The **Semiconductor Guidestar Laser**: A novel, affordable, low SWaP sodium guidestar laser for adaptive optics tracking of space objects

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ANU Advanced Instrumentation and Technology Centre (AITC)
Mount Stromlo Observatory, Canberra, Australia
8 November 2018
Outline

• Adaptive Optics research @ ANU AITC
• Laser Guide Star Adaptive Optics (LGS AO) 101
• 4 generations of sodium guidestar laser technologies
• ANU **Semiconductor Guidestar Laser** program
Adaptive Optics Research @ ANU Advanced Instrumentation and Technology Centre (AITC)

- World-leading AO research and development team:
  - 8-9 AO/laser/RTC instrument scientists
  - 4-6 postgraduates & 10-20 undergraduates
  - Supported by 20-25 ANU AITC engineering staff
- ANU AO program: research funding & commercial contracts
  - Astronomy on 8-40m telescopes (e.g. ESO VLT, Gemini, Keck, Subaru, GMT, ELT): LGS AO, GLAO, LTAO, MCAO
  - Laser communications (e.g. DST Group, ACT Government, Quintessence Labs, NICT): horizontal, space to ground, and ground to space
  - Space Situational Awareness (e.g. SERC, KASI): AOI, AOTP

Image Credit: Giant Magellan Telescope Organization
Laser Guide Star Adaptive Optics (LGS AO) 101

• Adaptive Optics
  – Wavefront sensor measures wavefront distortions caused by atmospheric turbulence
  – Deformable mirror corrects for these distortions in real time

• Laser Guide Star
  – Provides a reference source if/where none is available
Influence of telescope diameter

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

AO Imaging of space objects
AO Tracking & Pushing

- SERC Research Programs 1 & 4 (ANU, EOS Space Systems, Lockheed Martin)
- Objective: Mitigation of debris to debris collisions using photon pressure from AO-compensated high power IR laser
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)
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<tr>
<th>TIME</th>
<th>TITLE</th>
<th>PRESENTING AUTHOR</th>
<th>AFFILIATION</th>
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<tr>
<td>08:30</td>
<td>Opening Session and Keynote Address</td>
<td>Moriba Jah</td>
<td>University of Texas at Austin and SERC</td>
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<td>International Research Management Committee</td>
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<td>09:00</td>
<td>SERC Research Program 1 Review: Remote</td>
<td>Craig Smith</td>
<td>EOS Space Systems, Australia</td>
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<td>manoeuvre of space debris using photon pressure for active</td>
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<td>collision avoidance</td>
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<td>09:15</td>
<td>Adaptive optics corrected imaging for satellite and debris</td>
<td>Michael Copeland</td>
<td>Australian National University / Space Environment Research Centre, Canberra, Australia</td>
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<td>10:15</td>
<td>Multi-kW high beam quality CW laser for space</td>
<td>Yue Gao</td>
<td>EOS Space Systems, Australia</td>
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<td>debris manoeuvring</td>
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<td>15:30</td>
<td>Space Environment Research Centre: Space segment overview</td>
<td>Benjamin Sheard</td>
<td>Space Environment Research Centre, Mt Stromlo, Australia; EOS Space Systems, Australia</td>
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<td>16:45</td>
<td>Collision avoidance using ground based lasers</td>
<td>Liam Smith</td>
<td>Lockheed Martin, Colorado, United States</td>
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Sodium Guidestar Laser Technology State of the Art

• Three generations of sodium guidestar lasers to date:

ALFA CW dye laser @ Calar Alto Observatory (Spain)

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

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

(Image credit: Areté Associates)
Semiconductor Guidestar Laser Program

• ANU-led project to build a prototype for use in astronomy, space, and laser communications

• Project funding to date:
  – Government: Australian Research Council
  – Academia: ANU, UNSW
  – Observatories: AAO, GMT
  – Industry: EOS Space Systems, Lockheed Martin

• Laser vendor:

Areté Associates
Laser 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 Q2
Laser Installation & Testing @ Mount Stromlo (2019)

SERC Beam Transfer Optics & Laser Launch Telescope

- Laser Launch Telescope (LLT)
- Beam Pointing Mirror (BPM)
- Corner Fold Mirror (CFM)
- Elevation Fold Mirror (EFM)
- BTO Components on Laser Bench

ANU/Areté semiconductor guidestar laser head

EOS guidestar laser enclosure (3 optical benches in thermally controlled enclosure)
Thank you!
Any questions?