Coherent Time and Frequency Distribution System for a Fundamental Station

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Optical clocks has extremely good accuracy and stability. Both properties we would like to transfer into space geodesy.

Space Geodesy measures signal delays, therefore we require high accuracy and stability to track phase.

Highly accurate clocks allow to exploit GR for a height system.
Optical Clocks in Space Geodesy

C. Grebing et al., "Realization of a timescale with an accurate optical lattice clock," Optica, č. 6, s. 563–569, erven 2016.


Space Geodesy Instrumentation, where and how we can gain from ultrastable clocks

To reach $10^{-16}$ we must make our measurement stable and accurate.


Gola is
\[ \tau_1 = \tau_2 = \tau_3 = \tau_4 = \text{const.} \]

\[ \tau_{I1}, \tau_{I2}, \tau_{I3} - \text{proper calibration} \]
Optical Frequency Comb as an Ruler

- fs-laser
- $T_r = \text{const.}$
- $f_r = \text{const.}$
- spectrum
- reference frequency used for lock
- optical clocks
- event
- timing markers
- time
- frequency
Optical Frequency Comb as an Ruler

fs-laser comb

front-end

fs-
laser
comb

back-end

electrical
timing signal

Two-way stabilized link

T_r = const.

H-maser

reference frequency used for lock

f_r = const.

spectrum
Drift-free timing synchronization of remote space geodetic instruments

Example: FEL in Trieste

Optical Time Distribution system at Geodetic Observatory Wettzell

H-Maser (frequency standard)

fs-laser

UTC(k)

ΔT

ΔT

ΔT

C/A code

Opt. Ref. Cavities

Comp. Clock

fiber links

UTC

Future

future
Campus Distribution for accurate Time

- laser - 1560nm
- laser lock unit
- 2x optical amplifier
- 10 links in operation
Error signal for the closed loop fiber stretcher

Most of the excursions appear to be caused by the air conditioning and movement of the radioteleskop.

Stationary link length ~300 m

Moving link TTW2

Most of the excursions appear to be caused by the air conditioning and movement of the radioteleskop.
Timing properties of the timing signals

<table>
<thead>
<tr>
<th>Signal Name</th>
<th>RMS Jitter</th>
<th>Temp. Coef.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electrical PPS 1</td>
<td>0.43 ps</td>
<td>0.84 ps/°C</td>
</tr>
<tr>
<td>Electrical PPS 2</td>
<td>0.43 ps</td>
<td>0.83 ps/°C</td>
</tr>
<tr>
<td>CMOS PPS</td>
<td>1.26 ps</td>
<td>2.2 ps/°C</td>
</tr>
</tbody>
</table>

Additive jitter by Back-end electronic
Error signal and time distribution of stationary link

To validate new timing system in terms of stability and absolute delay we developed TWOTT system Event Timer **NPET**. J. Kodet et al., Metrologia, 2016.
Time distribution of stationary link

- Maser room AC failure
- $\pm 1$ ps
- $8^\circ C$
Future reorganization of UTC(k)

- **H-maser EFOS60**
- **u-stepper**
- **f-distrib**
- **PC control**
- **Event timer 32**
- **In PPS**
- **Menlo Master**
- **Out PPS**
- **5xCs clk**
- **Switch metric**
- **Menlo Back End**
- **Event timer 32**
- **2x H-maser**
- **Menlo Back End**
- **Out PPS**
- **RTW**

Daily TIC or frequency difference measurement:
Circular T, rapid UTC,
The biases in the geodetic measurement techniques can be quantitatively obtained for the first time in a closure measurement configuration with a resolution of a few ps.
Thank you for your attention