

# Linear polarization issues for Laser Ranging to uncoated retro-reflectors [on HEO satellites]

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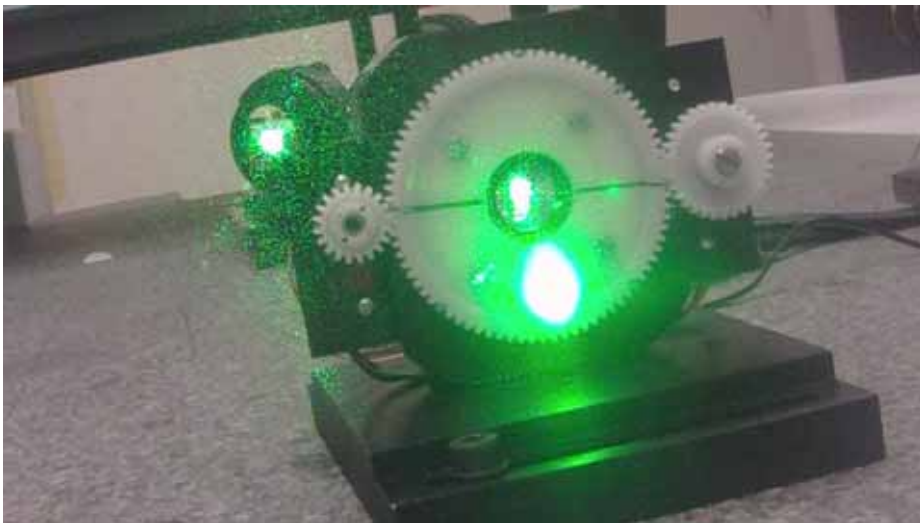
## *Overview*

- Compass M1 Polarization tests, as presented in Kötzing 2011
- Polarization tests to other uncoated-cube HEO satellites
- Conclusion, recommendation

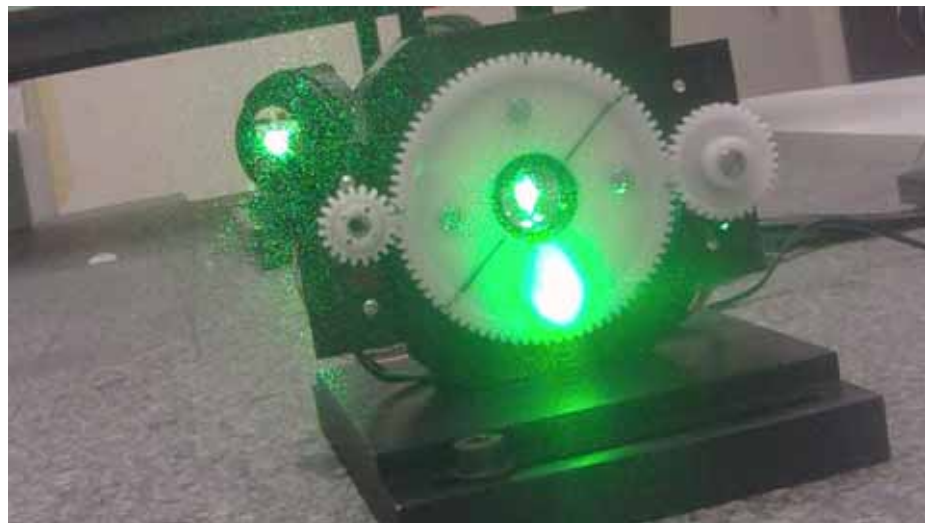
## Status of last year / workshop in Kötzing:

- Satellite Compass M1 / UNCOATED retros as target
- Few full passes of CompassM1 (about 4 hours) tracked
  - This gives about 2 Million points (2 kHz, 400  $\mu$ J pulses)
- Polarization plane was switched during tracking in *1 minute* intervals;
  - **1 Minute** with POL plane **ALONG** orbit of CompassM1 (even minutes)
  - **1 Minute** with POL plane **ACROSS** orbit of CompassM1 (odd minutes)
- 1-minute NPs were formed accordingly (about 250 NPs for 1 pass)
- Effects of POL plane orientation can be seen:
  - From 1 mm to  $\approx 0.2$  mm differences in range

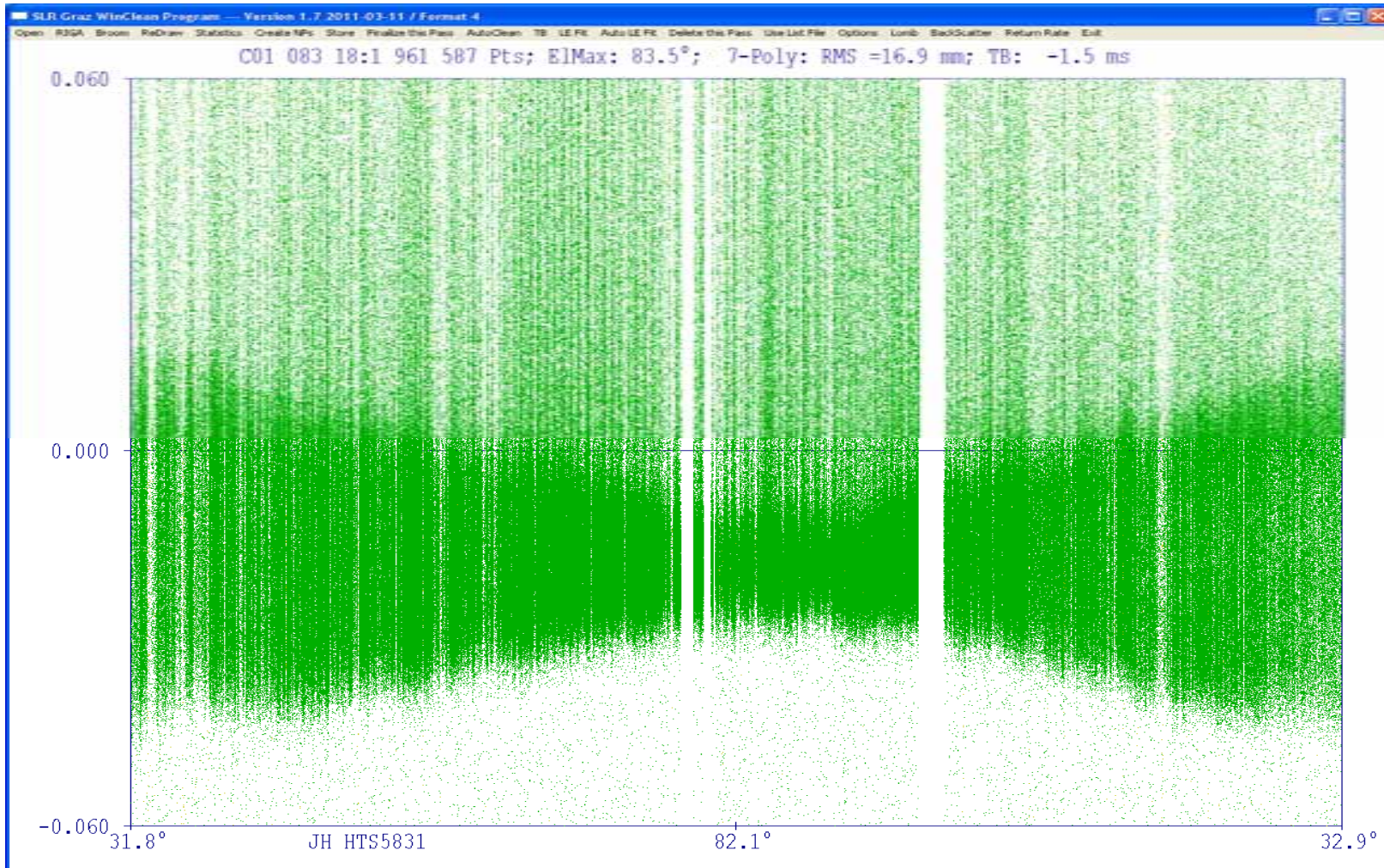
- We installed a  $\lambda/2$  waveplate on the laser table: rotation by  $\alpha$  rotates POL plane by  $2\alpha$
- Rotation is PC controlled; POL plane orientation can be chosen:
  - To compensate for mount / telescope motion; and/or
  - To adjust for the satellite orbital motion, resp. its velocity aberration vector
- For the ‚Arnold‘ experiment, the plate was rotated each minute by  $45^\circ$  (back and forth);
- This rotated the linear POL plane by  $90^\circ$ ; Goal:
  - In each ODD minute: POL plane orientated ACROSS orbit (‚Arnold‘ angle  $\odot$ :  $90^\circ$ )
  - In each EVEN minute: POL plane orientated ALONG orbit (‚Arnold‘ angle  $\odot$ :  $0^\circ$ )



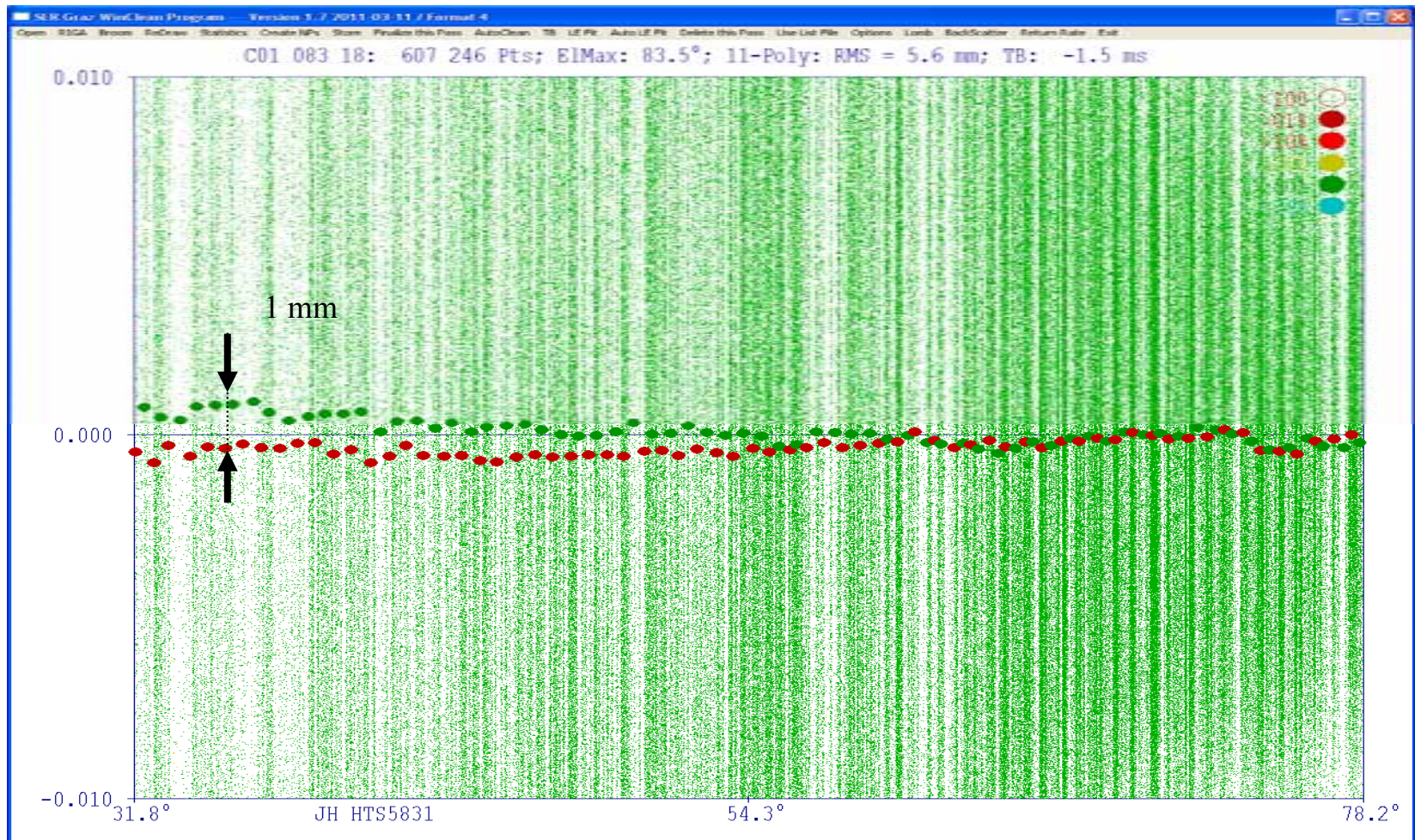
$\lambda/2$  waveplate at  $0^\circ$  (on laser table);



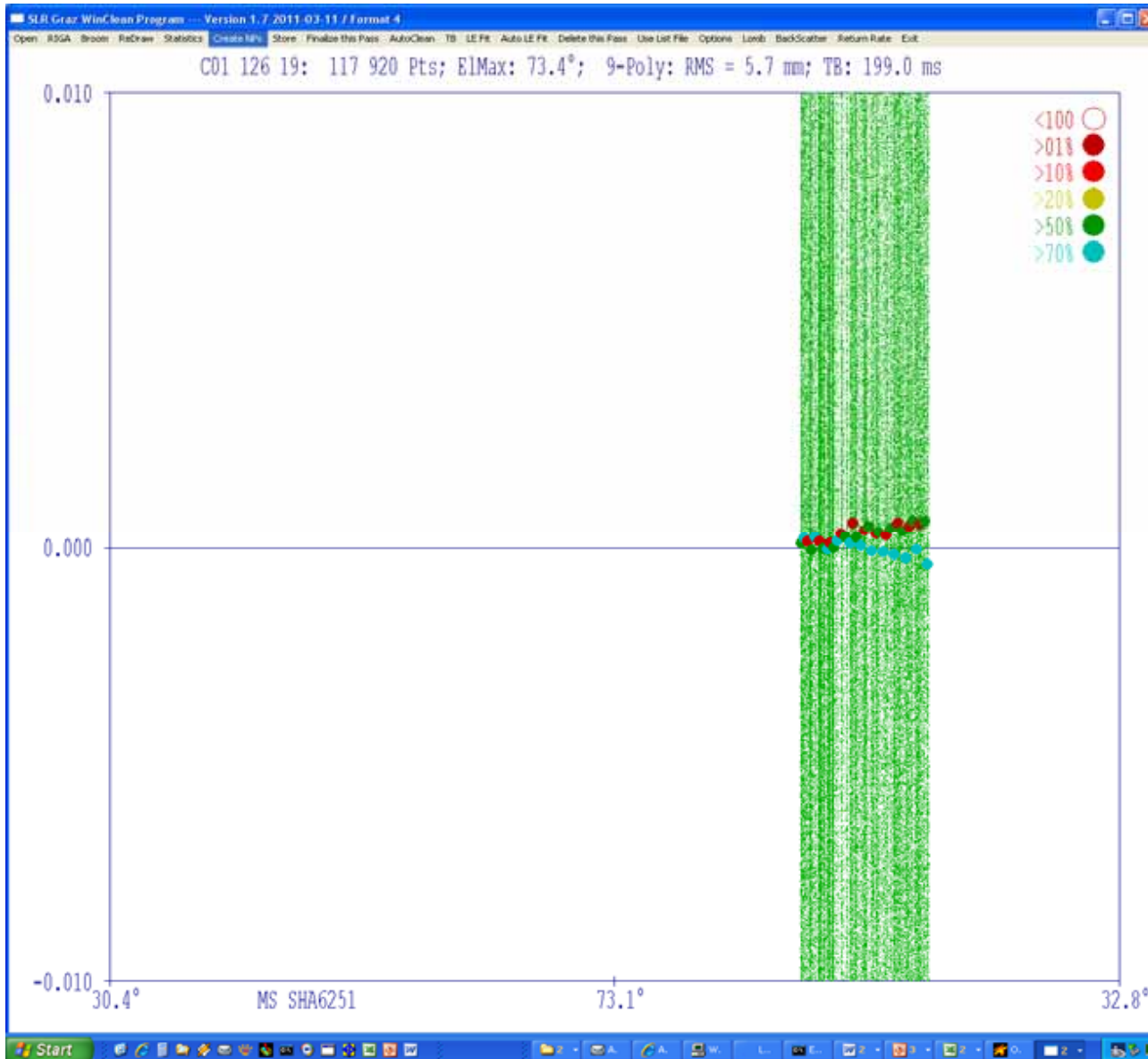
$\lambda/2$  waveplate at  $45^\circ$



- Main Return Line clearly visible; C-SPAD after-pulsing: Increased noise AFTER main track
- Panel geometry becomes visible; still almost 2 million points



- Green NPs: ODD minutes, POL plane *across* orbit; red NPs: EVEN minutes; POL plane *along* orbit
- The effect disappears towards CA according to theory; down to 200  $\mu$ m measurable



Observed with:

0° -45° - 90° POL switching;

switched at every full minute;

NPs: 1 Minute intervals;

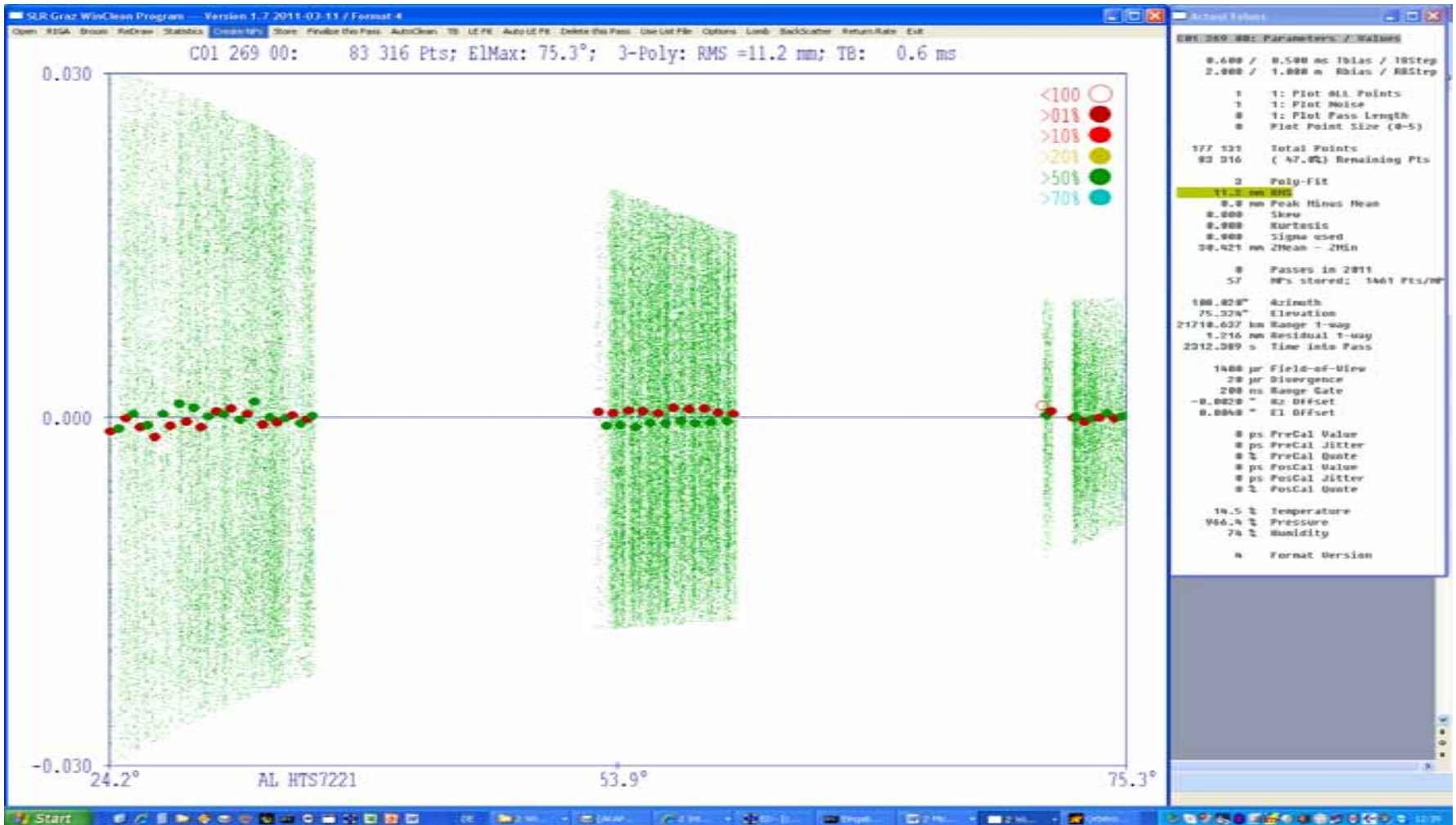
NP colors:

Red : 0° Along orbit;

Green: 45° to orbit;

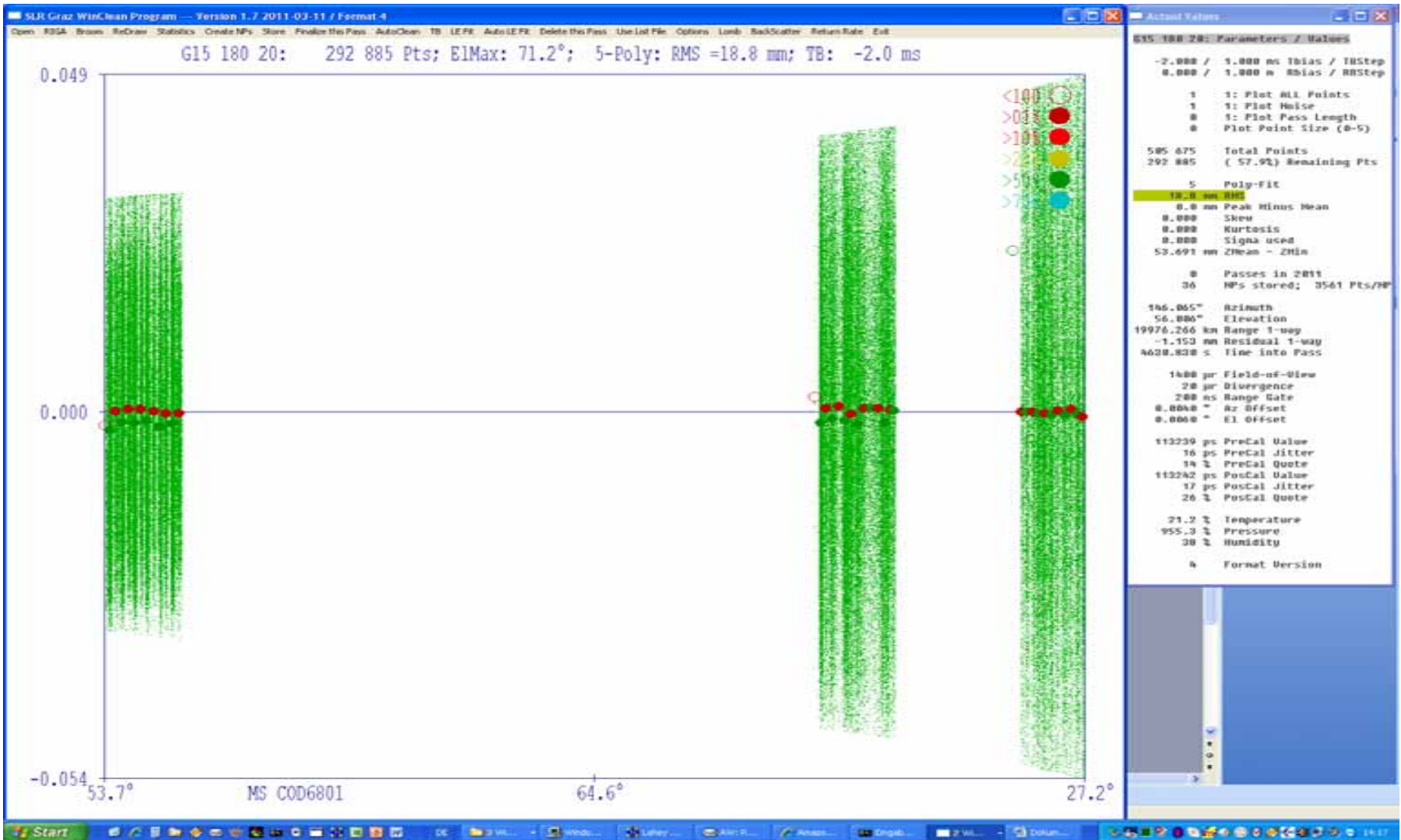
Cyan : 90° Across orbit

Max distance diff: 1.2 mm

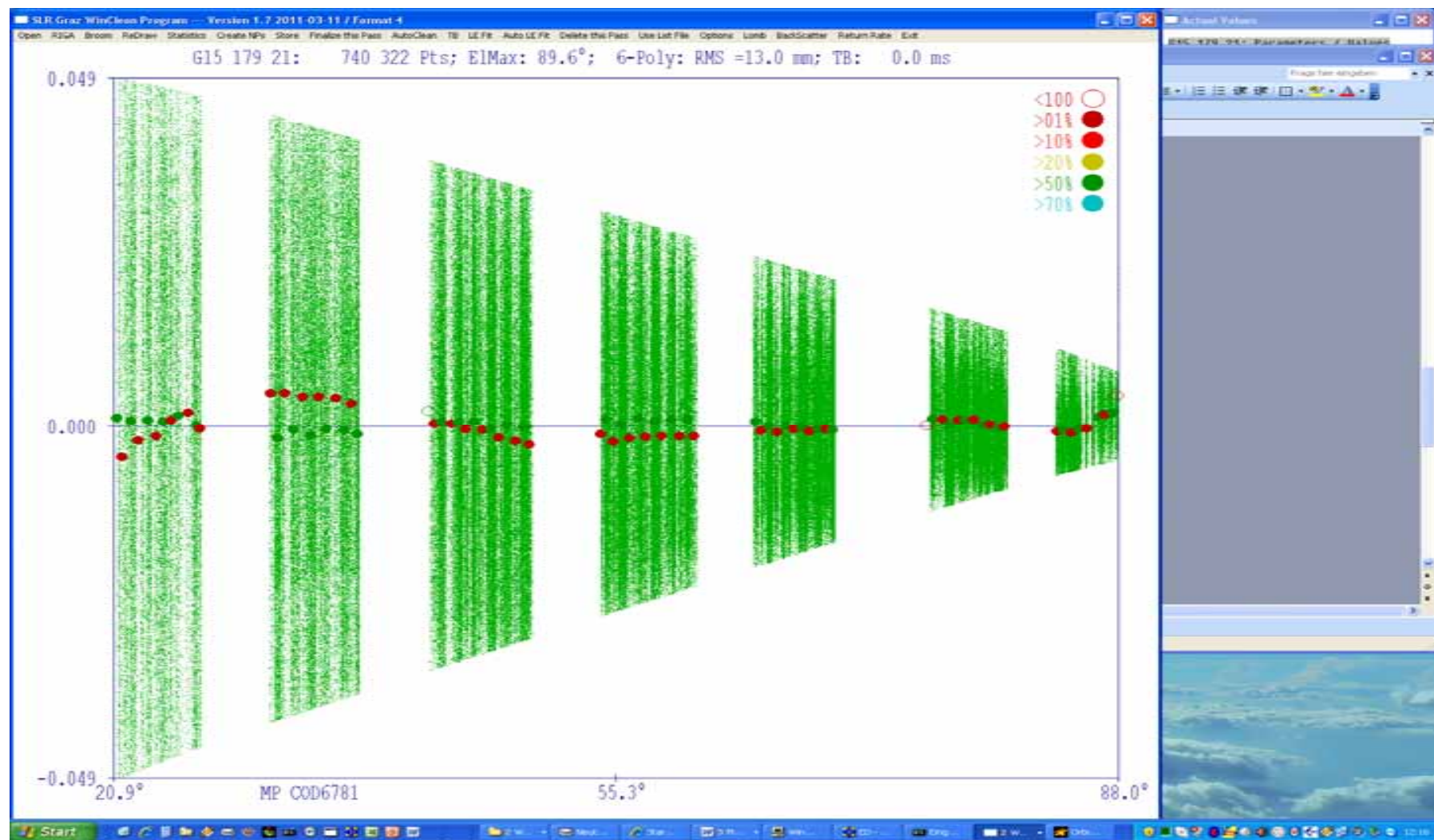


Block 1: No clear result; Block 3: no diff (high elevation, near CA)  
 Block 2: Green ahead (pol plane across orbit; mean diff: 0.9 mm)

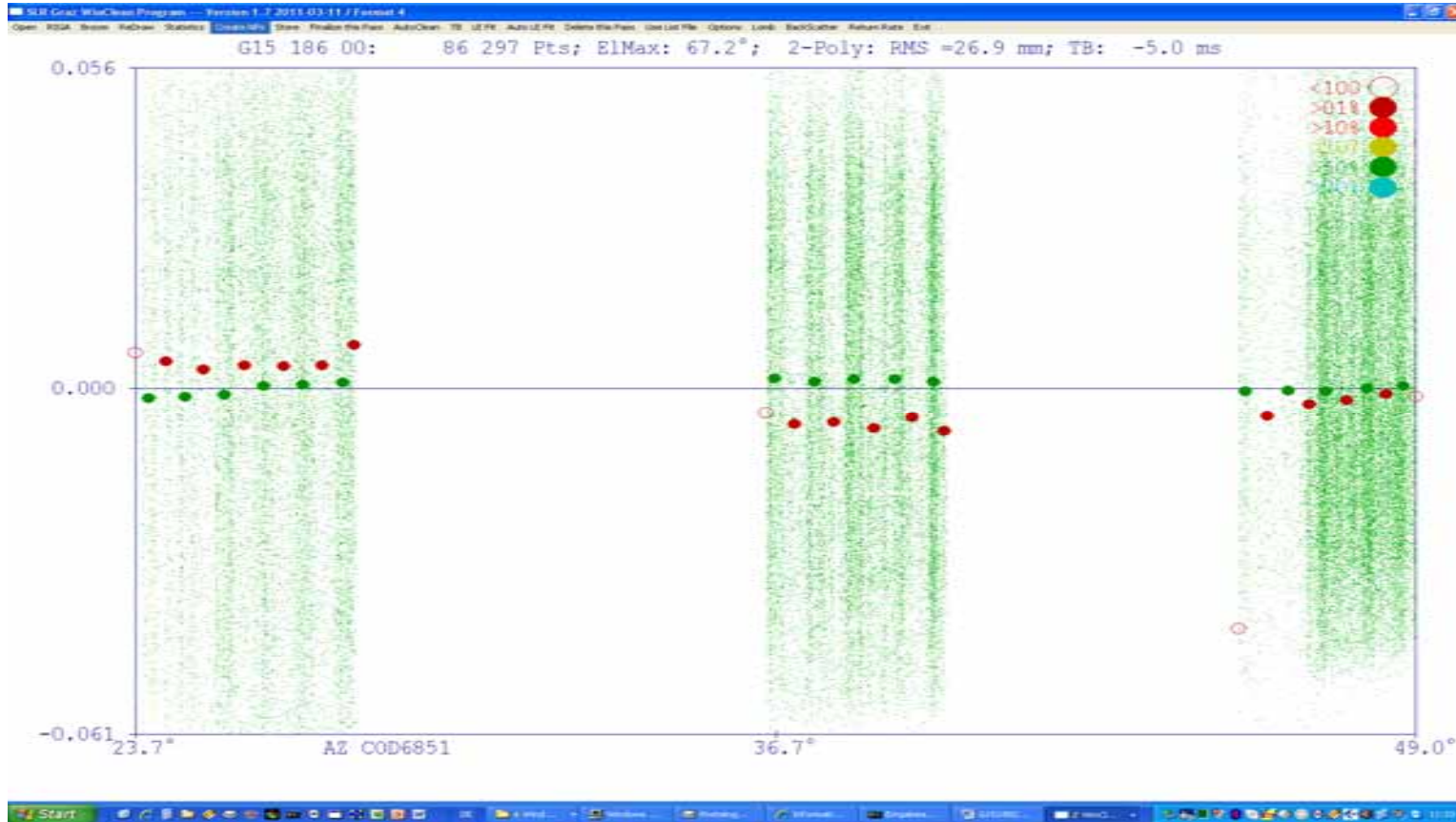




First block: about 2 mm difference between red and green points



2nd block: about 6.5 mm difference between red (across) and green (along orbit) points;  
 4th block: difference reverted



- Green/Red NPs are changing positions ....
- Red NPs (upper row at begin): POL plane ACROSS orbit
- Red NPs (lower row at begin): POL plane ALONG orbit
- Block 1: distance varies from **6.2 mm** down to **3.6 mm**
- Block 2: from **8.84** to **6.17 mm**; mean: **7.61 ± 0.91 mm**
- Block 3: From **5.30** to **1.0 mm** descending (fast !!!)

### - *Conclusion:*

- GNSS Satellites allow sub-mm NPs with kHz SLR techniques & Single Photon Detection
- BUT: Linear polarized laser pulses on uncoated retro-reflectors affect the measured ranges
- This effect can be up to 7 or 8 mm => incompatible with sub-mm ranging precision goal

### - *Recommendation:*

- The effect is not visible with circular polarization; therefore:
- Change linear polarization into circular polarization:
  - Insert a  $\lambda/4$  waveplate on the laser table;
  - Done in Graz at 2012-083 (2012-03-23);
  - Cost:  $\approx 400$  €;

**Thank you 😊**

