Space-Qualified Scanning LIDAR for Rendezvous and Docking Applications

EPIC Meeting on Photonics at the Final Frontier - September 2022

Thomas Kämpfe – Systems Engineer, Jena-Optronik GmbH, LIDAR group

Exploring new horizons. We are ready.
RVS3000(-3D) LIDAR

Product Family

- Smart & Versatile 3D Sensor for Space Applications

Berthing, Docking, Servicing, Sample Return, Landing
Outline

- Introduction of Jena-Optronik & Product overview
- Jena-Optronik LIDAR Heritage
- Rendezvous and Docking Sensor RVS3000
  - Concept & Technology
  - Applications
  - Development Roadmap
- RVS3000 Challenges for Photonic Subsystems
Jena-Optronik Company

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**Jena Optronik at a glance**

- **Sensors by Jena-Optronik** keep satellites stable and on track.
- Our **space optics & electronics** help to generate crucial Earth Observation data, helping to improve the quality of life.

Jena-Optronik is **DIN EN 9100:2018** certified

- **Location** Jena, Germany
- **Management** Peter Kapell (CEO)
- **Employee** 238 (as per December 2021)
- **Revenue 2021** 55,0 Mio €

International Partner & Customer Network
Jena-Optronik, Applications and Products

Areas of application

- Space exploration
- Human spaceflight
- Earth observation
- Telecommunication & Navigation
- Space logistics & Debris removal
- Space Situational Awareness (SSA)

Jena-Optronik Products

- Star Sensors (APS, ACL) ASTRO® product family
- Cameras / Camera systems
- LiDAR RVS® product family
- Space optics & electronics
- Services
Regional supply network
Jena-Optronik LIDAR Heritage

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space for success
Jena-Optronik LIDAR development for Rendezvous and Docking

**RVS-ARP**

RVS for ATV / HTV / Cygnus
48 Flight Models delivered, 48 under contract, flawless flight heritage

**LiQuaRD***

LIRIS-2 on ATV-5

**RVS3000(-3D)**

multiple FMs delivered & flown & contracted

* LIDAR Qualification for Rendezvous and Docking (DLR)
RVS3000-(3D) LIDAR System

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Scanning LIDAR principle

Scan head

azimuth
elevation

Fiber Laser

Scan pattern

Target

TX Path

RX Path

Scan head

Azimuth

Elevation

Scan pattern
RVS 3000(-3D) Key Features

**Scanning LIDAR advantages**

- Large degree of flexibility with respect to Field-of-View (<1x1…40x40 deg)
- High performance angular measurement (noise ~ 0.001 deg, bias < 0.05 deg)
- Range, azimuth, elevation and amplitude information
- Variable scan speed leading to adjustable point cloud resolution
  - Slow high-resolution scans with “megapixel” images
  - Fast scans for proximity operations with moving/rotating objects
- **No** “dead pixels”
- Single Shot Range 3σ Noise: < 1–2 cm; Single Shot Range Bias: < 1 cm (close range)

Scanning LIDAR in Debris Removal Scenario
RVS 3000(-3D) Key Features

RVS 3000-3D – Pose Estimation

- Pose calculated based on matching between RVS scan and target reference model
- Real-time algorithm application on dedicated image processing board
  - 2 Hz Pose Update Rate, 1s Latency
- Algorithm Flow:

1. Acquisition of LIDAR Scan
2. Matching LIDAR Scan vs. Model
3. Pose
RVS 3000(-3D) Key Features

RVS 3000 – Retro Reflector Tracking

- Identification & tracking of retro reflector objects
- JOP heritage retro identification algorithms
  - 2 Hz Update Rate
  - > 50 flights to ISS

RVS 3000-3D Pose Estimation

- Pose calculated based on matching between RVS scan and target reference model
- Dedicated image processing board
- Successful Docking in frame of NG’s MEV 02/2020 & 04/2021

*e.g.* JEM A Reflector!

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JOP RVS3000-3D - Scan & Pose of IS901 in Orbit
A Smart 3D Sensor for various Space Applications in a Single Box

3D Point Measurement
- cooperative/ non-cooperative targets
  - Scanning LIDAR
  - Time-of-flight ranging

3D Point Cloud
- low-level
  - Calibration & Correction
  - Filtering, ROI

3D Point Cloud
- high-level
  - Retro Tracking
  - 3D Pose Estimation
  - Hazard Detection

High Level Analysis
- Processed & Reduced Information
- CONOPS adapted communication to GNC

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EPIC Meeting on Photonics at the Final Frontier at European Space Agency (ESA) - September 2022
RVS3000 Family Evolution – Smart 3D Sensor Berthing, Docking, Servicing & Landing

RVS3000-3D
- Docking non-cooperative targets
- 6D Pose Estimation
- point cloud matching to CAD model
- TRL 9 production

RVS3000
- ISS/cooperative targets
- Retro Tracking
- TRL 9 production

RVS3000-X
- non-cooperative & cooperative targets
- Retro Tracking & 6D Pose Estimation
- Crew-handling Design
- Product line harmonization

Development on going

RVS3000-L
- non-cooperative & cooperative targets
- Landing Application
- Motion Correction & Hazard Detection

Development kicked-off

µRVS – the next step
- Single-photon avalanche diode array technology
- Powerful pulsed diode laser (~905 nm)
- Miniaturized scan mirror
- Reduction of mass, power consumption

Technology development
RVS3000-(3D) LIDAR System – Photonics
Challenges for Photonic Subsystems

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RVS3000 – Optical System

Optical System

Components:

1. TX output fiber laser, 1550 nm
2. TX collimator lens
3. Combiner mirror
4. Scan mirror, (gimbal mount)
5. RX spectral filter
6. RX focusing lens
7. APD detector
8. TX monitor output fiber laser
9. Monitor collimator lens
10. deflection mirror

Scan Mirror

- Material: AlBeMet, Ni-plated
- Au coating
- Weight 18g

Needs/Interests/Ideas:

- Coatings, glasses, lenses (optical systems)
- Scan mirrors/systems (electro-mechanical systems)
RVS3000 Fiber Laser Sub assembly

Fiber Laser in master oscillator power amplifier design

- Distributed feedback laser diode seed
- 2 pass preamplifier pumped by single mode laser diode (SMLD)
- main amplifier pumped by another SMLD and a multi mode laser diode (MMLD)

<table>
<thead>
<tr>
<th>Wavelength</th>
<th>1550 nm</th>
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<tbody>
<tr>
<td>Pulse length</td>
<td>3 ... 8 ns</td>
</tr>
<tr>
<td>Pulse repetition rate</td>
<td>20 kHz ... 120 kHz</td>
</tr>
<tr>
<td>Avg. power</td>
<td>&lt; 350 mW</td>
</tr>
<tr>
<td>M^2</td>
<td>&lt;1.2</td>
</tr>
</tbody>
</table>

**Needs/Interests/Ideas:**

- Laser diodes
- Fibers, Fiber couplers, Fiber optics
RVS3000 RX Detection

**APD InGaAs detector**
- biasing voltage in the range of 50 to 70 Volts at room temperature to have a nominal gain of 10
- APD voltage regulated & temperature stabilized

**Amplitude Detection**
- pulse amplitude detection enables compensation of time-walks due to nonlinearities and noise

**Needs/Interests/Ideas:**
- APDs, APDs arrays, LIDAR detectors
- Detectors with integrated readout electronics/circuits
Conclusion

- RVS3000 is a space qualified LIDAR capable of autonomously acquiring and tracking cooperative and non-cooperative targets, for rendezvous and docking applications

- RVS3000 3D with pose matching opens up new application areas (satellite servicing, HDA for planetary landing..)

- Main further development goals
  - Improvement of scan performance (point density, scan rate..)
  - Improvement of laser performance (divergence, max pulse power, max range)
  - Towards a smart sensor (object recognition, mode choosing, high level data analysis)

- A major key is to improve components in the optical subassemblies

Thank you for your attention