Photodiode optical to electrical signal delay

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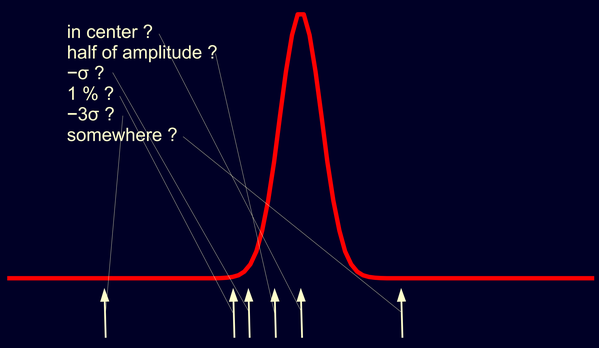
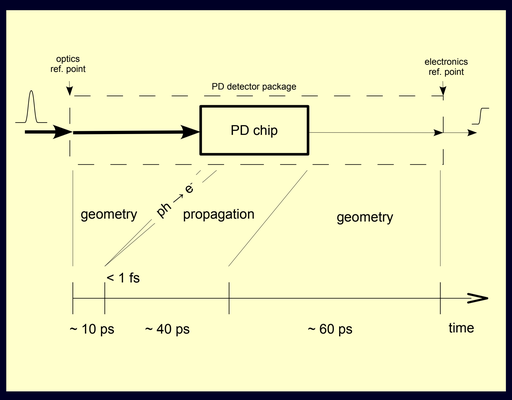
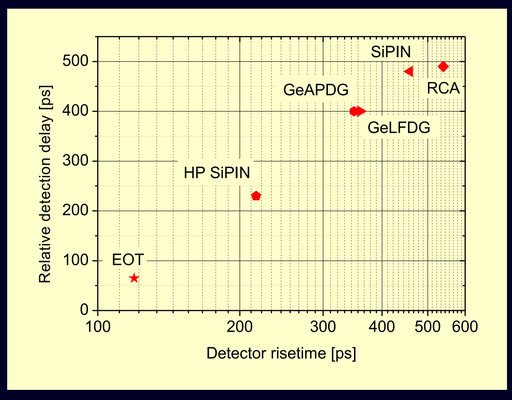
In time resolved experiment the time position of optical signal can be measured by many types of optical detectors. We are using semiconductor photodiodes and picosecond laser pulse. The typical measurement of time position is relative, but position of laser pulse, its speed, the length of cables from photodiode, speed of electrical signal, these all values are known and traceable, so let to ask:

If the output pulse is displayed on oscilloscope, where is the actual time position of detected optical signal?

Or, more correctly, if we will use very fast photodiode and very fast oscilloscope, how the relative signal delay will change?

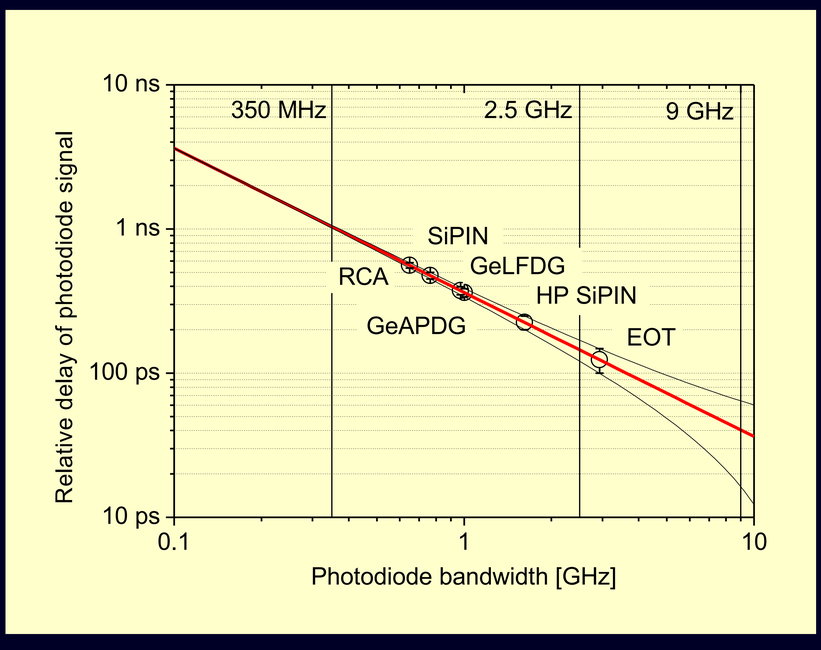






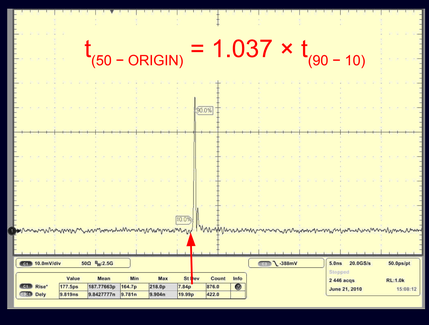
The block scheme of signals and delays in photodiode package between optical and electrical reference points. The only source of different delays of different photodiode chips is the different bandwidth of particular chips. The theoretical description is not straightforward as the Gaussian filters are non-causal description but the observed electrical signal is strictly causal. Two laser (42 ps @ 778 nm and 8 ps @ 532 nm) was used. Used data are average form several series

Measured data for 6 different photodiodes. Two oscilloscopes was used. The LeCroy SDA 9000, 40 Gsamples/s with the 9 GHz analogue bandwidth (for EOT and GeLFDF) and Tektronix DPO 7254, 40 Gsamples/s with analogue bandwidth of 2.5 GHz (all other samples). Assuming near to Gaussian pulse profile the effective bandwidth has been calculated from measured risetime.

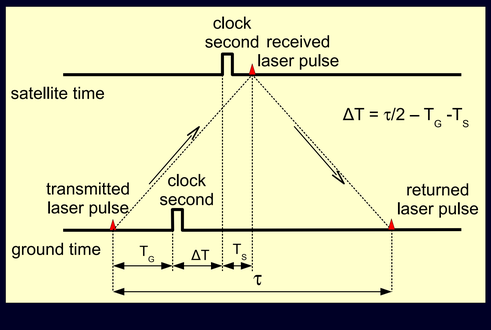


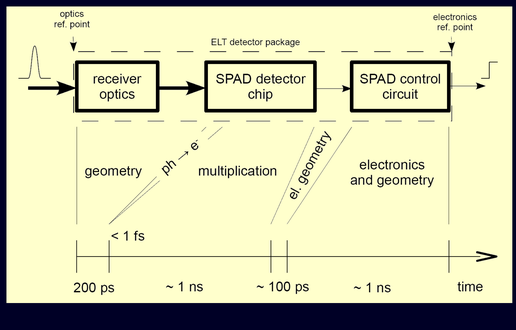
Results are summarized in left big graph. It is possible to find a relative offset of delay, that the shifted relative delay is almost exactly (note the χ^2 of red fit is 3×10^{-13}) inversely proportional to detector (oscilloscope) bandwidth limit. The asymptotic value can be called the time position of optical signal.

Applied results are displayed on oscilloscope screenshot below, EOT photodiode is in this case limited by 2.5 GHz scope bandwidth. The calculated time position of optical signal is signed by red arrow, it is 140±22 ps before leading edge on 50 % of amplitude, i.e. $1.037\times t_{R(90-10)}$ before trigger event.



Motivation for experiment – ground-space time synchronization by picosecond laser pulses





The motivation for above mentioned experiments is an advanced satellite laser ranging (SLR) application. Two time scales synchronization by pulse laser in visible range, its principle is described above. In compare with classical microwave communication it allows decrease the systematic error in signal delay down to 10^{-11} s, i.e. about 1000 times better.

One of requirements of grant provider is the detail mapping of absolute delays in experiment, as shown in scheme above. The individual contributors of the photon detection delay with the rough estimate of the typical values. As a byproduct of this the presented experiment has been completed.

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