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A Laser Scanner Chip Set for Accurate Perception Systems

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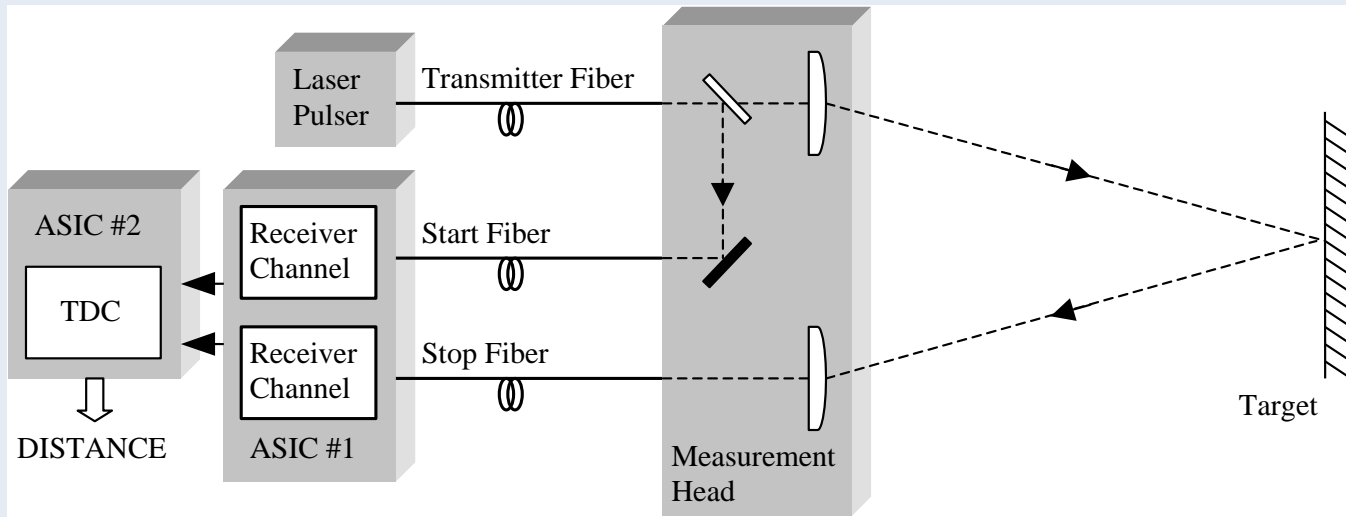
Outline

- Introduction to pulsed TOF laser ranging
- Error sources
- Integrated optical receiver
- Integrated time-to-digital converter



Concept of pulsed time-of-flight laser radar

- transit time of a short pulse is measured



$$\Delta R = c \cdot \frac{\Delta t}{2}$$



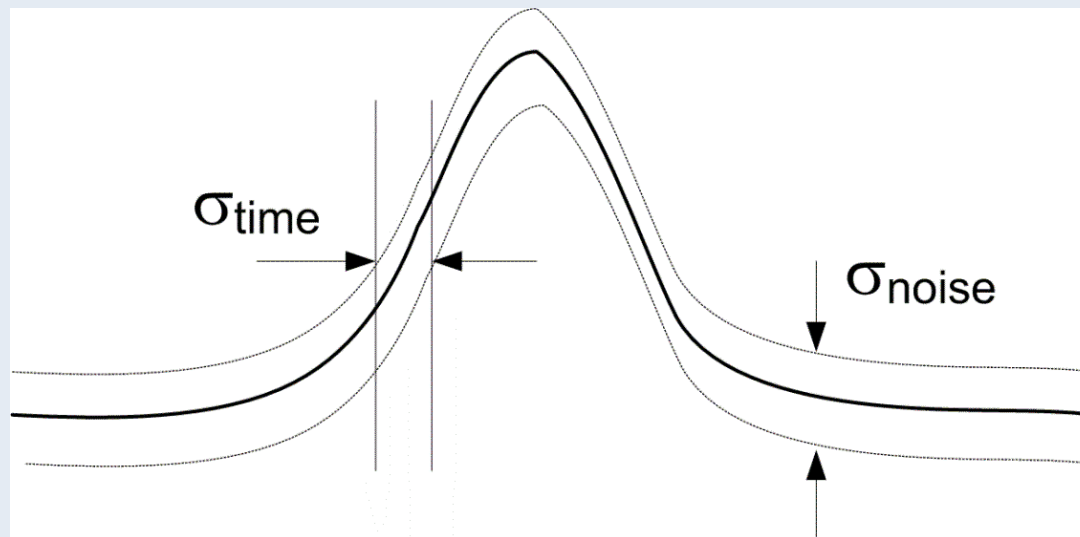
Pulsed TOF laser radar blocks

- laser diode transmitter
 - 10-100W peak power
 - ~3ns pulse length, limited by the driver
 - pulsing rate <50 kHz
- optical receiver, REC
 - input “weak optical pulse echo”
 - output “accurate logic level timing pulse”
- time-to-digital converter, TDC
 - measures start – stop1 (stop2,..) time intervals



Error sources (1)

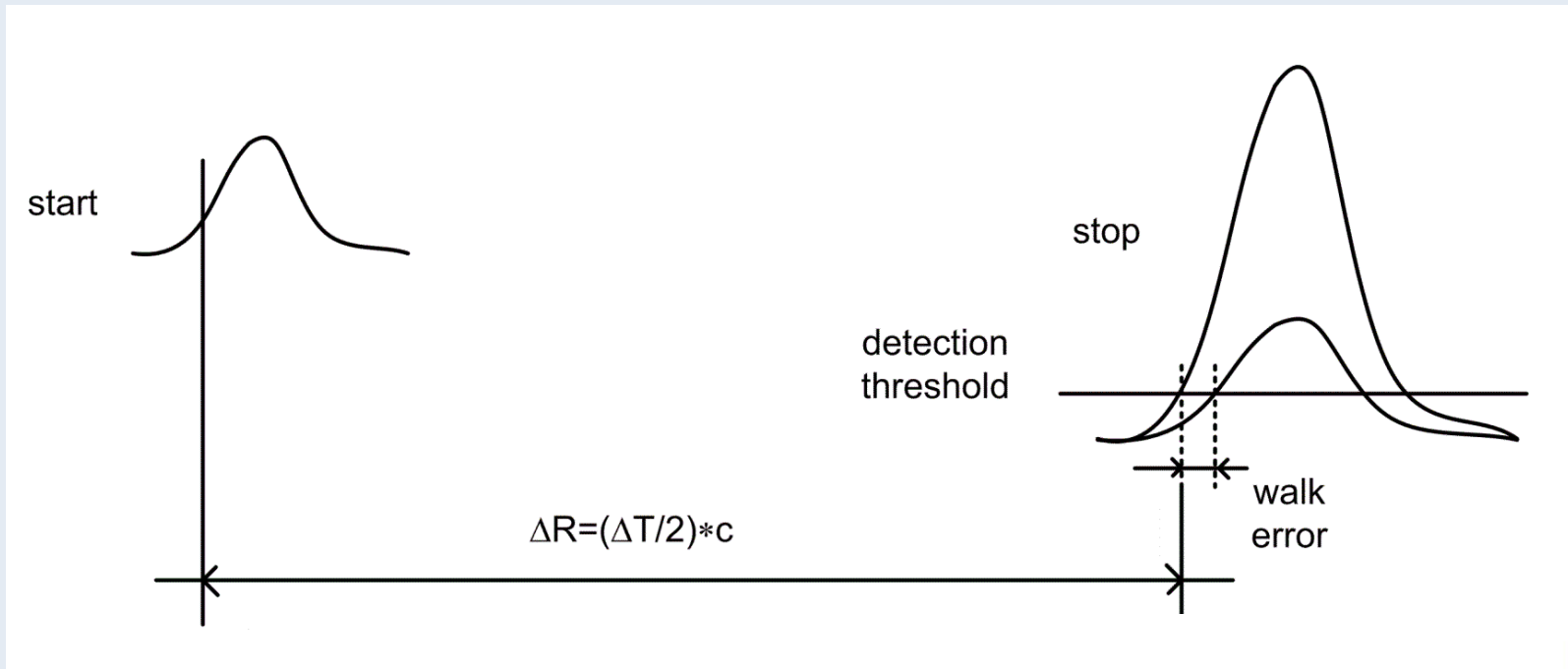
- *random* error due to **noise** → jitter



$$\sigma_{time} = \frac{\sigma_{noise}}{\partial v / \partial t} \approx \frac{\sigma_n}{v_p / t_{rise}} \cong \frac{t_{rise}}{SNR} \cong \frac{1.5ns}{10} = 150ps \approx 3cm$$

Error sources (2)

- *systematic* error, **timing walk**
 - amplitude range <1:100 000, walk $\sim 2\text{ns} \approx 30\text{cm}$



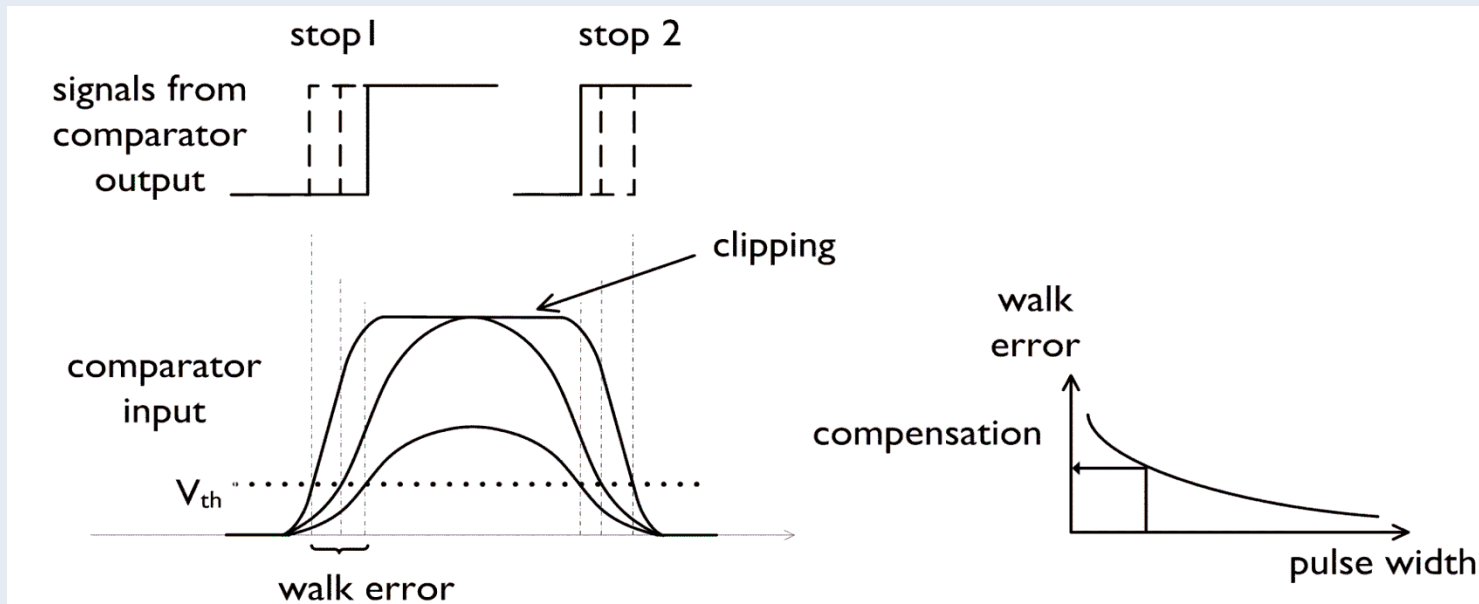
More performance

- Cm- or mm-level measurement precision with pulsed laser TOF radar?
 - Averaging
 - Helps only with random error sources (noise)
 - Increases measurement time
 - Compensation
 - Other parameters can be measured in order to reveal and correct the amount of systematic error. Echo pulse amplitude, for example
 - More electronics

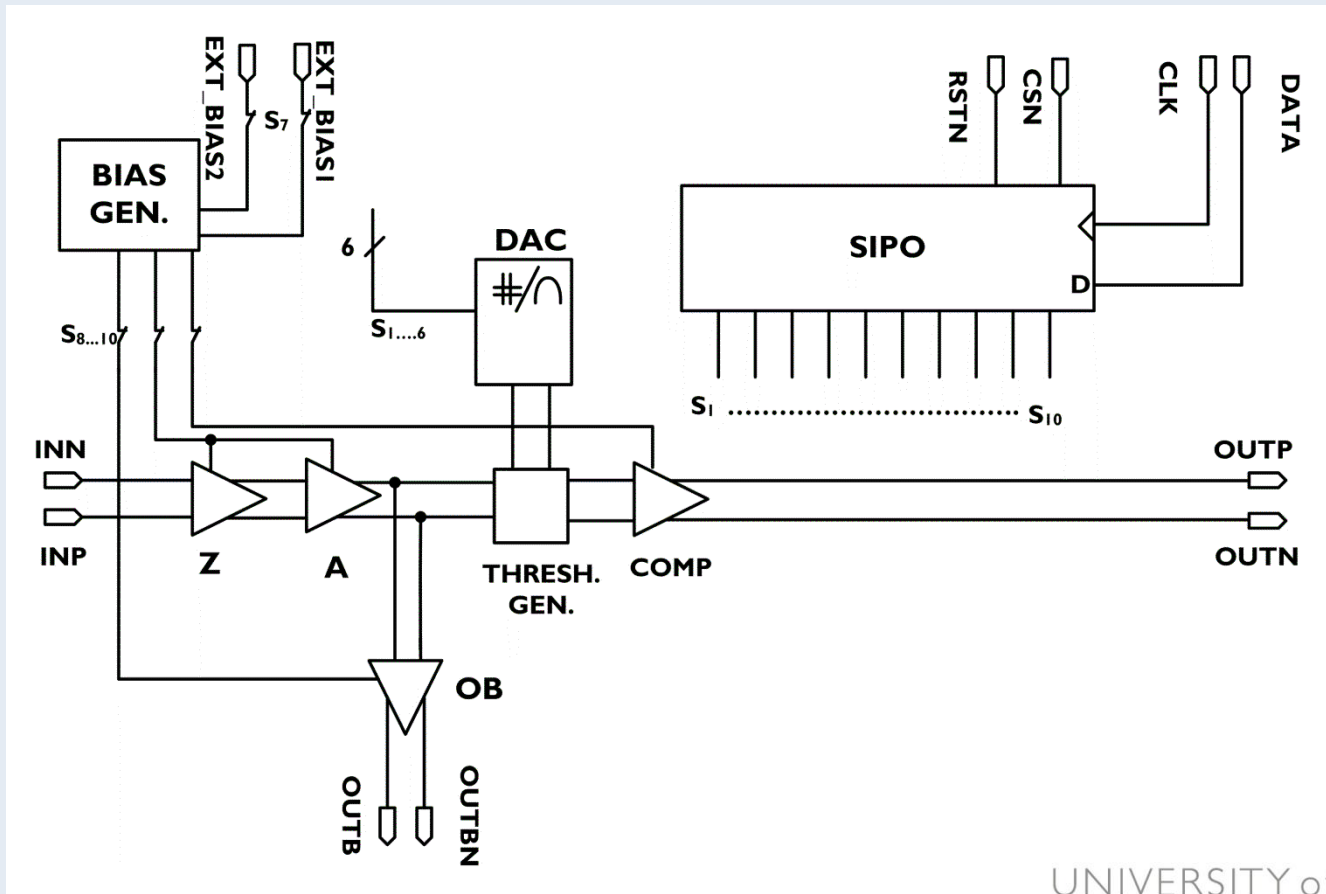


New compensation method

- pulse width based walk error compensation
- in "time-domain", works also for "clipped signals"!!!

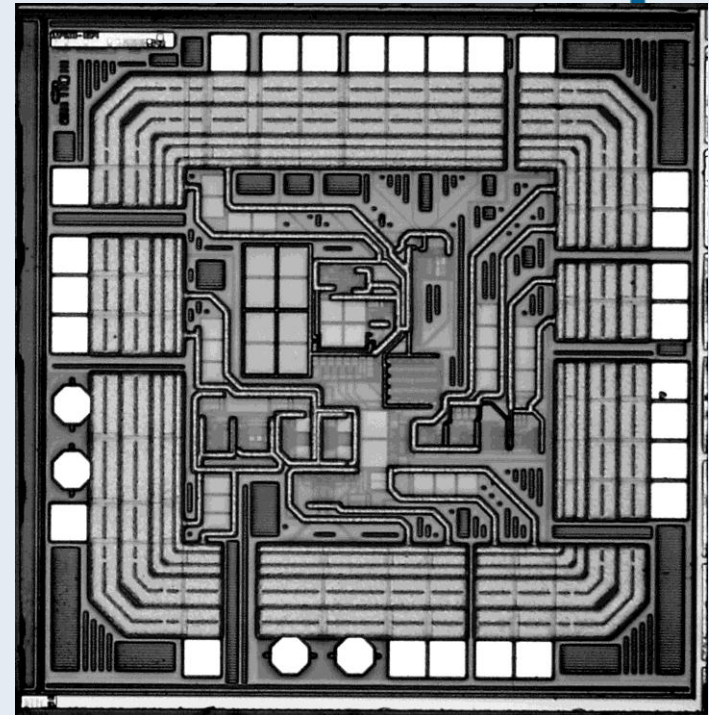


Receiver block diagram

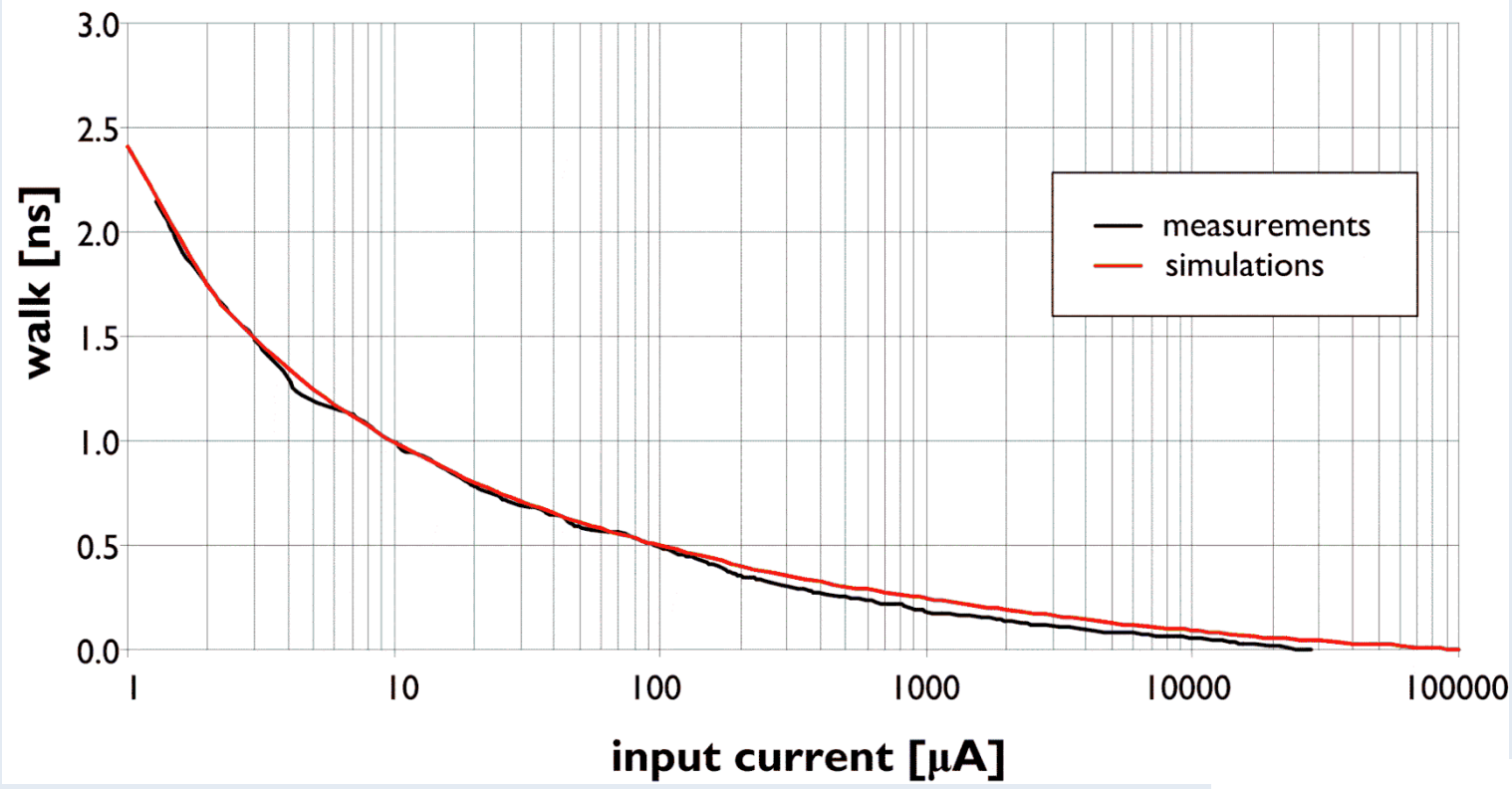


Receiver realization

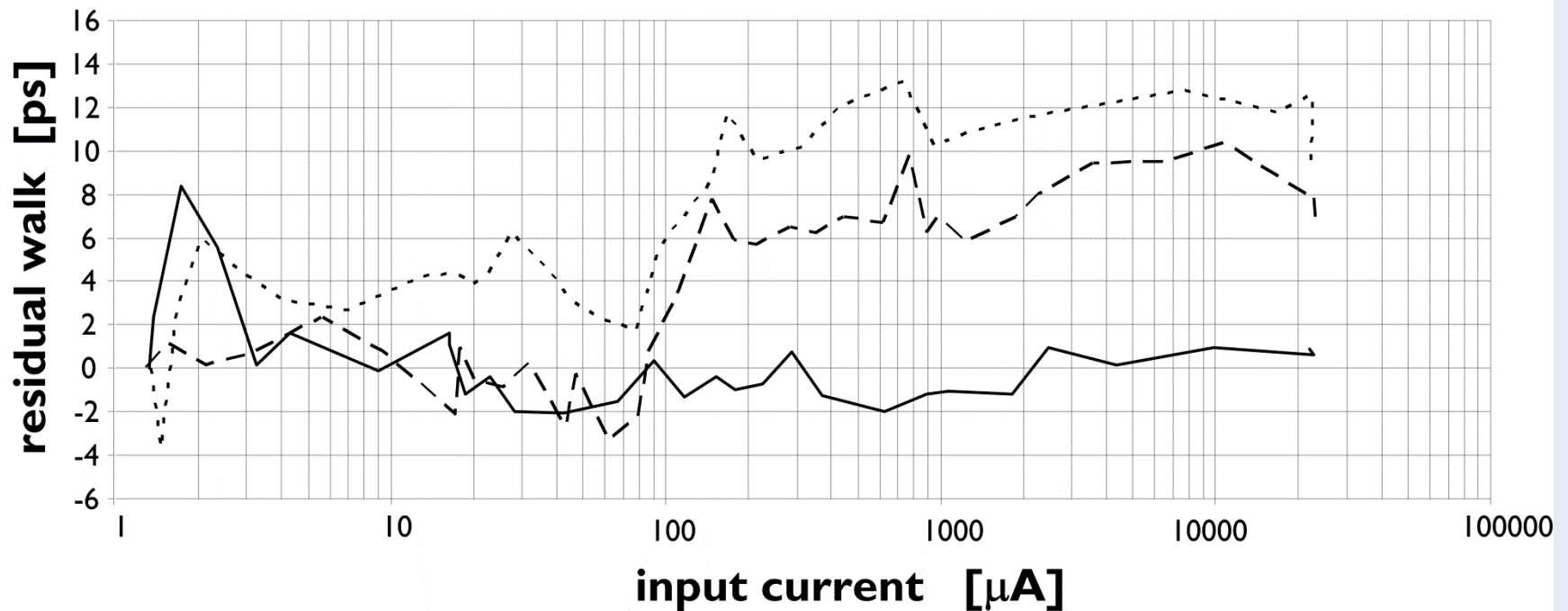
- 0.35 μm SiGe BiCMOS
- chip size 1.6 mm x 1.6 mm
- BW \approx 300MHz
- input noise \approx 100nA_{rms}
- eq. $Z_T \approx$ 70k Ω



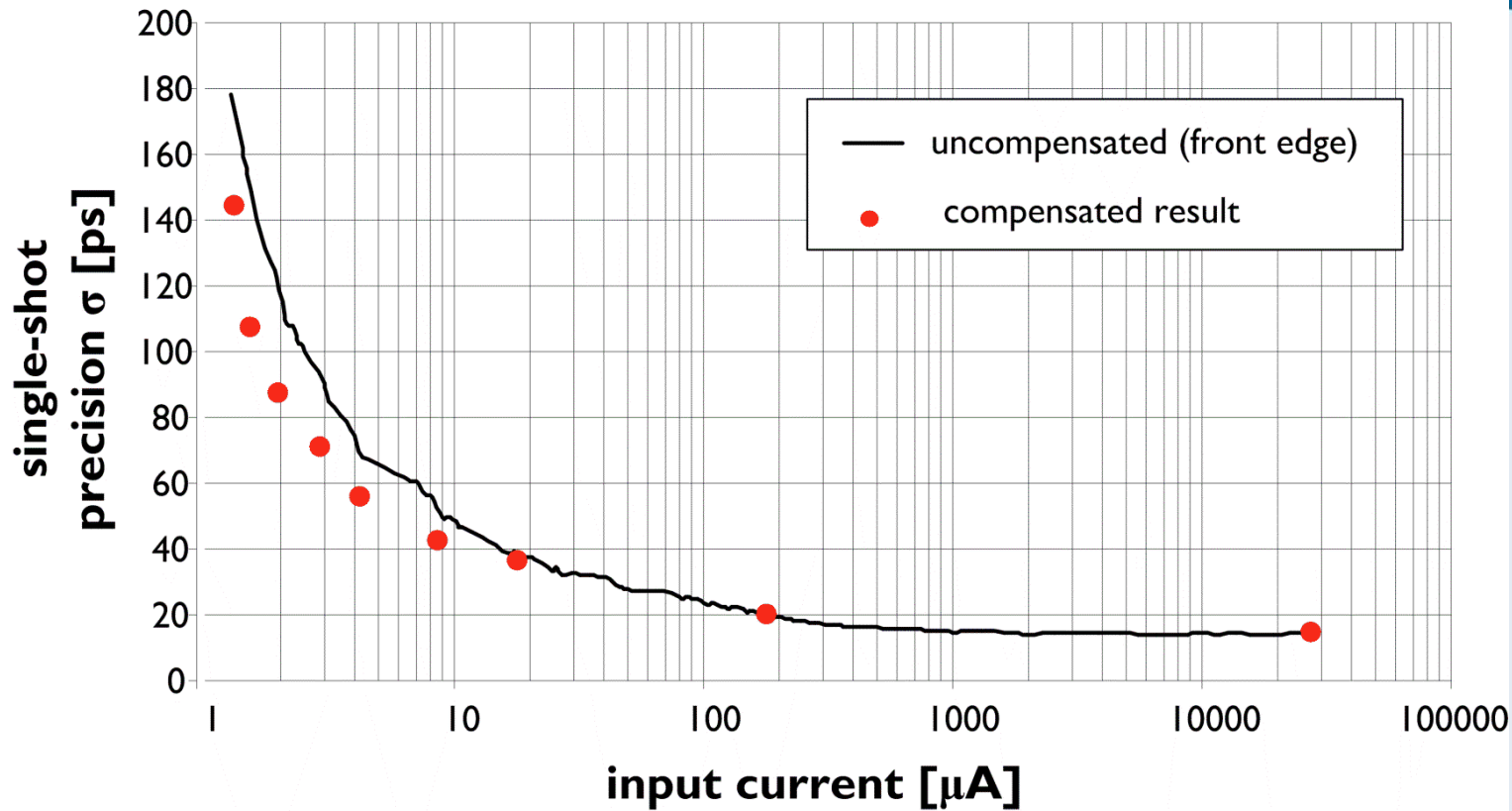
Timing walk without correction



Timing walk after "time - domain" compensation

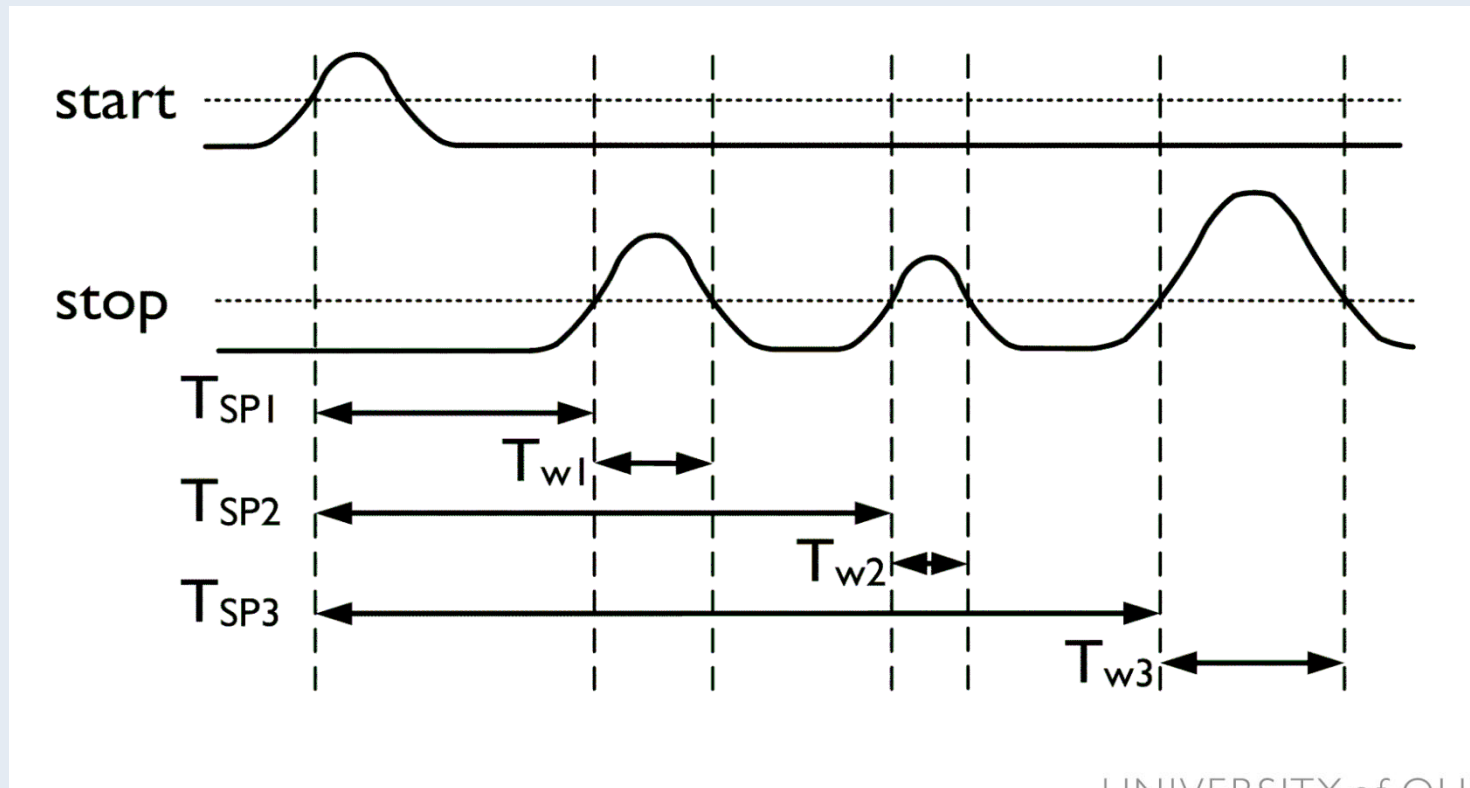


Single shot precision

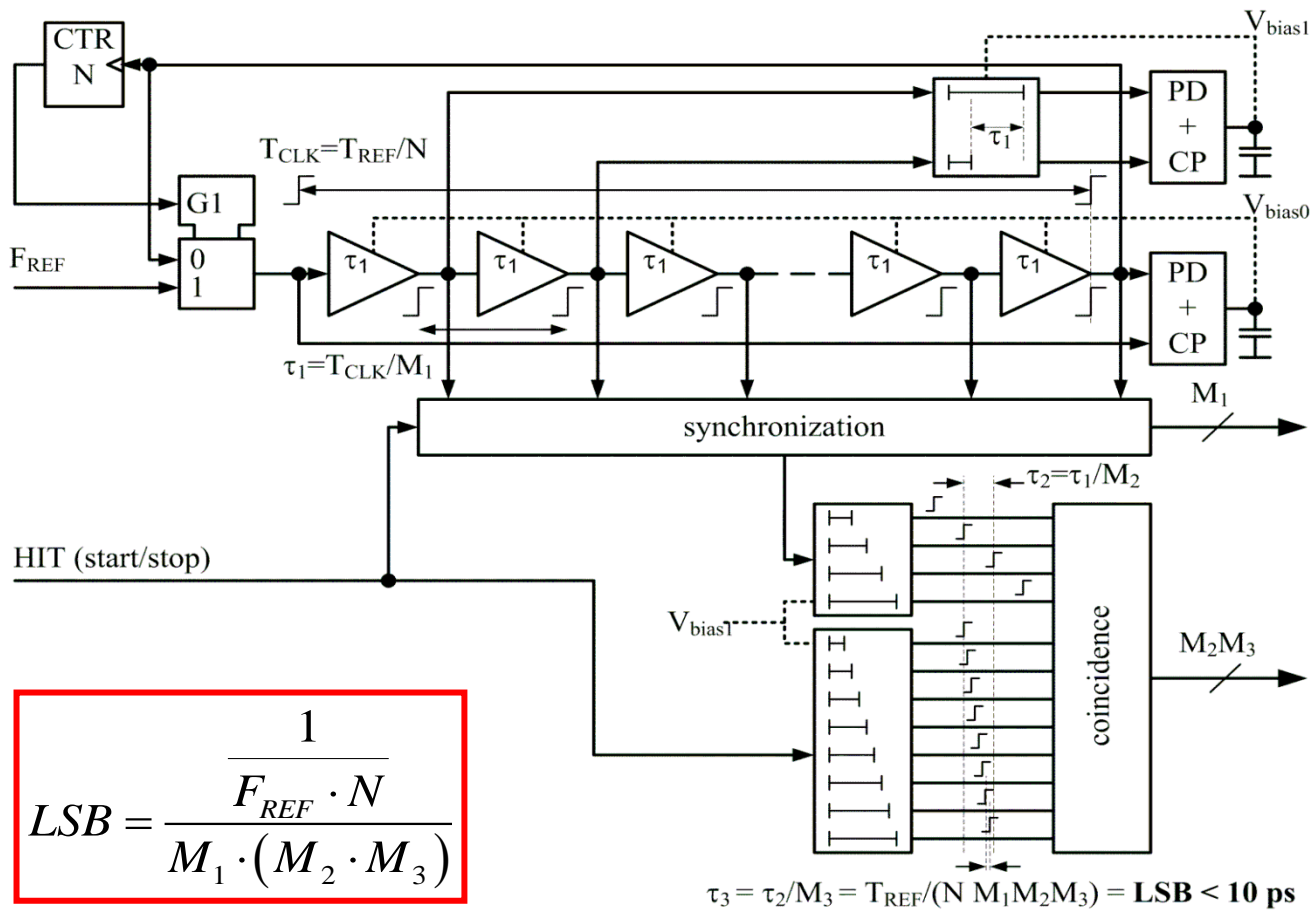


TDC functionality

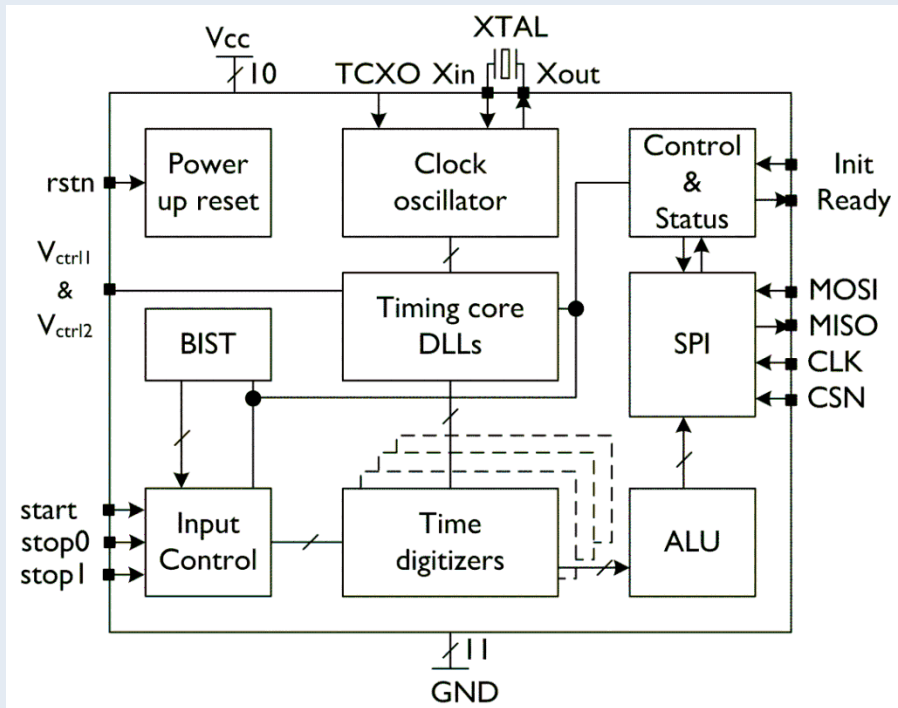
- 7-channel time-to-digital converter



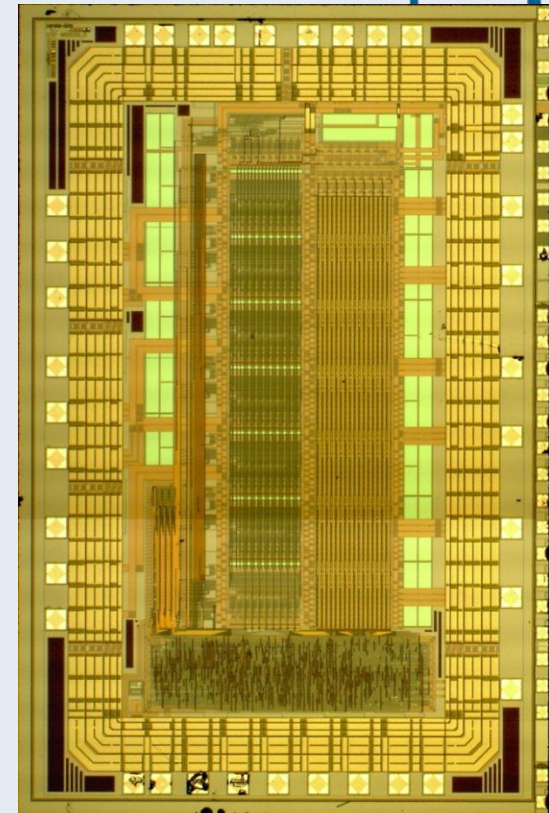
TDC principle



7- channel fully integrated CMOS TDC

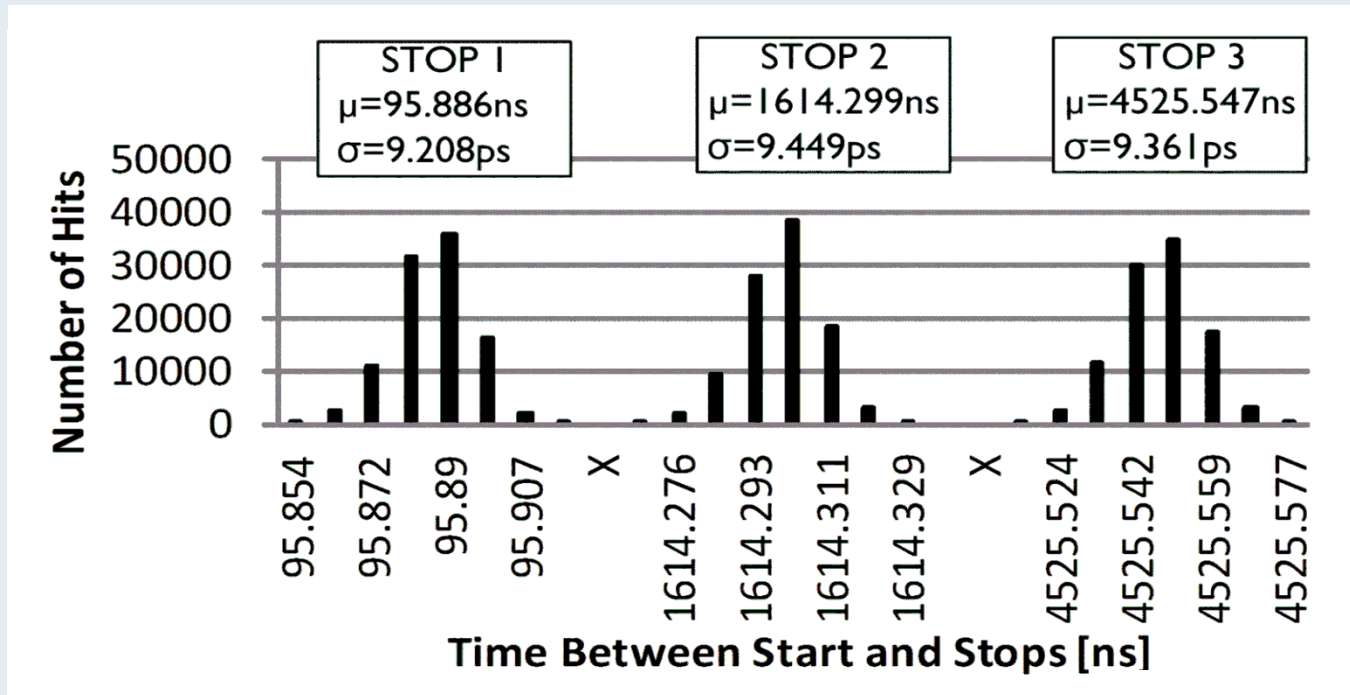


0.35 μ m CMOS
chip size 2.4mm \times 3.7mm

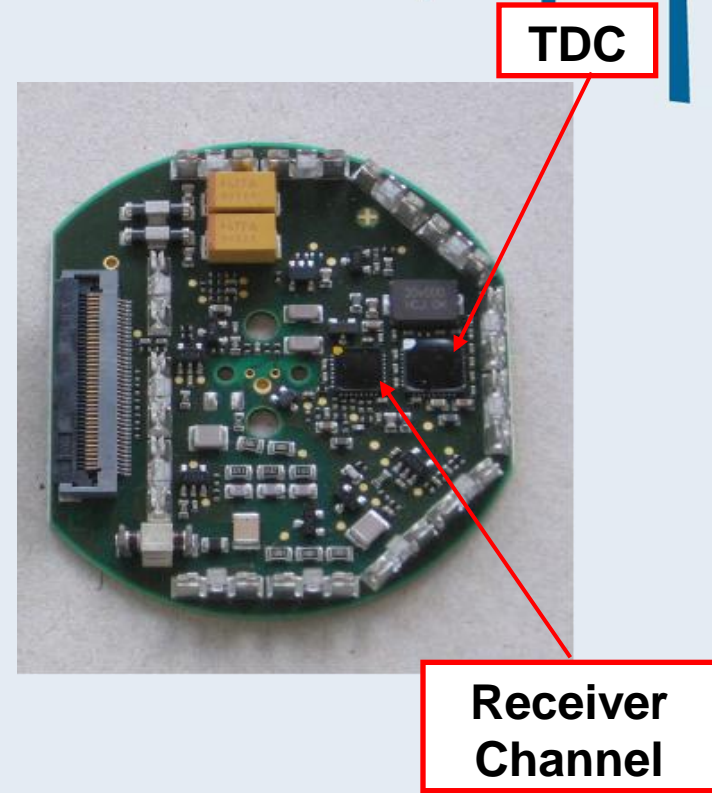
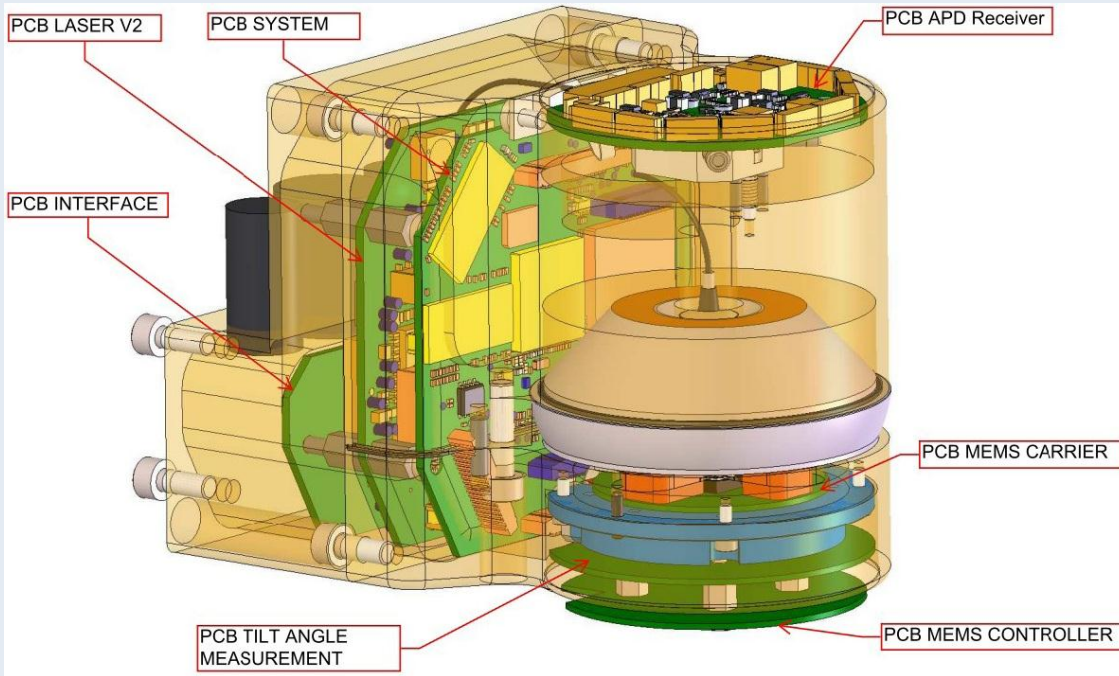


Performance

- single shot precision 10ps, range +/-74us, drift <0.5ps/°C



Minifaros laser scanner



Receiver -TDC chip set →

**generic pulsed TOF laser radar micromodule
for a variety of emerging applications**

Thank you for your attention!