Orbital Debris Laser Ranging Station Stuttgart

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• Long tradition in development and application of lasers
  • Development of disk lasers
  • Standoff detection of dangerous materials
  • Laser-powered micro drives for satellites
  • Damage tests and qualification for space optics
  • …

• New application idea (~2010):
  • Observation and removal of space debris

• But: No experience in satellite tracking / laser ranging
Orbital debris research station @ Uhlandshöhe

- Main goal:
  - Gain experience with satellite laser ranging

- 2013: First light (passive)
- 2014: Satellite tracking and astrometry
- 2015: First ranging to terrestrial targets
- 2016: Satellite laser ranging
Orbital debris research station @ Uhlandshöhe

- Main goal:
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- 2016: Satellite laser ranging
The telescope

Transmitter telescope

Receiver telescope

Direct drive mount
Hardware design

- Inexpensive hardware
- COTS components
- Can be set up independently of external partners

<table>
<thead>
<tr>
<th>Hardware Component</th>
<th>Brand</th>
<th>Cost (K€)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mount</td>
<td>Astelco</td>
<td>35</td>
</tr>
<tr>
<td>Telescope</td>
<td>Planewave</td>
<td>25</td>
</tr>
<tr>
<td>Camera</td>
<td>Andor sCMOS</td>
<td>10</td>
</tr>
<tr>
<td>Laser</td>
<td>Innolas</td>
<td>20</td>
</tr>
<tr>
<td>SP Detector</td>
<td>idQuantique</td>
<td>10</td>
</tr>
<tr>
<td>Gating and synchro</td>
<td>CERN White Rabbit</td>
<td>10</td>
</tr>
<tr>
<td>Event Timer</td>
<td>PicoQuant</td>
<td>20</td>
</tr>
<tr>
<td>Optical components</td>
<td>various</td>
<td>10</td>
</tr>
<tr>
<td>Auxiliary hardware</td>
<td>various</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>150</strong></td>
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</table>
Passive optical channel

- **Focal length**: 2939 mm
- **Aperture**: 432 mm
- **Camera resolution**: 2560 x 2160
- **Pixel size**: 6.5 µm
- **Field of view**: 0.32° x 0.27°
- **Camera scale**: 0.45 arcsec / pixel
- **Frame rate**: Up to 50 Hz

- **Leap frog tracking**
- **Continuous tracking**

**Accuracy**: ~2 arcsec
**Smallest object**: ~10 cm
Transmitter

- Small diode-pumped Nd:YAG laser
- Fibre transmission from base to telescope
- Automatic beam control and steering
- 10 cm aperture, 50 µrad divergence

**Innolas AOT 1-YAG**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
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</thead>
<tbody>
<tr>
<td>Wavelength</td>
<td>1064 nm (IR)</td>
</tr>
<tr>
<td>Puls duration</td>
<td>&lt; 3 ns</td>
</tr>
<tr>
<td>Repetition rate</td>
<td>1 kHz (to 10 kHz)</td>
</tr>
<tr>
<td>Pulse energy</td>
<td>300 µJ</td>
</tr>
</tbody>
</table>
Receiver

- Dichroic beam splitter near focal place
- idQuantique single photon detector
  - InGaAsP APD
  - 30% efficiency @ 1064 nm
  - 80 µm diameter
  - Dark noise ~ 2 kHz
- Can be used gated or free running
- Alignment done via software
  (no moving parts)
Instrument control and DAQ

- Event Timer: PicoHarp 300
  - 4 ps resolution
  - Timing 12 ps + $10^{-8}$ dT
  - Max. data rate: 5 MHz
- GPS clock: Jackson Labs Fury GPS
  - Motorola M12+ timing receiver
  - 20 ns (1 sigma) to UTC
- Gating and synchronisation: CERN White Rabbit
  - 5 inputs / outputs
  - Sub-ns synchronisation between devices
  - Pulse generation and timetagging
  - Synchronisation to UTC
Test targets

Stuttgart TV tower
Diffuse target @ 3 km

Retroreflector at monument (distance 5307.2 m)
Test targets

Retroreflector at monument (distance 5307.2 m)

Stuttgart TV tower
Diffuse target @ 3 km
What can we do with this design?

• For „standard“ satellite laser ranging:
  • This design can be an inexpensive alternative to traditional SLR stations
    ➔ Need to push picosecond pulses through the fibre

• For space debris laser ranging:
  • Need stronger fibres, and high repetition rate
    ➔ Currently, space debris laser ranging still needs a Coudé system
What can we do with this design?

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- DLR Stuttgart will start building a Coudé system in 2016
Collaborations & current projects

• ESA project with Graz and Wettzell
  • 1064 nm laser ranging to space debris
  • Calculate orbits from observations
• DLR project with other institutes:
  • BACARDI database for 1M objects incl. data management, conjunction warning etc.
    ➔ Planned to be „open“

• Other projects for EU, German defense department etc.
Summary & Outlook

- DLR Stuttgart is building up space debris observation hardware
- Facilities are dedicated 100% to space debris research (no routine tasks)
- SLR planned for 2016
- SDLR facility in preparation