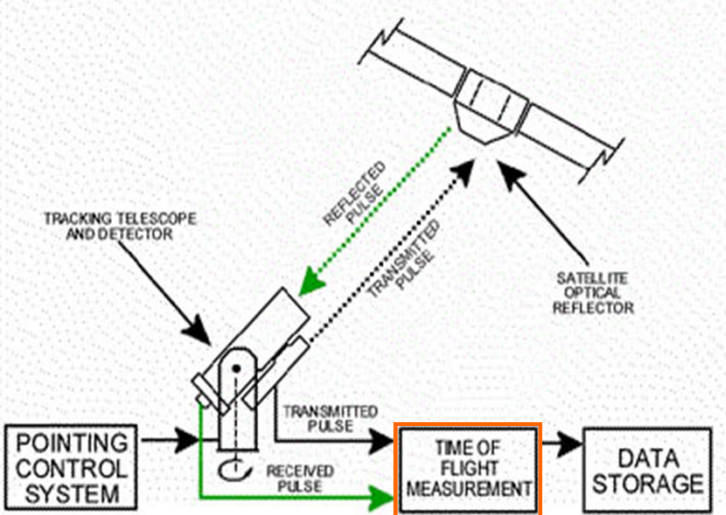


Application area for Riga Event Timers was focused mainly on Satellite Laser Ranging where the highest performance of the measurement equipment is especially needed.



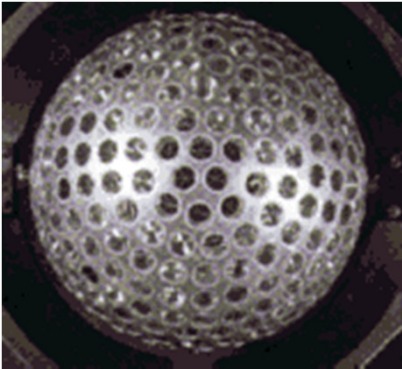
Top-quality Event Timers with pico-second resolution are needed for time-of-flight measurement to achieve required precision of satellite ranging.

| <i>Satellites</i> | <i>Range</i> |
|-------------------|--------------|
| LEO | < 2000 km |
| Geodetic | ~6 000 km |
| GPS | ~20 000 km |
| Geo-stationary | ~36 000 km |
| Lunar | ~420 000 km |

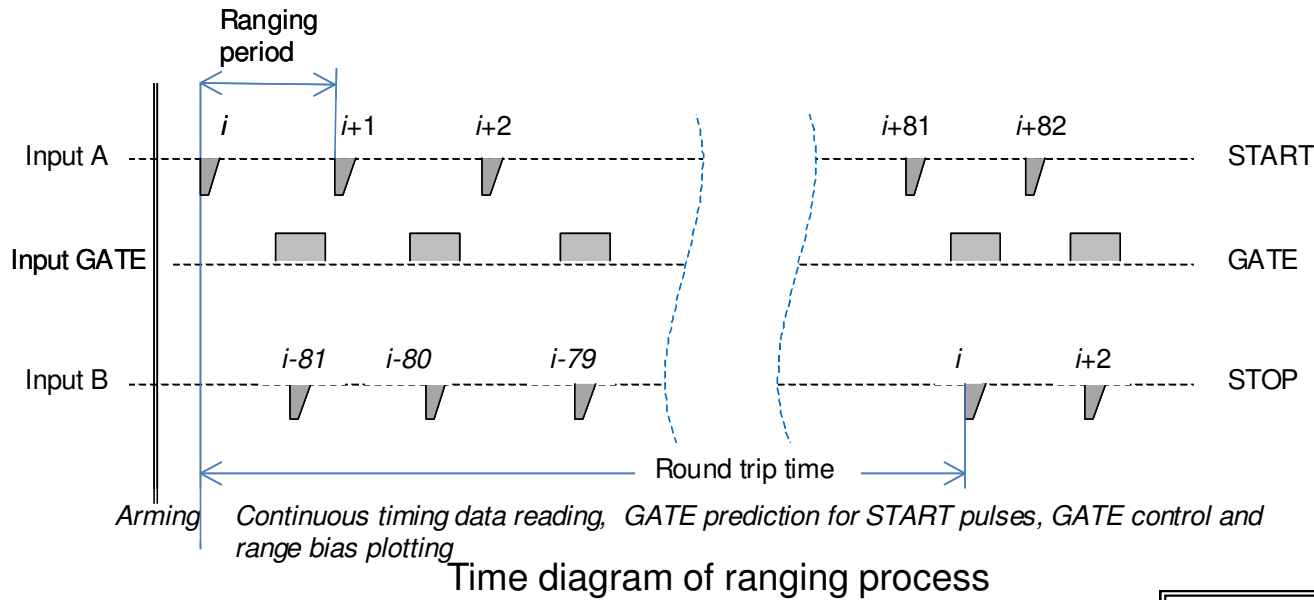
| <u>Single shot RMS resolution:</u> | |
|------------------------------------|--------|
| Currently | 1-2 cm |
| Desirable | 2-5 mm |

LAGEOS

Altitude: up to 5958 km
 Inclination: 109.8 deg.
 Size: 0.6 m
 Mass: 411 kg.

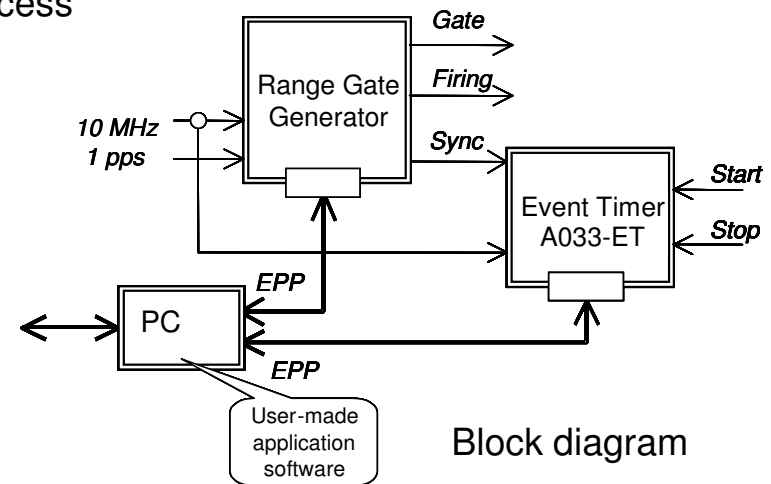


High frequency Satellite Laser Ranging



Three existing alternatives:

- get the START events from ET and control GATE input and firing (Range Gate Generator, EDI);
- register the START event by simple timer (precision 0.5 ns) and control SPAD (Austria);
- control firing so that a corresponding STOP pulses hit to predicted GATE area (China).

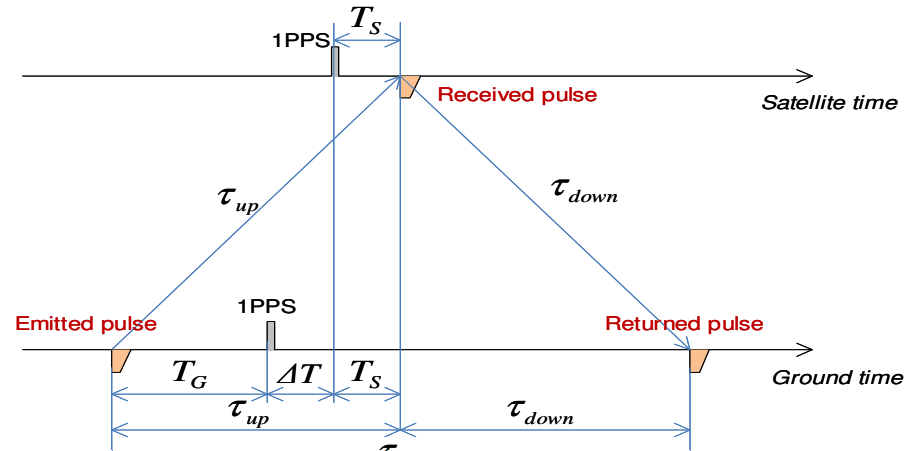


Almost of 50 % of Satellite Laser Ranging Stations in the world have Riga Event Timers

Laser Time Transfer by Laser Link

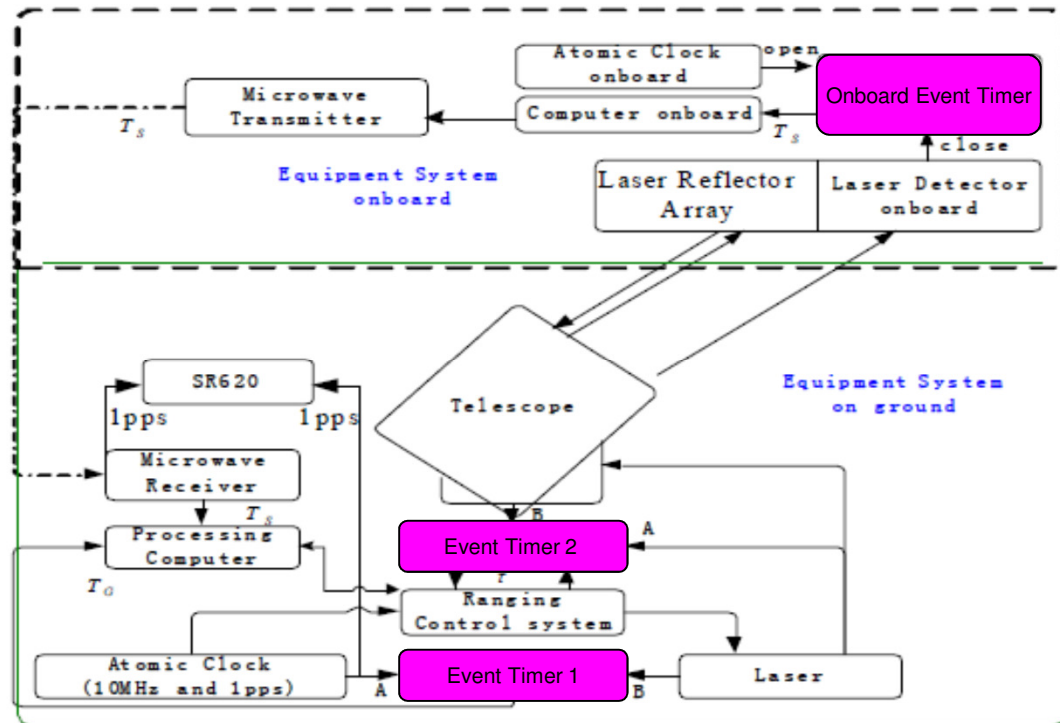
Laser Time Transfer principle

$$\Delta T = \tau_{up} - T_S - T_G$$

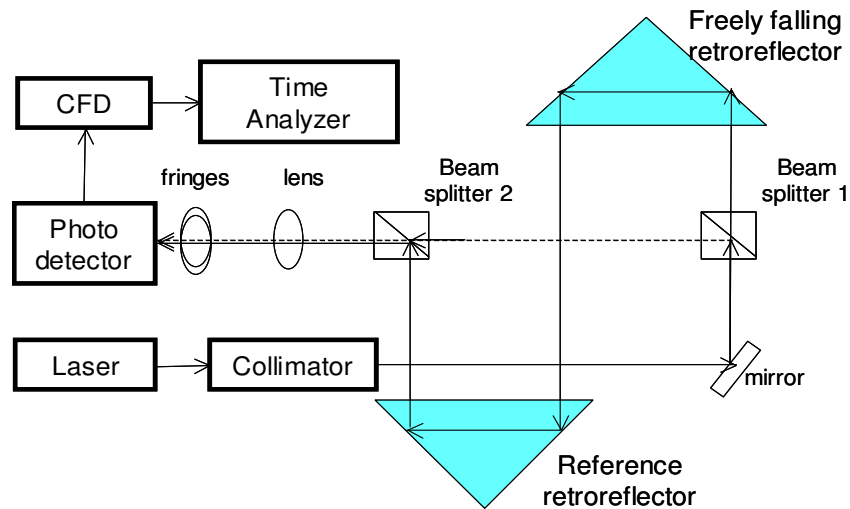


Time Transfer by Laser Link implementation in Shanghai SLR station using Riga Event Timers

Only the institutions of China Academy of Sciences bought 15 Event Timers A033-ET. Beside this the Shanghai Observatory has a signed Contract with EDI for development of fast multichannel Event Timer module.

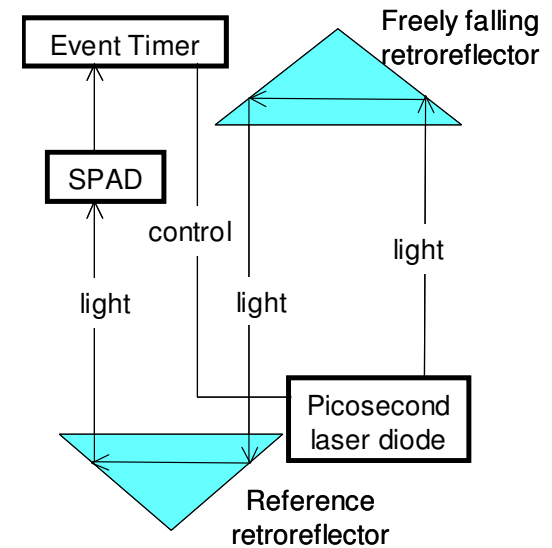


Free-Falling Absolute Gravimeters



Typical structure of Gravimeter (MPG-2)

Fringe frequency changes from 4 KHz up to 7 MHz at the end. Number of fringes about 1 million. Zero-crossing detection with precision 70 – 100 ps RMS (gravimeter FG5).



Proposed structure of Gravimeter

Event Timer with USB interface provides about 300 000 measurements. For ET 1 mm precision at distance 25 cm the relative error for g evaluation is $3.7E-6$.

Presentation at IAG Symposium on Terrestrial Gravimetry (TG-SMM 2013, 17 – 20 September 2013, Saint Petersburg, Russia) called a great interest on the representatives from Finland, Russia, China

LIDAR and 3-D scan system

LIDAR and 3-D laser scan systems find distances to surface of the object by timing the round-trip time of a pulse of light.

The main requirements are:

- measurement resolution: +/- 2 mm
- measurement rate: more than 100 KSPS

Event Timers with USB interface provides:

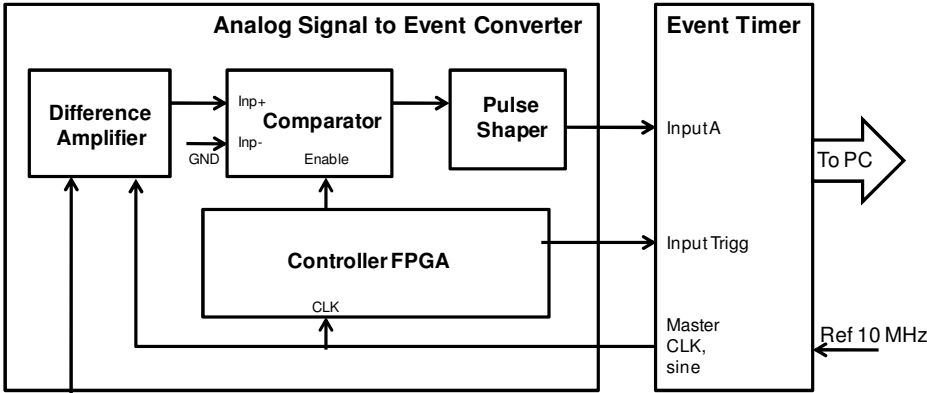
- measurement resolution: better than 1 mm RMS and
- measurement rate: more than 1 MSPS

and can be successfully used for these tasks.

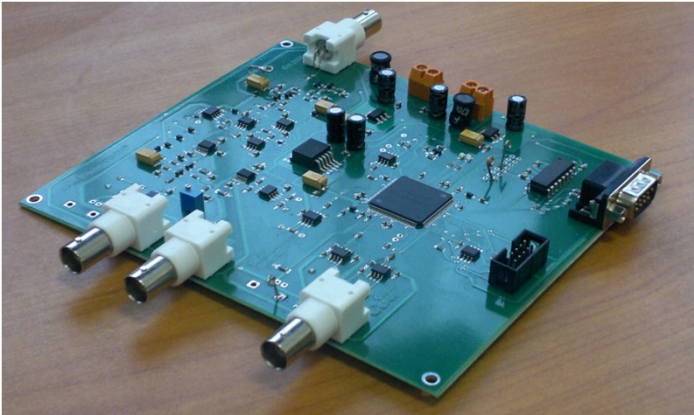
“Proof of concept” of new developed LIDAR system based on MPET is verified by space LIDAR developers and is proposed by ESA for using in LIDAR systems and altimeters in satellites.

Analogue signal analysis

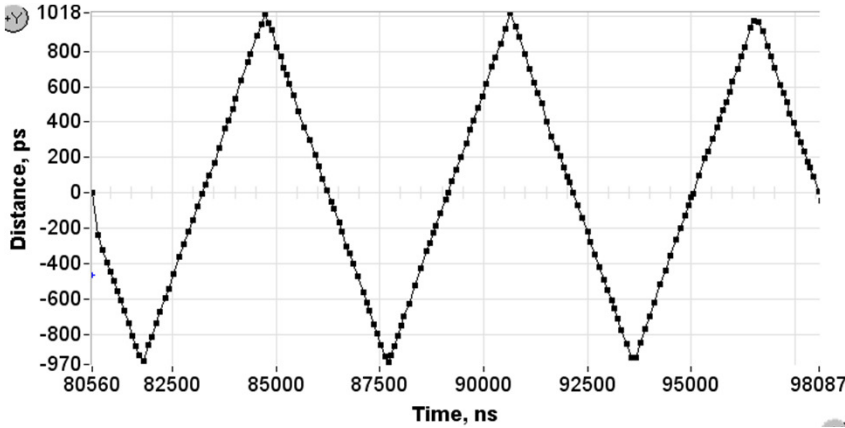
Block-diagram



Implementation

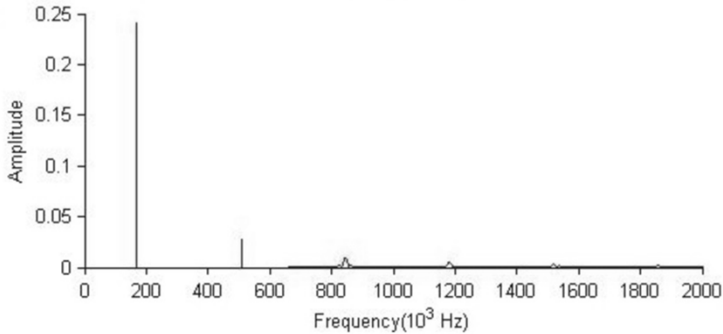


Input analog signal



SAW function time-to-time presentation

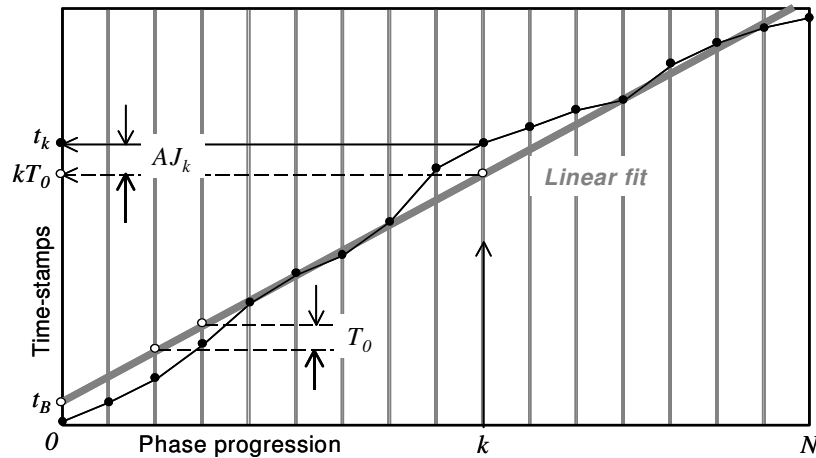
$$r(t_k) = A_r \sin(2\pi f_r t_k); \quad k = 1, 2, \dots, N$$



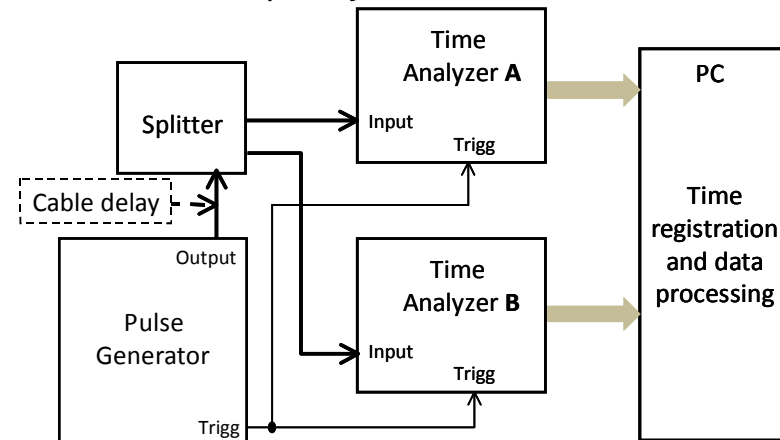
SAW function spectrograms

Pulse generator jitter analysis

Explicit jitter measurement



Implicit jitter measurement



$$D_2[T] = \text{cov}(A, B)$$

accumulated jitter function:

$$AJ_k = t_k - (kT_0 + t_B), \quad k = 0, 1, \dots, N$$

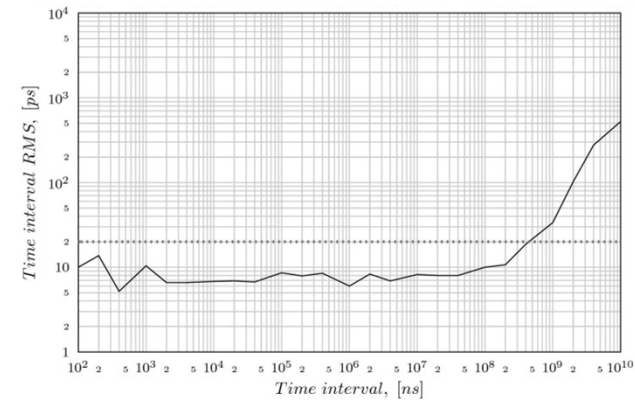
periodic jitter function :

$$PJ_k = AJ_k - AJ_{k-1}; \quad k = 1, 2, \dots, N$$

cycle-to-cycle jitter function :

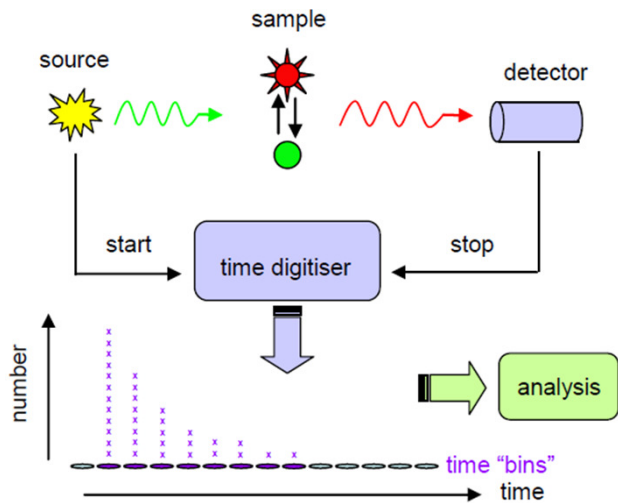
$$CJ_k = PJ_k - PJ_{k-1}; \quad k = 2, 3, \dots, N$$

Jitter functions characterize modulation functions



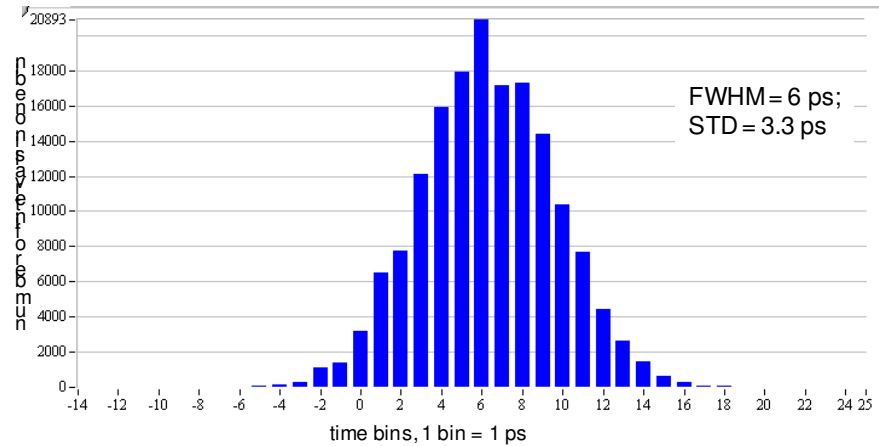
Jitter dependence on time interval for generator T5300U (produced in Poland)

Single Photon Counting Systems

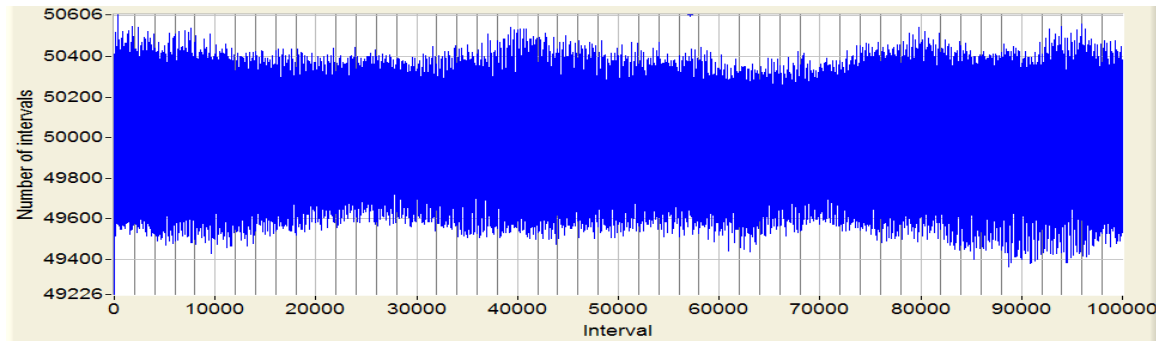


Time-Correlated Single Photon Counting for fluorescence

Distribution of measured intervals in the range 100 ns. Relative error for 1 ps bins is 5 femtoseconds.



Histogram of intervals measured by couple of Event Timers A033-ET



The experiments with a couple of Event Timers A033-ET, executed in request from the HORIBA Managing Director in Scotland Dr. David Mcloskey, show that Event Timers satisfy requirements of TCSPC method in repetition rate, resolution and linearity.