Graz 2 kHz System

Graz kHz SLR System:
Design, Experiences and Results

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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

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The 2 kHz Laser: Main Specs

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

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The 2 kHz Laser: Design

SEED (SESAM): 70 MHz

Regenerative Amp.

Lambda/2

Lambda/4

Post Amp.

Pulsed

URDM

SHG

HR

Start Det.

Isolator

URDM

Cont.

URDM

Cont.

SEED (SESAM): 70 MHz

Cont.

URDM

Made by HIGHQ 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;

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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;

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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 µJ @ 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!
Last 1000 Residuals kept in memory; new resid compared to these;
If enough (e.g. 5) resid are within a band (e.g. 100 ps) of new resid: IDENT
Minimum # and bandwidth are variable, set by system, automatics, observer;
ID resid (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 ...

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**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 😞

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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;

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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;

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LA1 119 02:

- Retro Clusters;
- Only Returns from nearest Retro used for NP formation;
- 362 k Returns remaining;
- 7.6 mm RMS;
G89 284 21:

- 311 k Returns;
- 135 k Ret's 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 ...)