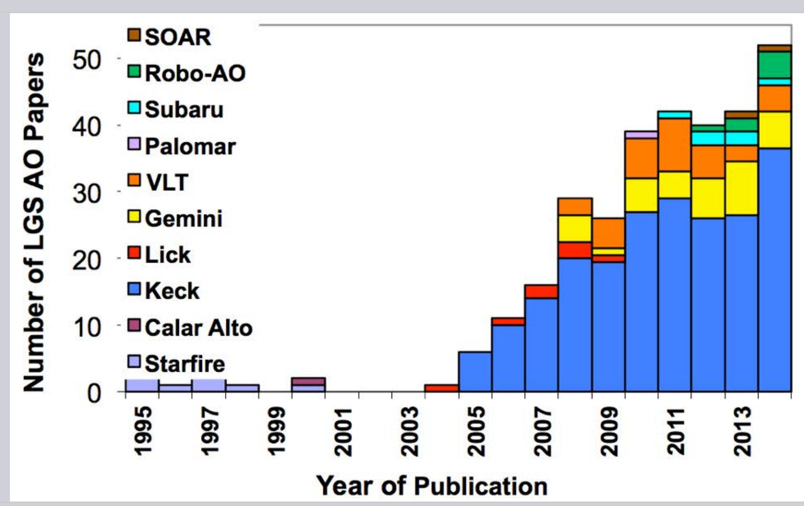

Figure 6: LGS AO Science Papers Published per Astronomical Observatory (Ref: Wizinowich, PASP 125, 798 (2013))

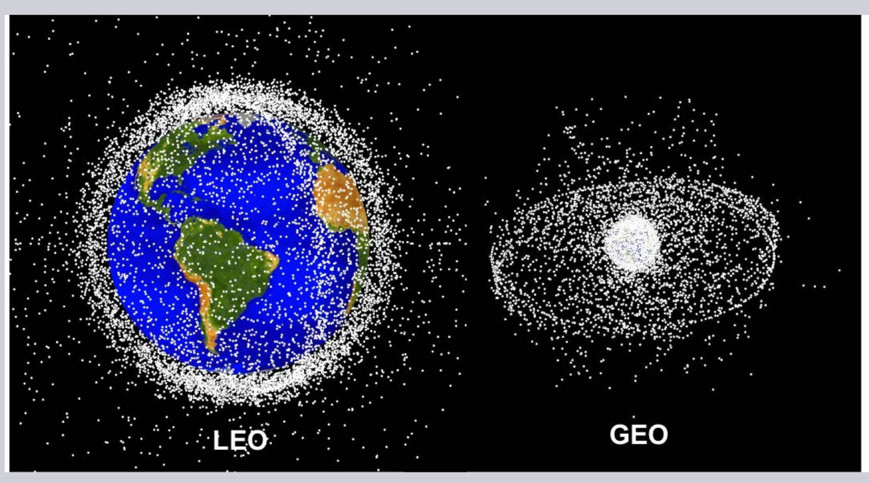

Figure 7: Space Objects Orbiting the Earth at LEO and GEO in 2010 (Credit: EOS)

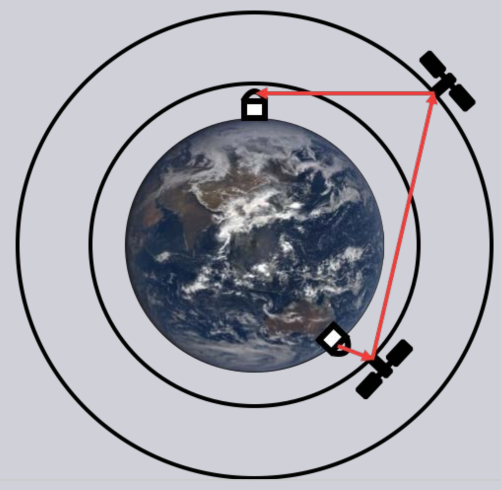

Figure 8: Principle of Ground-Satellite, Satellite-Satellite, and Satellite-Ground Laser Communications

AITC, for more information visit
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Who we are

The Advanced Instrumentation and Technology Centre (AITC) is part of the Research School of Astronomy and Astrophysics at the Australian National University. The AO group works on projects ranging from astronomy (GMT/Gemini/Subaru) to Space Situational Awareness (SERC/KASI-AO) and Cheap and Compact AO (CACAO).

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