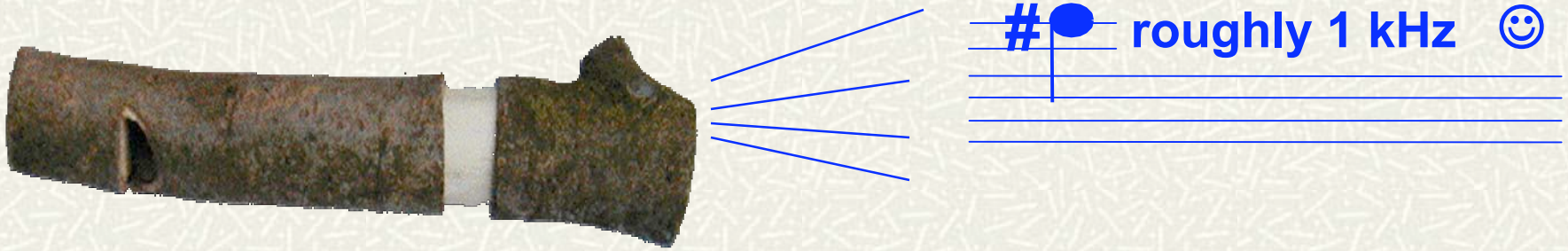
Graz 2 kHz System



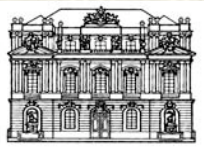
Graz kHz SLR System:

Design, Experiences and Results

G. Kirchner, F. Koidl

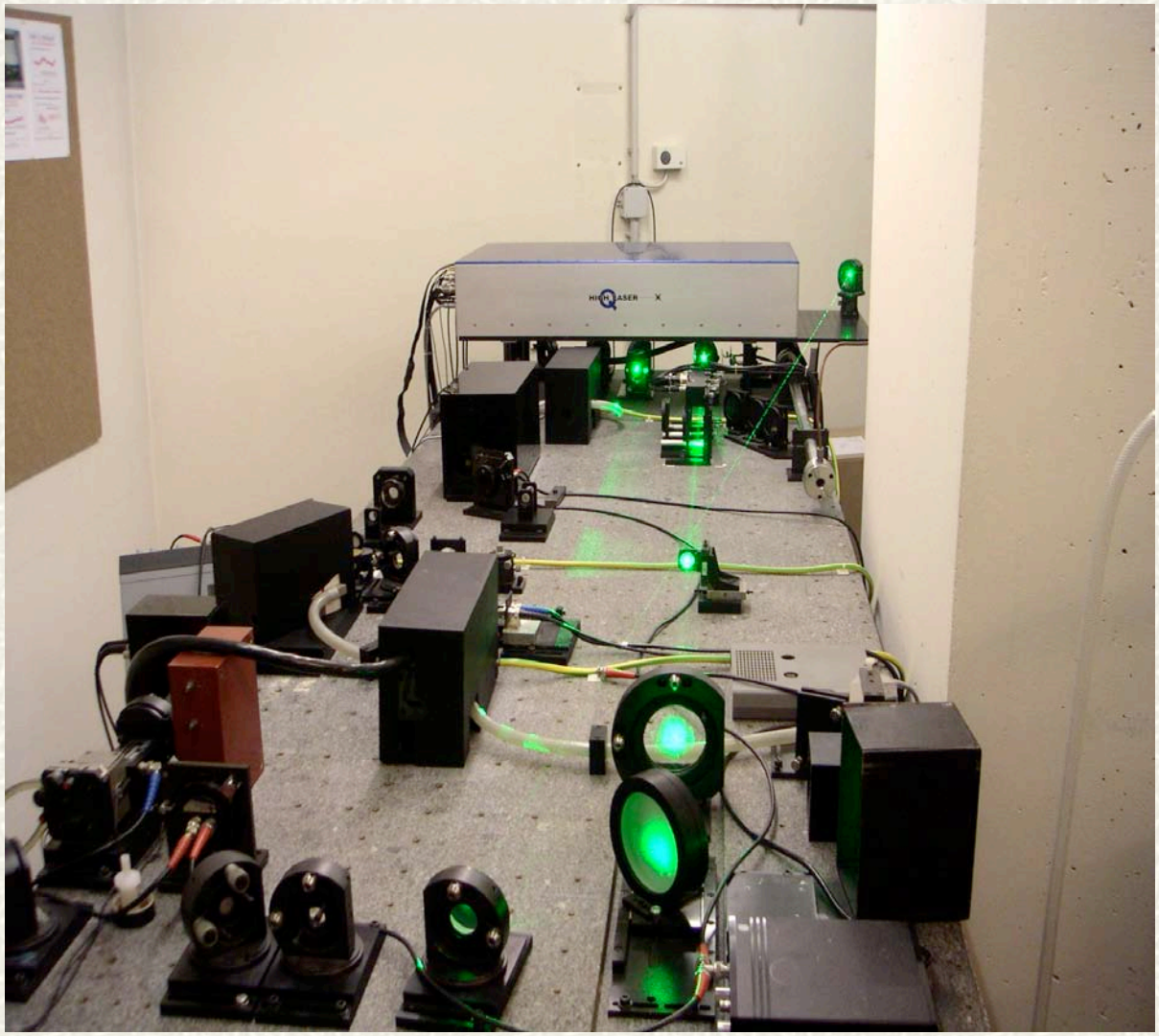
San Fernando, June 2004

The 2 kHz Laser is Operational



- Since ~2000: All Upgrades with respect to kHz:
  - Event Timers; RG Generator; Software etc.
- 05/2003: First suitable kHz laser appeared;
  - Offered by HighQLaser Company / Austria
- 10/2003: kHz Project granted;
- 03/2004: All papers signed, kHz laser ordered;
- 09/2004: First test passes, successful;
- 10/2004: Graz kHz SLR System OPERATIONAL

The 2 kHz Laser: Main Specs



- Nd:Vanadate;
- DPSSL;
- 10 – 2000 Hz;
- 2000 Hz routine;
- 10 ps Pulses;
- 400 □J / shot
- @ 532 nm;

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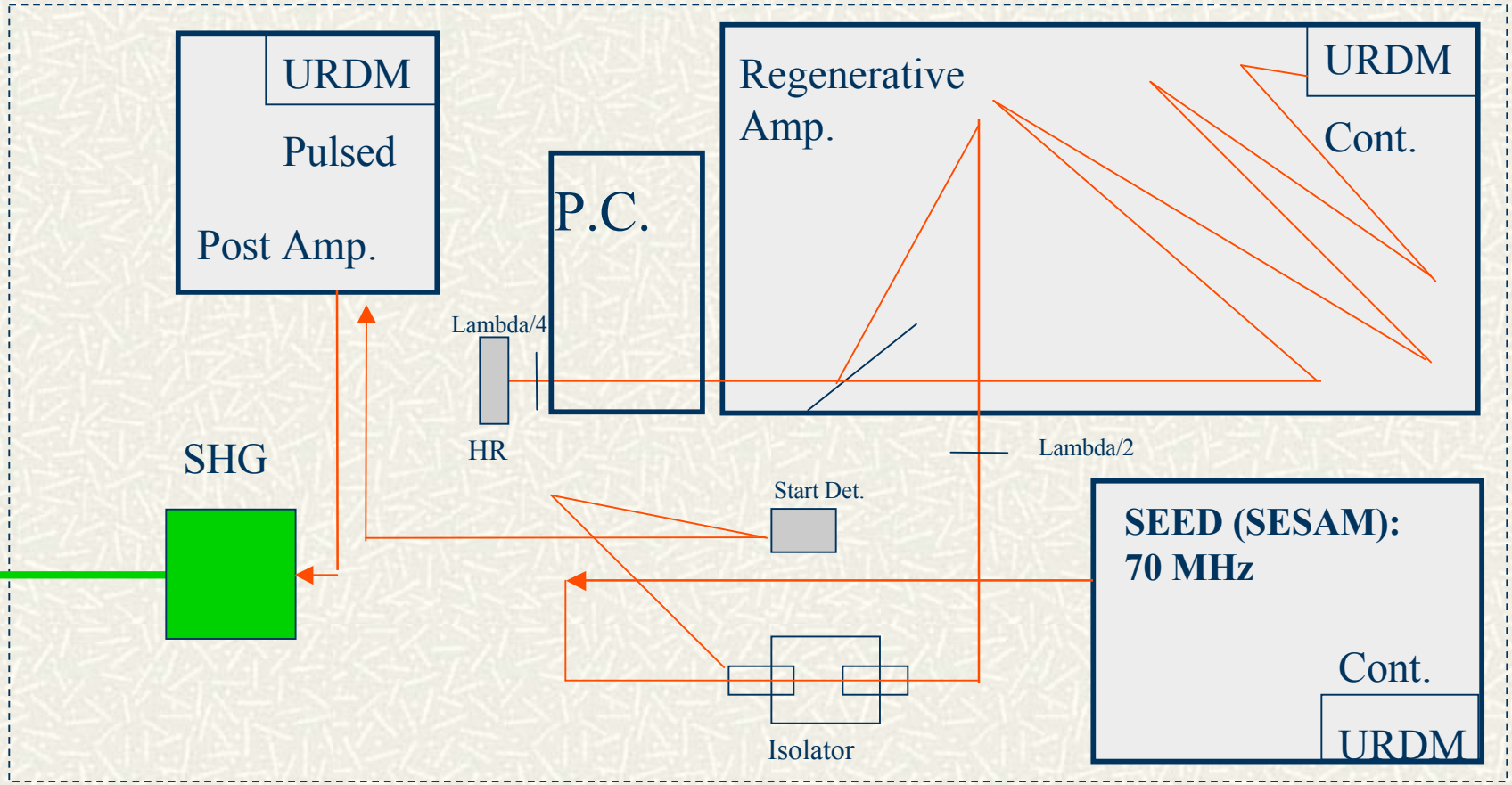
The 2 kHz Laser: Design



Made by HIGH Q LASER => An Austrian Company

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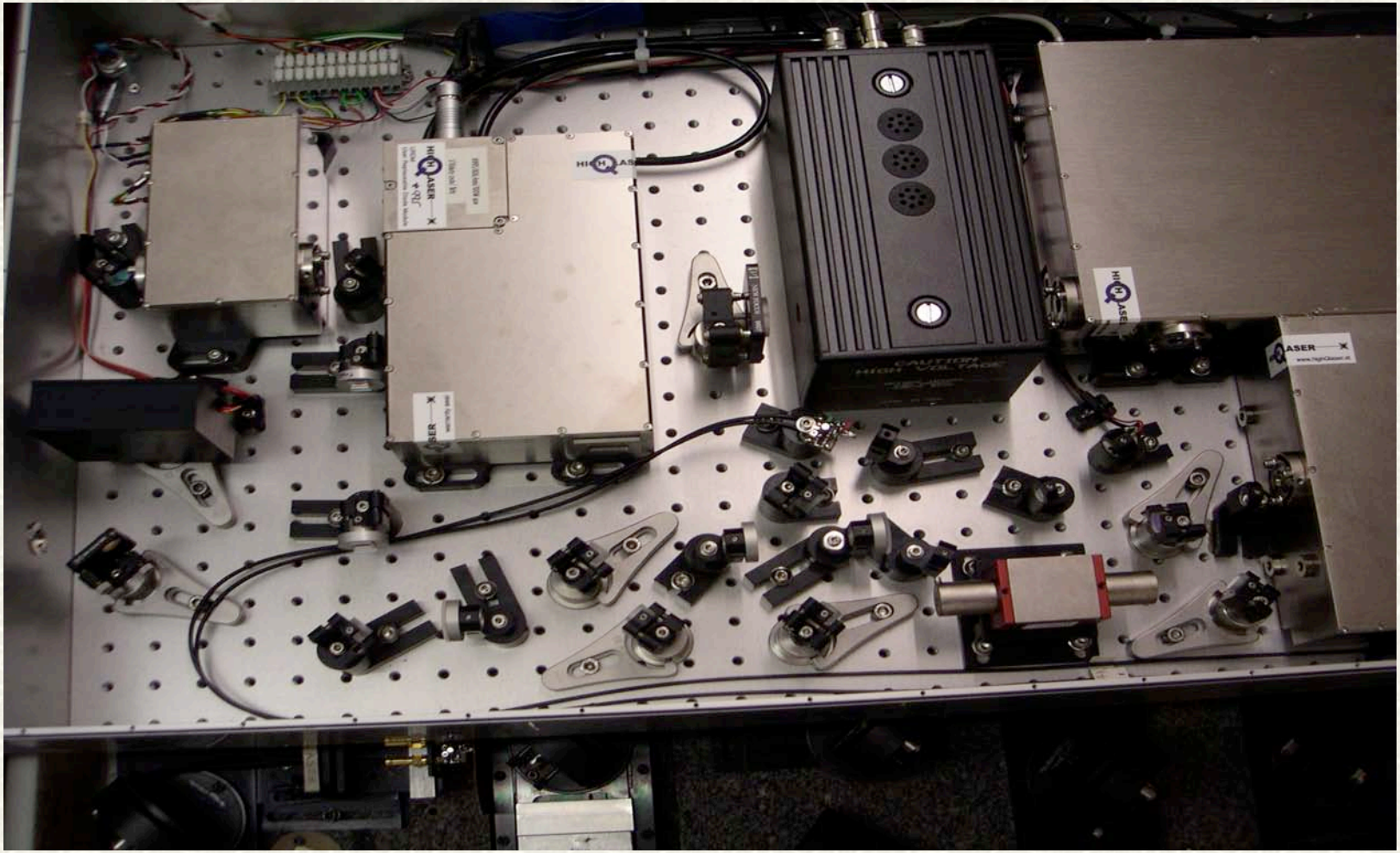
Internal View



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Range Gate Generator

- Designed and built in Graz (FPGA-Chip);
- < 0.5 ns resolution, < 1 ns accuracy;
- Receives next gate events via 16-bit interface from PC;
- Buffers up to 300 next gate events;
- RG for C-SPAD about 65 ns before return arrives;

- Generates also laser firing/control commands;
- Shifts laser pulses automatically to avoid overlaps;
- Programs LC scattering shutter / attenuator for LEOs;

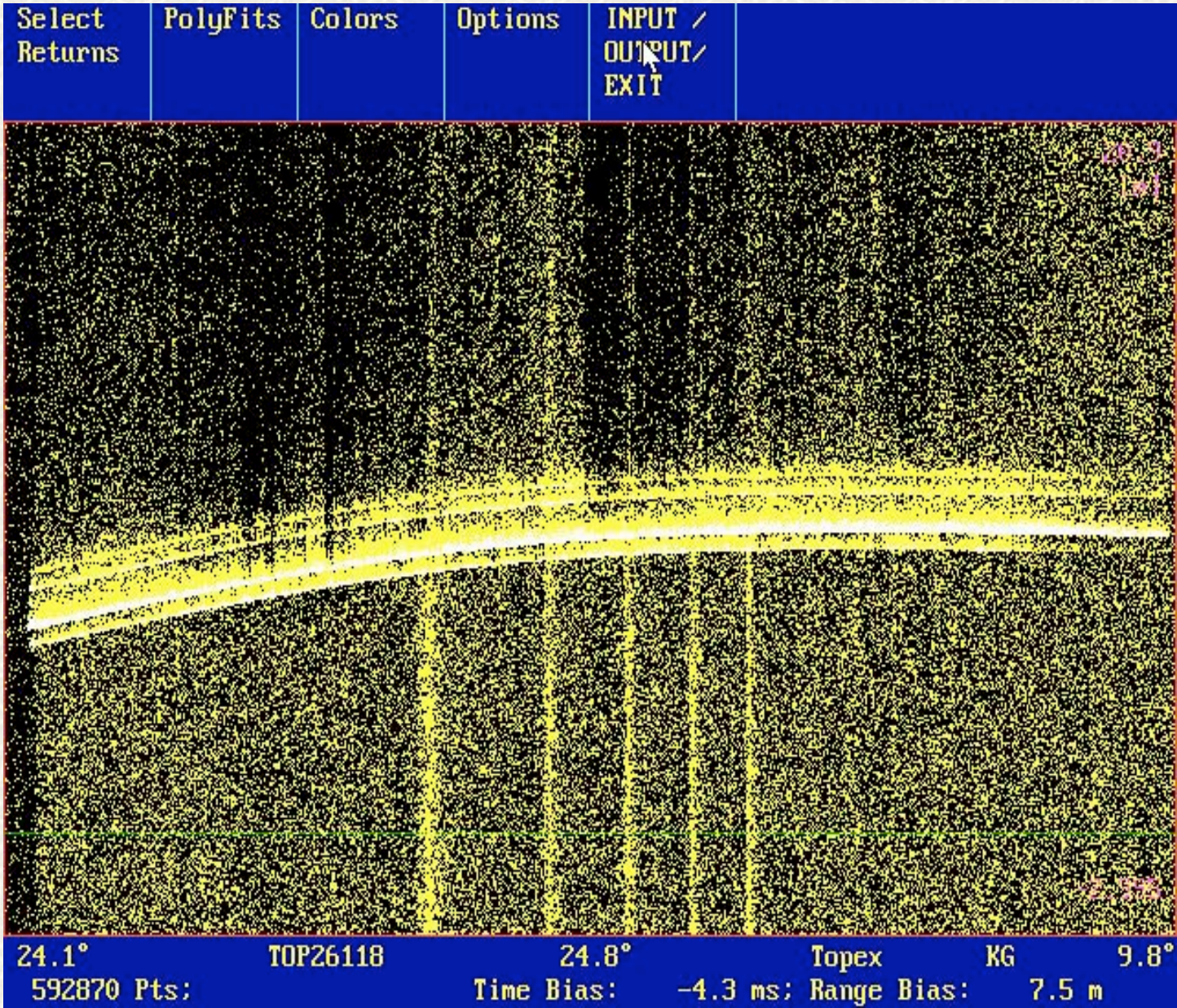
Receive / Transmit Overlap

- At 2 kHz, overlaps occur:
  - Laser fires when Single Photons arrive;
  - Backscatter blocks C-SPAD receiver;
- Solution: Laser Firing slightly shifted;
  - Controlled automatically via FPGA;
  - No PC control / time needed;

WITH Overlaps

TOP 261 18:

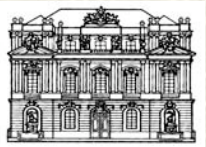
- TEST Pass;
- Overlap-Avoid Circuits OFF;
- NO Shift of Laser Firing;
- Periodical Noise Increase due to Overlap
- 600 k Pts recorded;
- 424 k Rets remaining



Received Energy Control

- Even with low energy laser (400 □J @ 532 nm):
- High satellites (Glonass, GPS etc.): SPEs only ...
  - Max. Return Quote: Few percents;
  - (some 10 Returns per second max.)
- LAGEOS: Return Quote most times < 15%; SPEs !
- LEOs: Divergence / Pointing / Atmosphere:
  - ALL in same order of Magnitude (5“ – 10“);
  - Big fluctuations of received energy;
  - Gives sometimes very strong returns;
  - But also a significant amount of SPEs ...

Received Energy Control



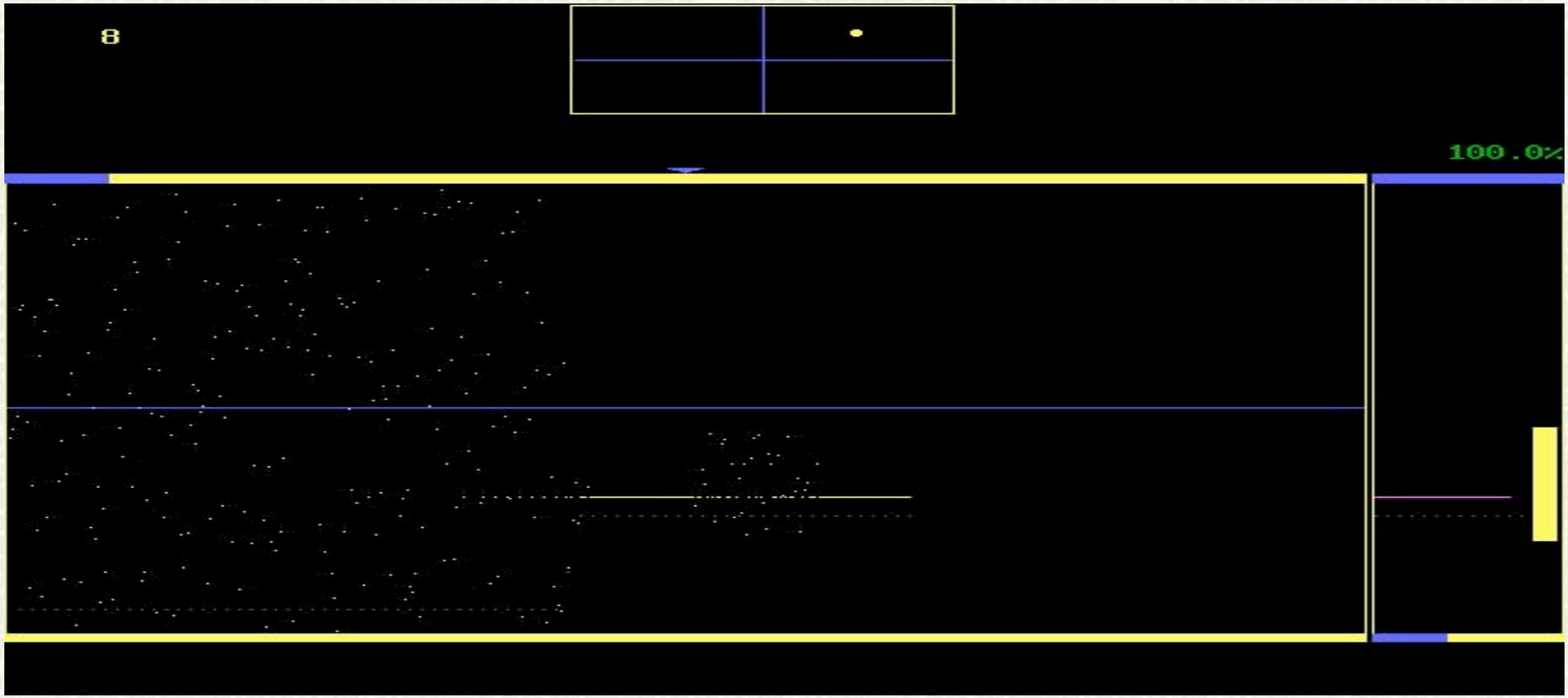
To reduce these fluctuations for LEOs:

- **We measure the energy of each Return;**
  - **Time between Compensated / Uncompensated Pulse:**
  - **0 – 240 ps maps to 1 – 1000 PEs;**
  - **Measured with standard E.T. (1.2 ps resolution);**
- **A fast LC shutter / attenuator in front of SPAD:**
  - **Scattering LC Polymer Shutter, analog mode;**
  - **< 1 ms switching time for 1:500 contrast ratio;**
  - **Received energy controlled nearly shot-by-shot !**
- **First tests successfully started now; looks promising !**

kHz Real Time Software

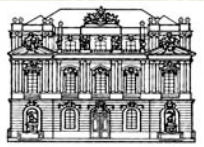
- 2.7 GHz PC; MS-DOS system;
- 3 standard interfaces to external world;
- All events etc. buffered;
- Many automatics implemented:
  - Automatic RG, TB, Track, Search Mode etc.
  - Better / faster due to kHz rate !

Real Time Return Identification



- Last 1000 Residuals kept in memory; new resid compared to these;
- If enough (e.g. 5) resids are within a band (e.g. 100 ps) of new resid: IDENT
- Minimum # and bandwidth are variable, set by system, automatics, observer;
- ID resids (yellow) filled into histogram (right); max. bin only displayed;
- Max Bin value used to guide RG automatics etc.

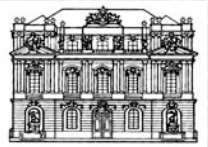
Graz kHz Results: Returns



Huge increase of returns per pass; examples:

	Old: 10 Hz, 35 mJ	New: 2 kHz; 0.4 mJ
LAGEOS:	14.000	up to **400.000** Returns / Pass
ENVISAT etc:	5.000	up to **400.000** Returns / Pass
TOPEX:	7.000	up to **750.000** Returns / Pass
AJISAI:	8.000	> **1.000.000** Returns / Pass ☺
GPS 35/36:	300	about **10.000** Returns / Hour ...

kHz Results: Points / NP

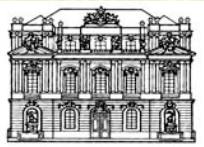


Huge increase in returns per NP; examples:

- LAGEOS: Up to **35.000** Returns / NP
- STARLETTE: Up to **42.000** Returns / NP
- AJISAI: Up to **50.000** Returns / NP

- In NP File: We state „9999“ if actual number exceeds that ☹
- Starlette at 10 Hz System: 26 Rets / NP average ☹

Operational Experiences

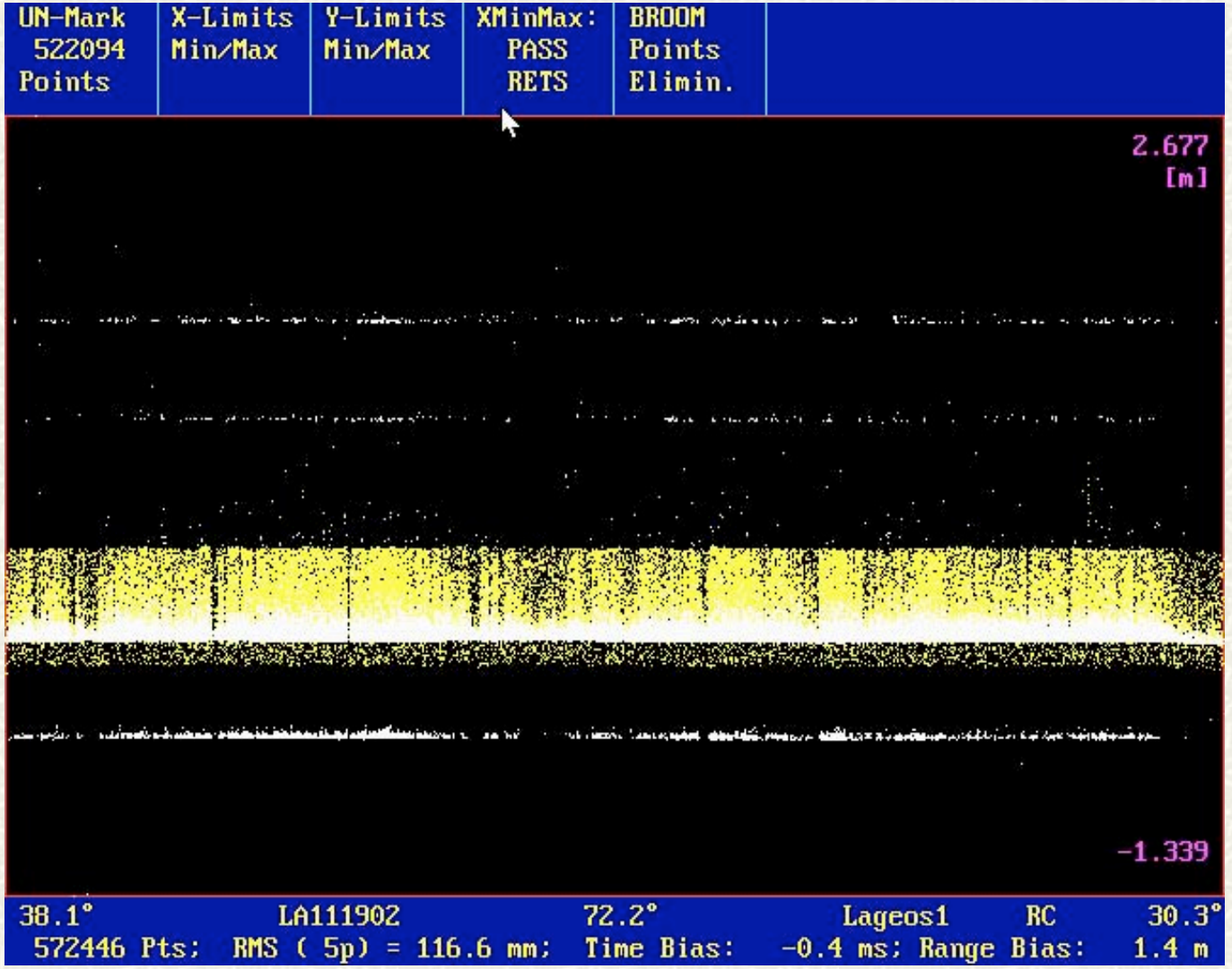


- Day & Night: Similar results / amount of data;
- NPs: Only delivered if > 100 Returns / NP (☺)
- Automatic routines: Faster / better due to kHz;
- Acquiring is easier / faster due to kHz
- Single Shot Accuracy: 2.5 – 3.5 mm (LEOs)
  - ➢ Better due to 10 ps, and uniform pulses;
  - ➢ Worse: More Sat signature at lower energy;

Example: Lageos 1, Raw data

LA1 119 02:

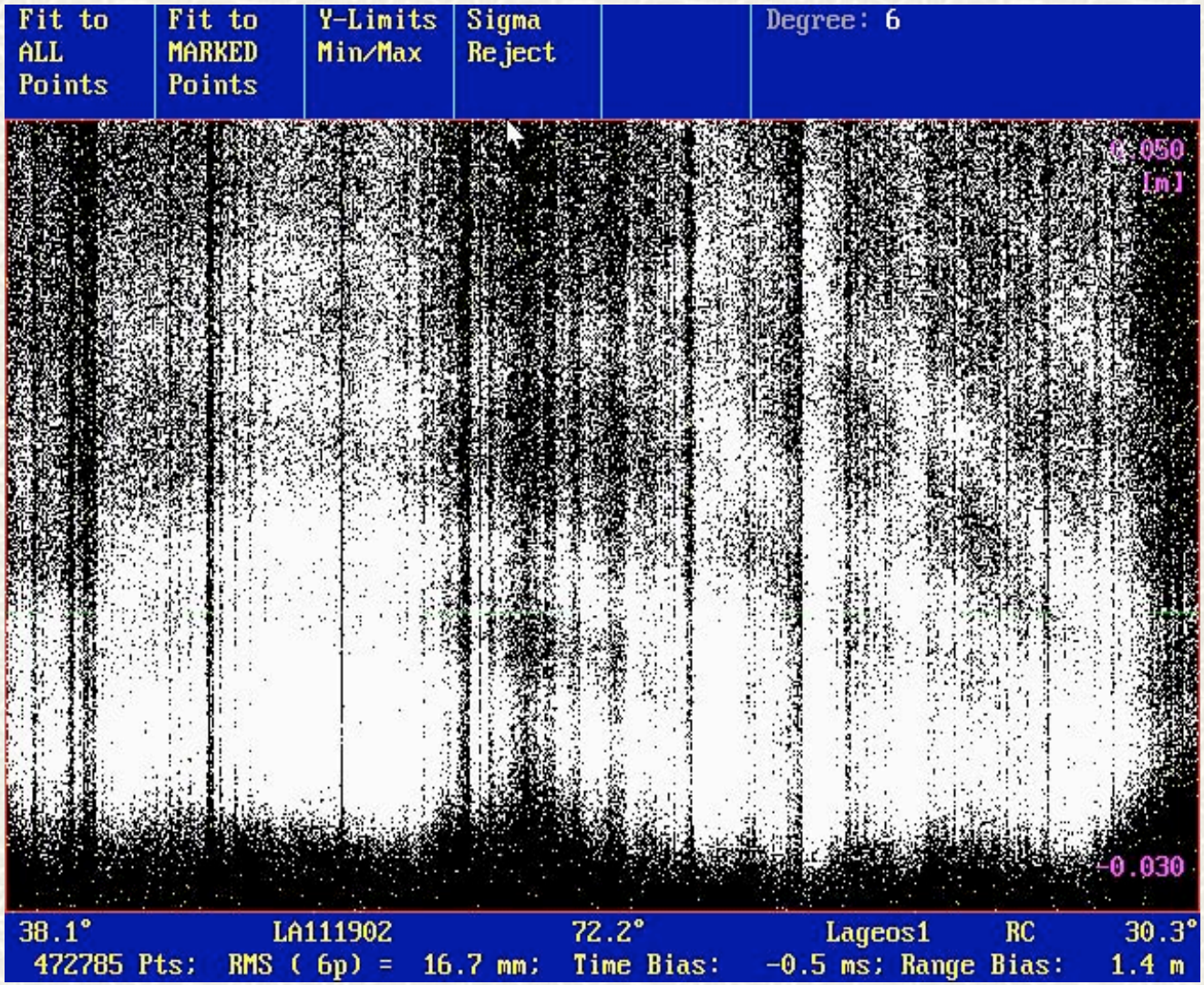
- 570 k points recorded;
- 380 k returns;
- 7.6 mm RMS;
- < 1% side tracks
- White: Ident.
- Yellow: Noise;
- No other noise stored;



Same Lageos 1 pass ...

LA1 119 02:

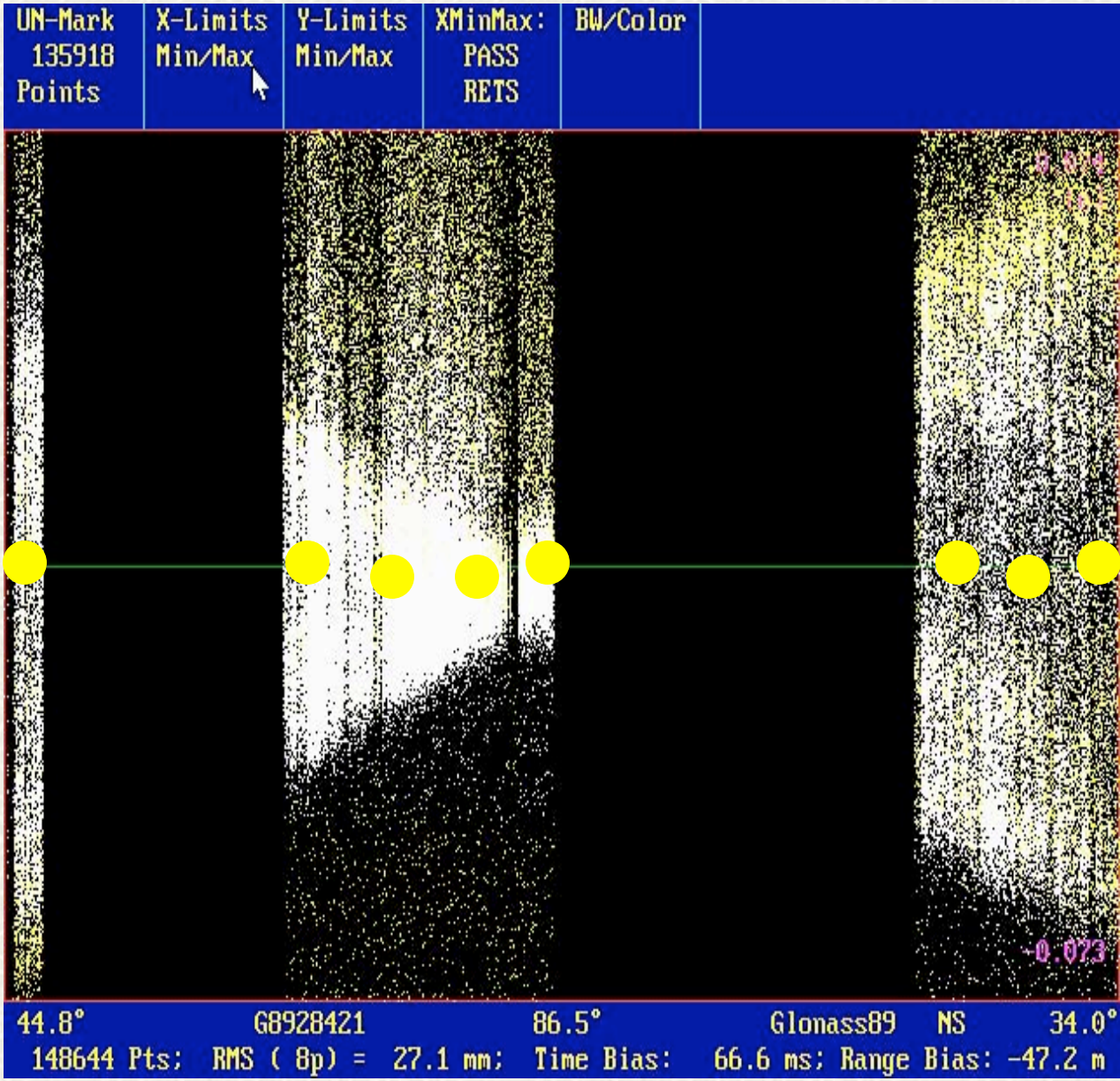
- Retro Clusters;
- Only Returns from nearest Retro used for NP formation;
- 362 k Returns remaining;
- 7.6 mm RMS;



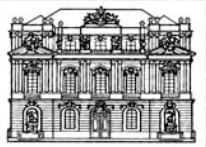
Glonass: Retro Panels visible

G89 284 21:

- 311 k Returns;
- 135 k Rets remaining
- White: Identified;
- Yellow: Noise;
- Shows Retro Panels;
- NPs: Show only some strange average … (CoM constant ???)



Conclusions



- Last year in Koetzting - after only 2 weeks of 2 kHz operation - we asked:

IS kHz the FUTURE OF SLR ???

- This year in San Fernando, after 8 months of experience with 2 kHz operation, our answer is:

- (That means: YES – we think so ...)