Proposed SLR optical bench required to track debris using ~1550 nm lasers.

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Abstract: A previous study has indicated that by using ~1550 nm wavelengths a laser ranging system can track debris objects in an “eye safe” manner, while increasing the expected return rate by a factor of ~2/unit area of the telescope\cite{1}. In this presentation we develop the optical bench required to use ~1550nm lasers, and integration with a 532nm system. We will use the optical bench configuration for NGSLR as the baseline, and indicate a possible injection point for the 1550 nm laser. The presentation will include what elements may need to be changed for transmitting the required power on the ~1550nm wavelength, supporting the alignment of the laser to the telescope, and possible concerns for the telescope optics.

Maximum Eye Safe Power

<table>
<thead>
<tr>
<th></th>
<th>532 nm</th>
<th>1064 nm</th>
<th>1550 nm</th>
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</thead>
<tbody>
<tr>
<td>10 sec exp.</td>
<td>0.0001 J</td>
<td>0.001 J</td>
<td>0.982 J</td>
</tr>
<tr>
<td>0.25 sec exp.</td>
<td>0.0001 J</td>
<td>0.001 J</td>
<td>37.76 J</td>
</tr>
</tbody>
</table>

- Based on results using USAF LHAZ6.0 which is calculated using 2014 ANSI standards
- Calculated using 1 ns pulse, 50 Hz rep rate, 25 cm beam diameter
- 1550 nm remains eye safe at orders of magnitude higher power than 1064 or 532 nm

Figure 1: NGSLR optical bench \cite{2}

- 1) Mirror at base of Coude path
- 2) Camera for alignment of laser to telescope
- 3) Removable mirror, installed for alignment, removed for operation
- 4) Variable power Beam Expander

Discussion

- Three optics need to be removable without re-alignment when replaced,
  - the 1550 nm injection mirror,
  - the optic splitting the 532 nm signal for alignment
  - the optic splitting the 1550 nm signal for alignment
- The 1550 nm beam expander might need to have the ability to be adjusted
- The 1550 nm side is an aperture share setup
- The 1550 nm transmission mirror in this design is mostly a transmission optic with a small mirrored section (aperture sharing)
- Due to shared paths for the transmission and receive the detector should be gated to protect from backscatter light from the transmission
- Detector may also require chopper wheel for additional stray light reduction
- The 1550 nm laser might be large enough that placement on the optical bench is impracticable, could use a fiber to couple the laser to the bench
- Parts or all of the 1550 nm optical bench could be placed above the 532 nm optical bench

Additional considerations

- Telescope optics, particularly the Coude path mirrors, need to be able to handle high power laser pulses in the 1550 nm wavelength
- The optical bench should be designed to be as modular as possible to facilitate installation into different systems

References:

\cite{1} Tracking orbital debris in a busy airspace environment (3115). M. Shappirio et al., 2014 ILRS conference proceedings

Figure 2: Debris tracking components on NGSLR optical bench. Components in blue 532 nm, red 1550 nm and black are components that need to be added/removed to swap operation from one wavelength to the other.

- 4) The one 532 nm optic that needs to be removed for 1550 nm operation the alignment mirror
- 5) 1550 nm injection mirror
- 6) 1550 nm transmission mirror (see discussion section)
- 7) ~1550 nm diode to monitor outgoing laser power
- 8) 1550 nm Beam Expander (x10 fixed)
- 9) Camera for alignment of laser to telescope
- 10) Beam chopper for stray light suppression
- 11) Removable mirror, installed for alignment of the 1550 nm laser, removed for operation.