Space Debris Laser Ranging Activities in Zimmerwald

Thomas Schildknecht,
Julian Rodriguez, Pascal Sauer,
Pierre Lauber, Lucia Kleint

Astronomical Institute, University of Bern, Switzerland

ILRS Virtual Workshop 2023

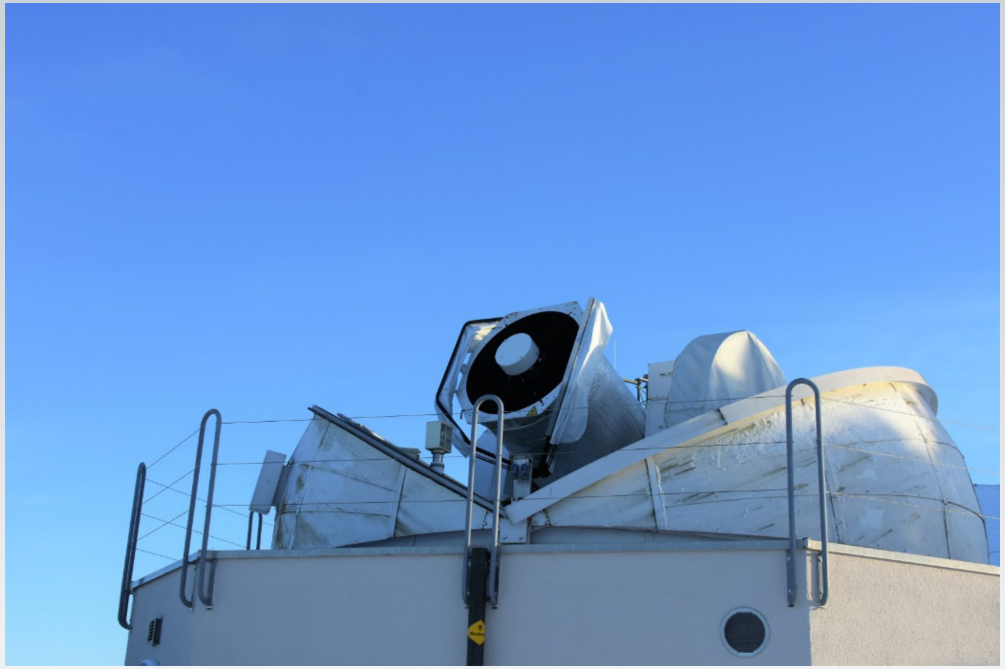
Space Debris Laser in Zimmerwald

Design Considerations

- 47W, 200Hz laser system
- piggy-back on 0.8m ZimMAIN
  - no interference with geodetic SLR operations
  - requires separate transmit optics and new receiver chain
  - might be too heavy
  - requires new tracking and control software
- piggy-back on ZIMLAT
  - not an option because new 1kHz geodetic laser system to be mounted piggy-back on ZIMLAT
- ZIMLAT Coudé
  - could profit from existing receiver chain and software
  - transmit/receive switch can handle 100/200Hz
  - time sharing with geodetic SLR operations

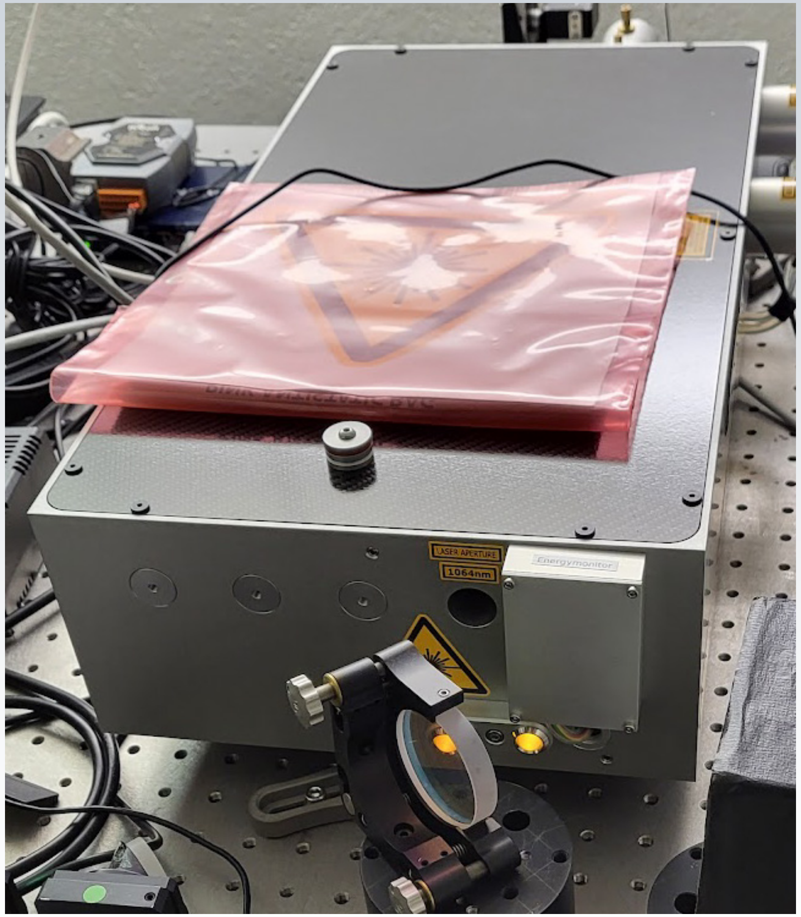
→ preferred solution to start with

(bistatic system to be evaluated in future)



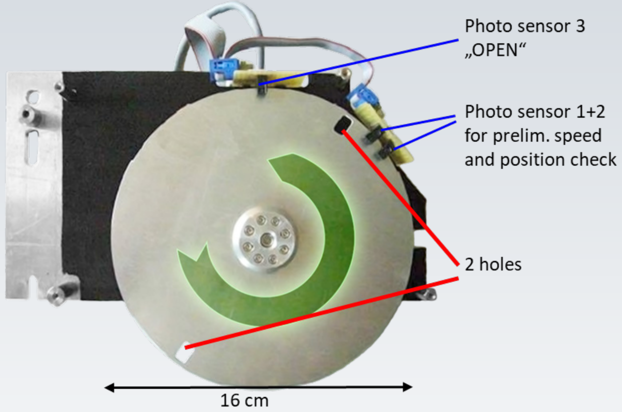
Space Debris Laser System

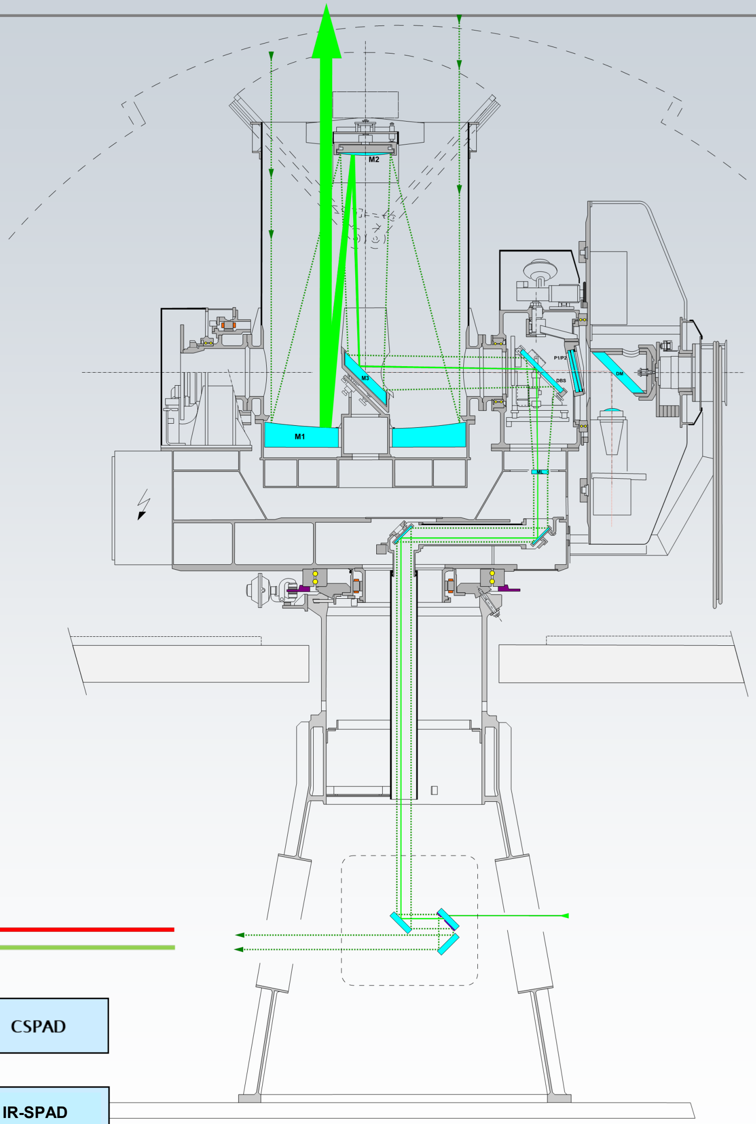
INNOLAS EVO II-200 Laser specifications

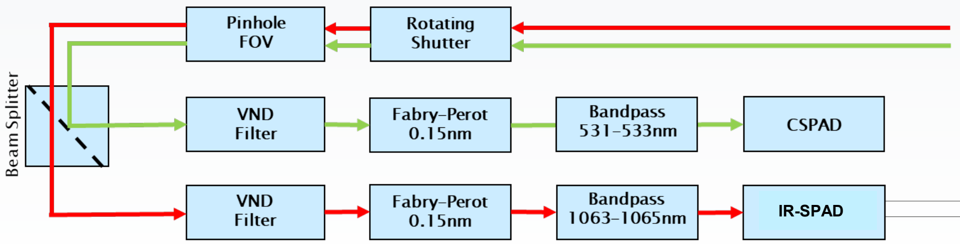


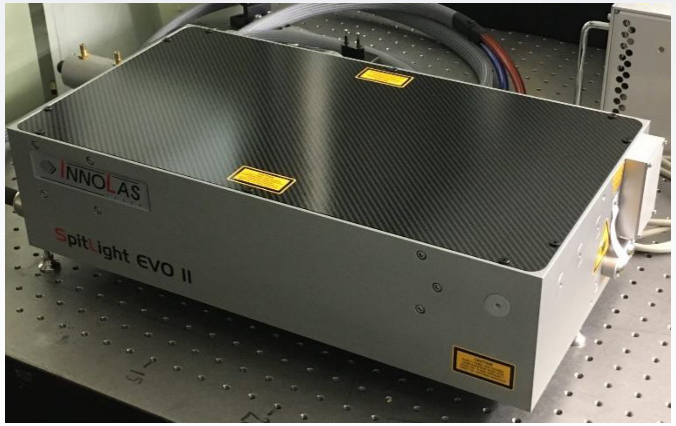
Wavelength	1064 nm
Pulse repetition rate	200 Hz (100 Hz subsampling)
Pulse length (min)	7 ns
Pulse energy (adjustable)	<1 mJ – 236 mJ
Pulse-to pulse timing jitter	±1 ns
Average power (@200Hz)	< 0.2 W – 47 W
Beam diameter (1/e)	8mm
Beam divergence	<0.5 mrad
Polarization	Linear (horizontal)

ZIMLAT Coudé Configuration









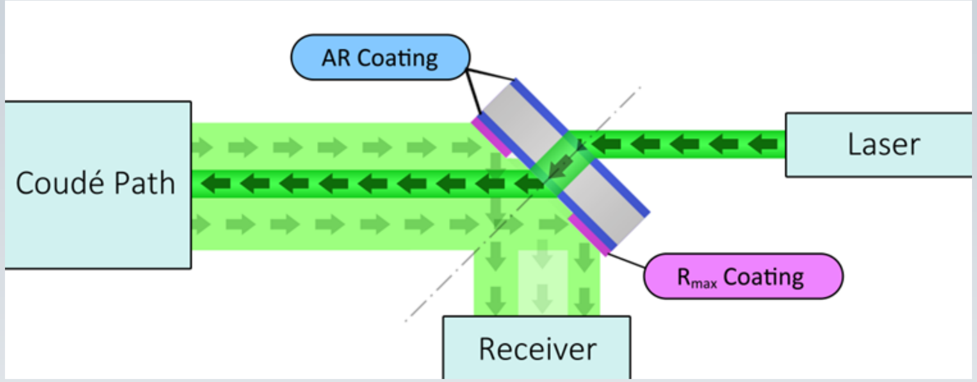
Challenges of a Monostatic Coudé Configuration

Calibration Measurements

- transmit/receive switch open during calibration
  → stray light/reflections from the telescope enter receiver

→ need to attenuate transmission beam

(also required for eye safety when using terrestrial target)

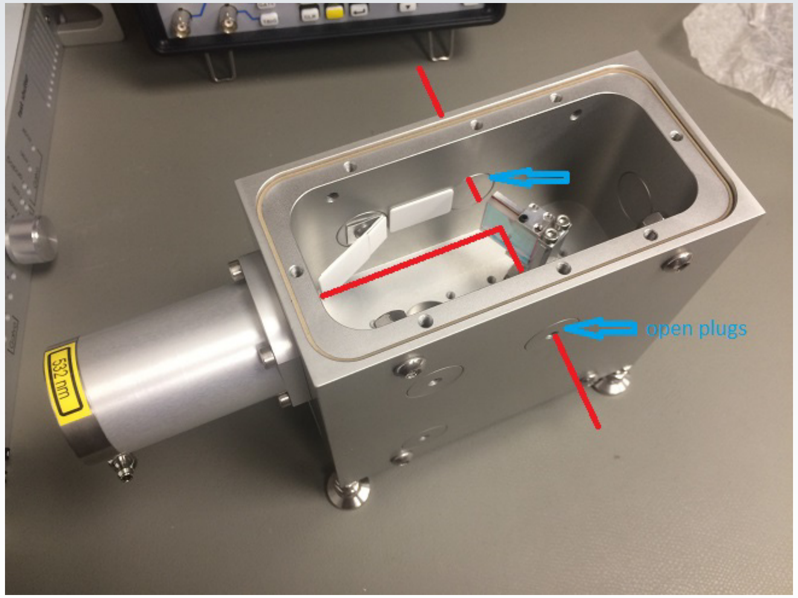


Beam Attenuation

- < 10µJ required

→ 4*10^{-5} attenuation

- 10^{-2} internal attenuation
- 10^{-3} external attenuation



Challenges of a Monostatic Coudé Configuration

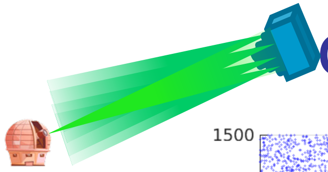
Transmit – Receive Conflicts

- problem: time of flight ~ x*pulse repetition interval
  → laser transmitted while receive switch open (would destroy receiver)
- standard procedure:
  - change laser repetition rate from 100Hz to 109Hz (200Hz to 218Hz) (no issue for geodetic 1W laser)

→ requires 6 separate working points

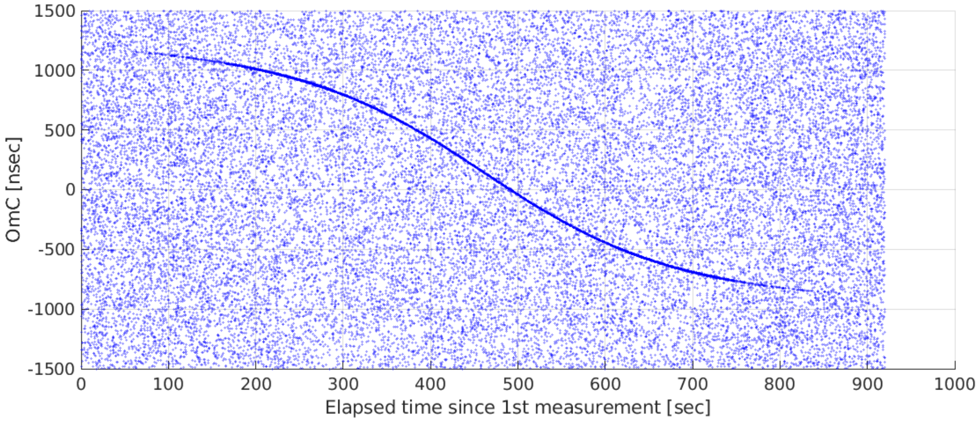
  - laser parameters needed to be optimized for each working point (thermal conditions!)
  - 6 working points:
    - 101.5 Hz (±1.5 Hz)
    - 104.5 Hz (±1.5 Hz)
    - 107.5 Hz (±1.5 Hz)
    - 193.2 Hz (±3.4 Hz)
    - 200.0 Hz (±3.4 Hz)
    - 206.8 Hz (±3.4 Hz)
- "afterglow" of lenses in the transmit/receive path not yet quantified

Processing Weak Signals from SDLR

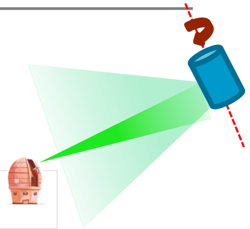


Case A: High Signal-to-Noise

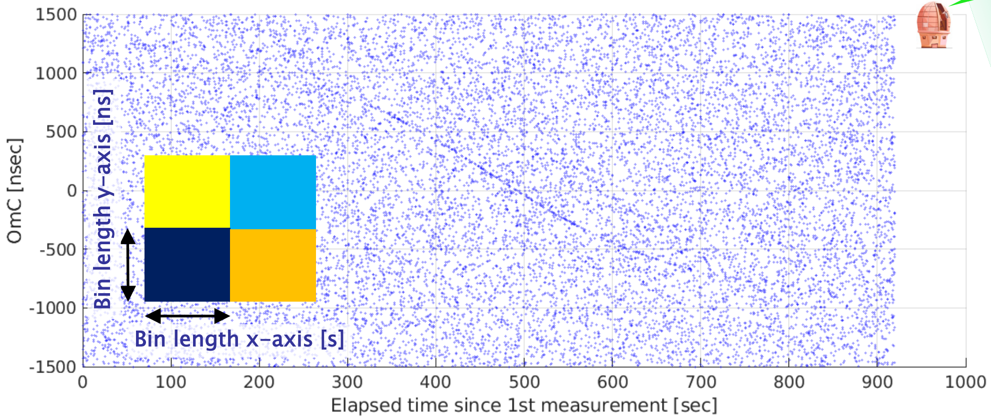
100Hz



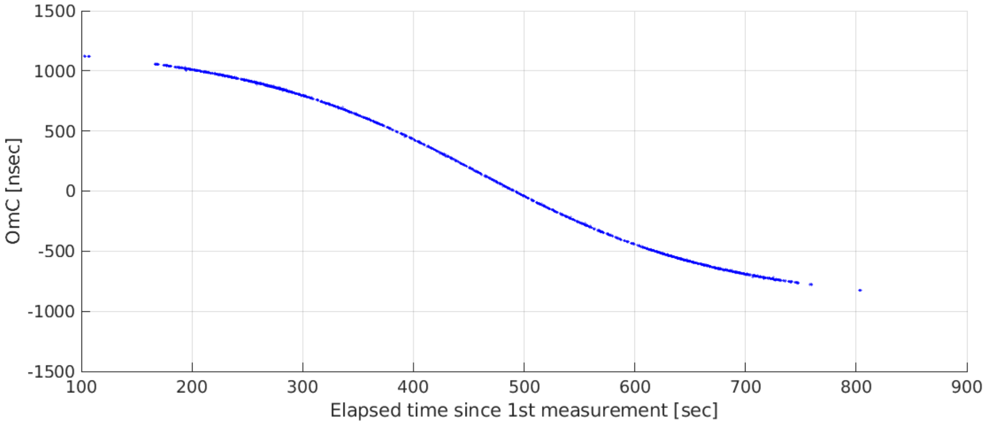
Case B: Low Signal-to-Noise

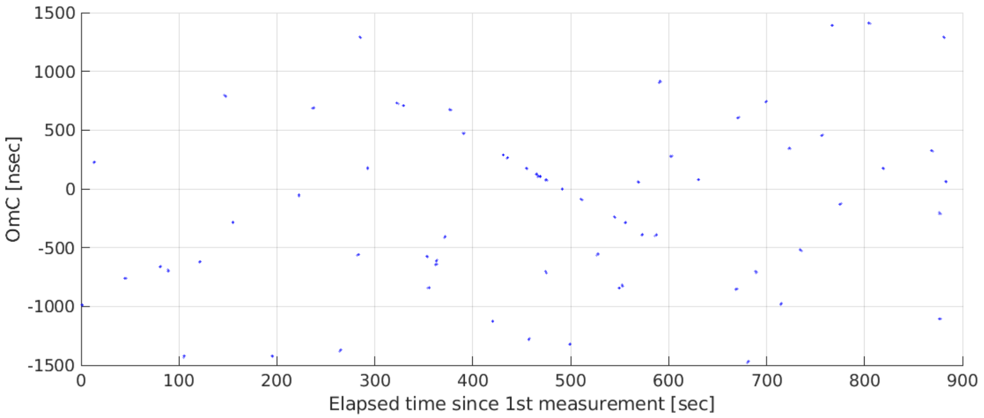


100Hz



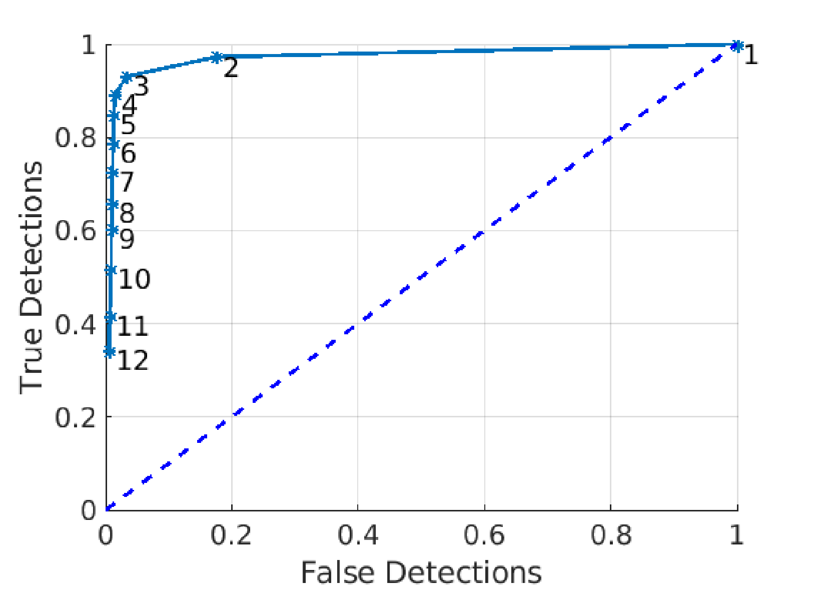
Filtered signal with traditional methods





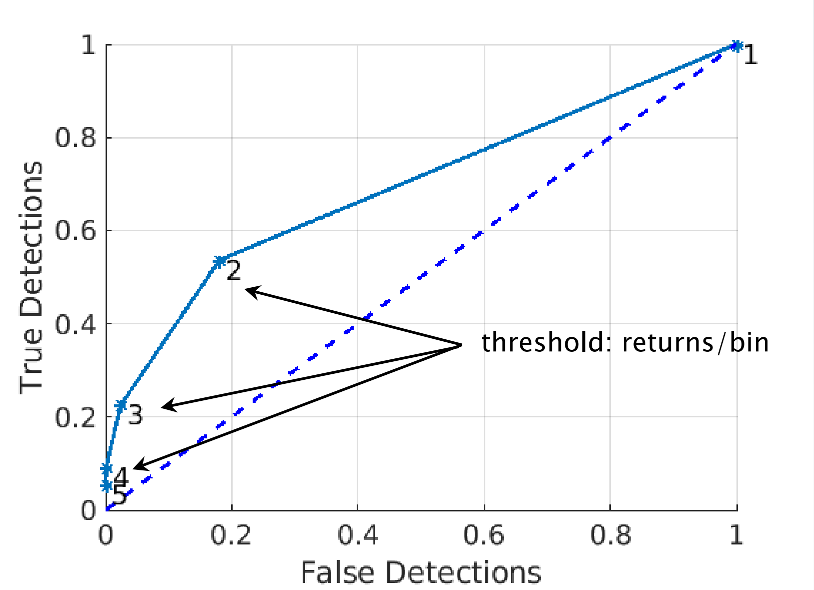
Quantitative Analysis:
Receiver Operating Characteristic Curves

Case A: High Signal-to-Noise



(1ns x 2s rectangular bins)

Case B: Low Signal-to-Noise

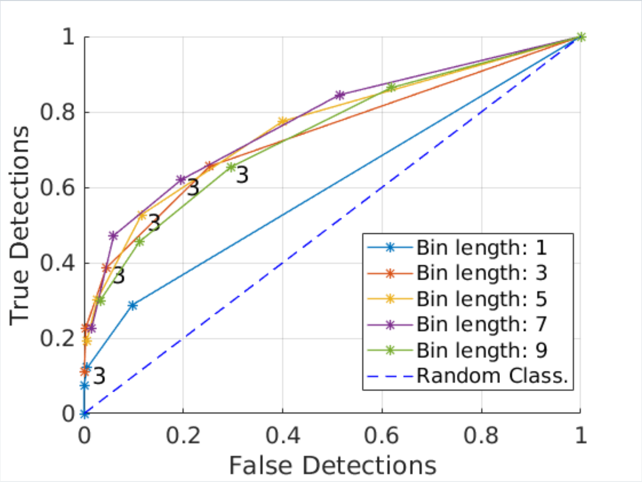


How can we improve the performance?

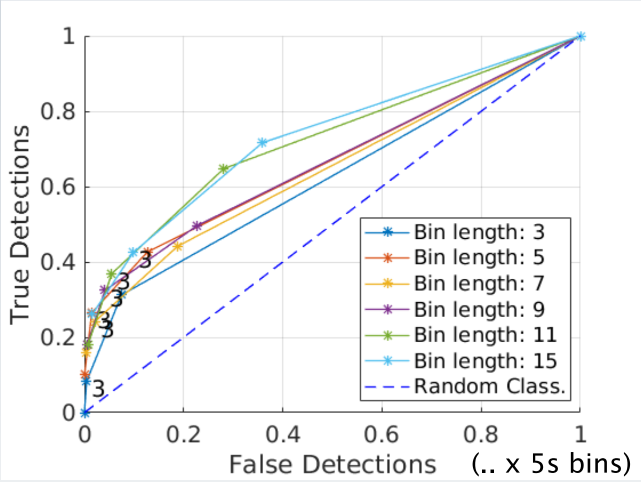
Processing Weak Signals from SDLR

Optimization of Bins

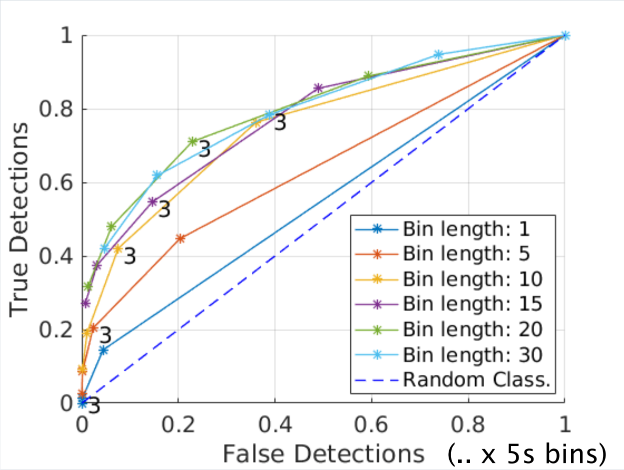
Bin length in x-axis

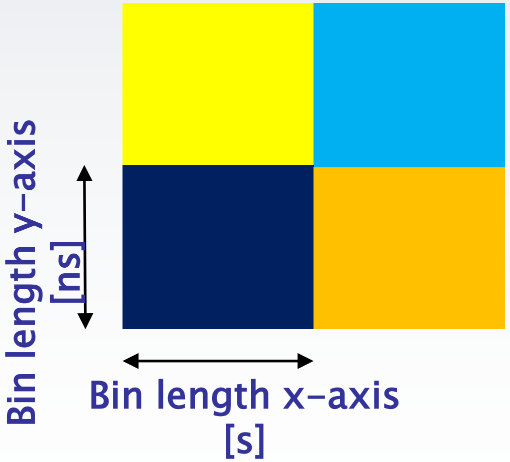


Bin length in y-axis



Bin shape: hexagons

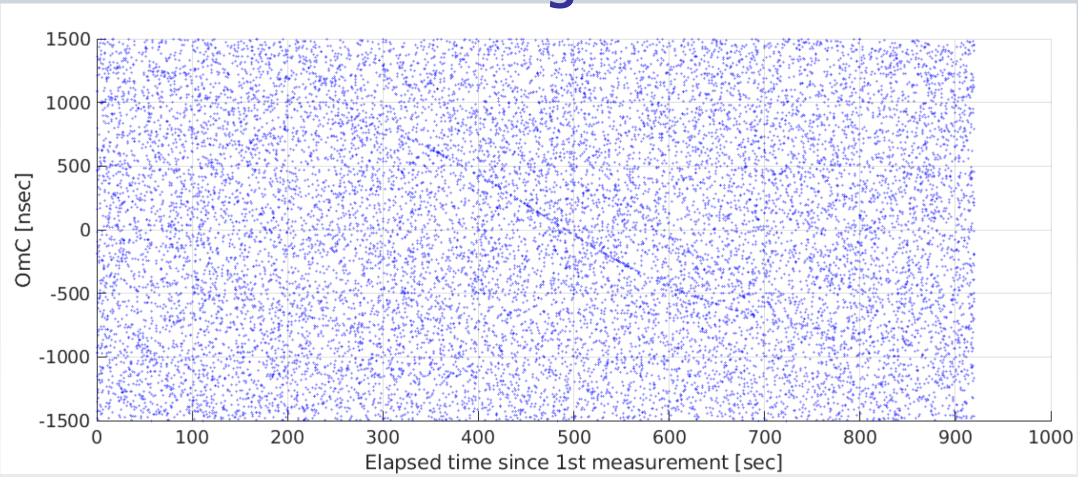




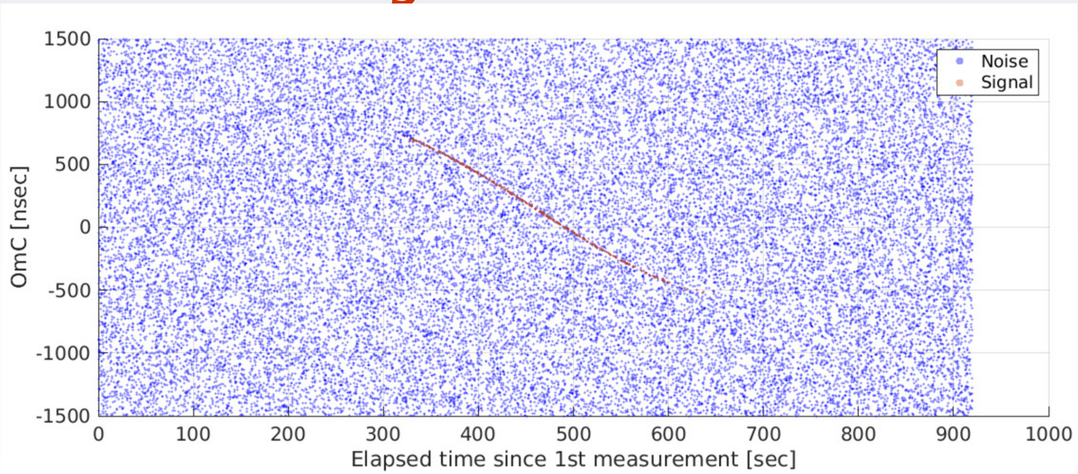
- Reduction of sampling bias → Edge effect
- Low perimeter-to-area ratio → No overlaps or gaps
- Capability to adapt to curve patterns
- Correlations between all possible combinations

Processing Weak Signals from SDLR

Case B: Low Signal-to-Noise



Filtered signal with new method



Summary

- A space debris laser is currently installed in the Coudé path of the ZIMLAT telescope
  - 40W 100/200 Hz
- A monostatic Coudé configuration poses specific challenges
  - 10^{-5} attenuation for calibration needed
  - laser repetition rate: 6 separate working points for laser
- New algorithms for processing weak signals for SDLR were developed and validated by J. Rodriguez

Thank you for your time!