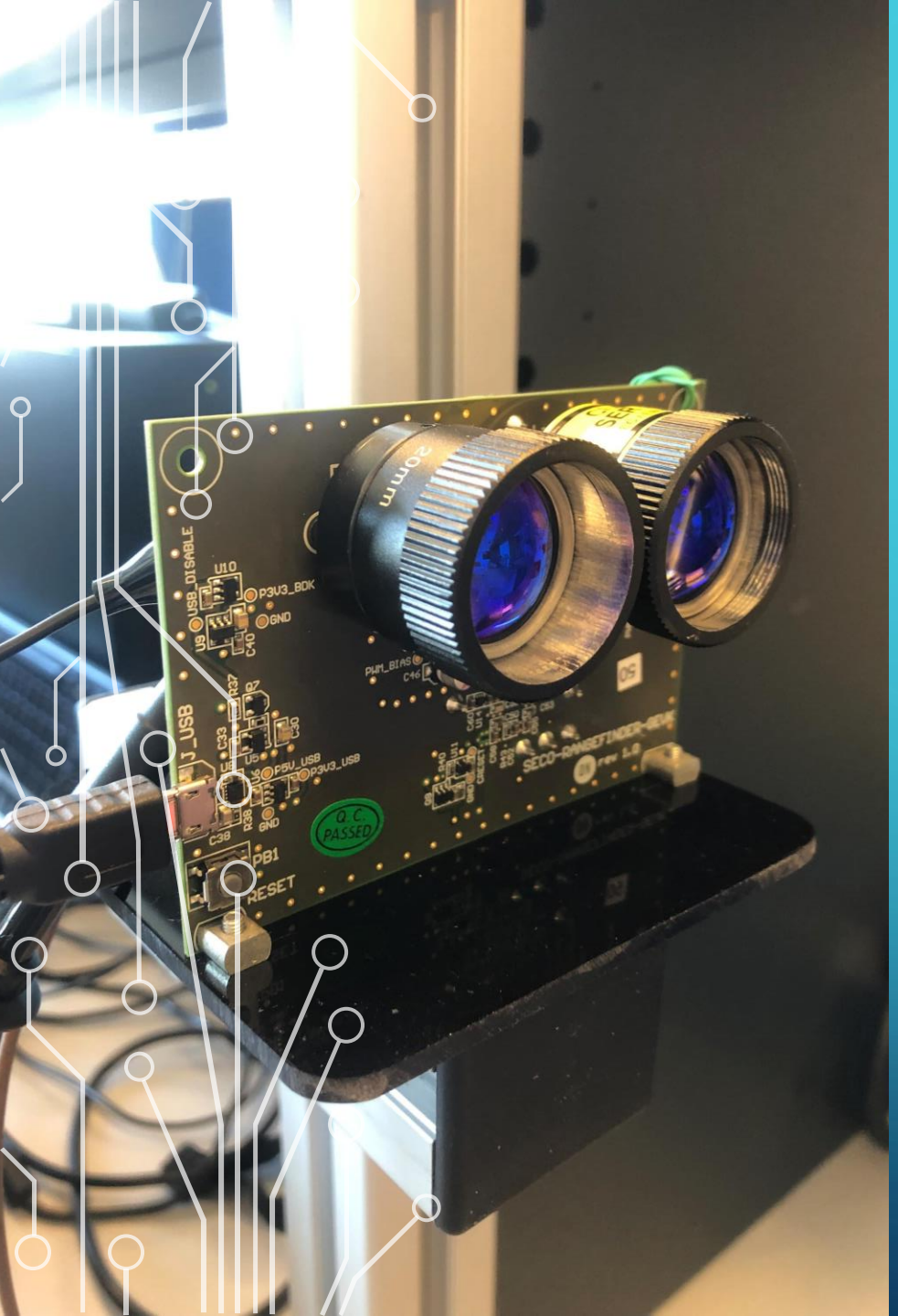
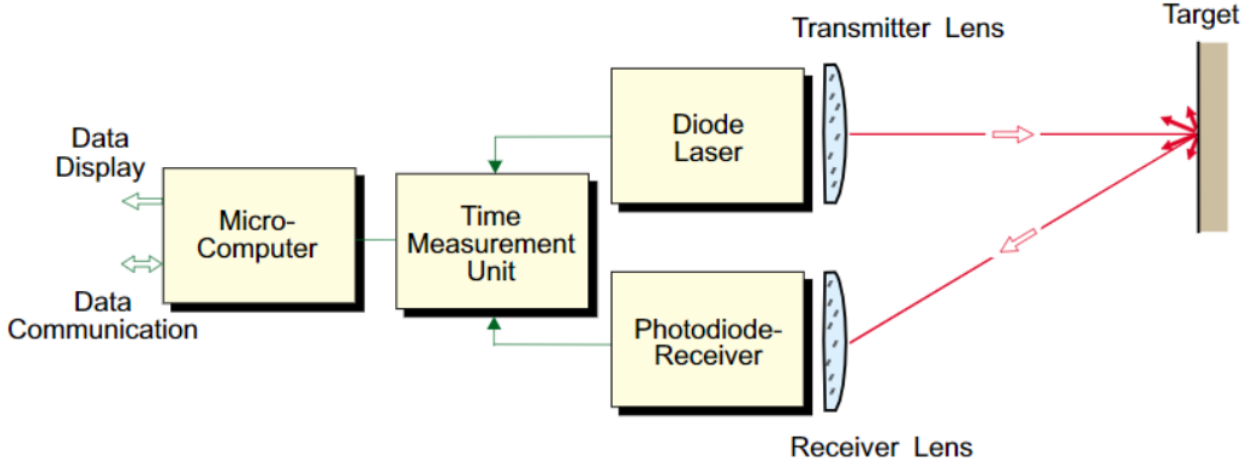


LIDAR

LIGHT DETECTION AND RANGING

DISPOSITION

- Layout of the LiDAR
- Reflectivity of different surfaces
- Distance calculation
- Various experiments with the LiDAR



LAYOUT OF THE LIDAR

- Distance and time measuring tool
- Diode laser
- Reflection

CALCULATION OF THE DISTANCE

$$R = \frac{1}{2}c\Delta t$$

R: distance

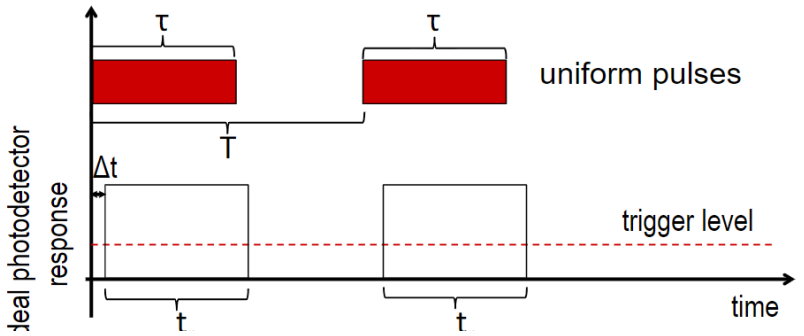
c: speed of light

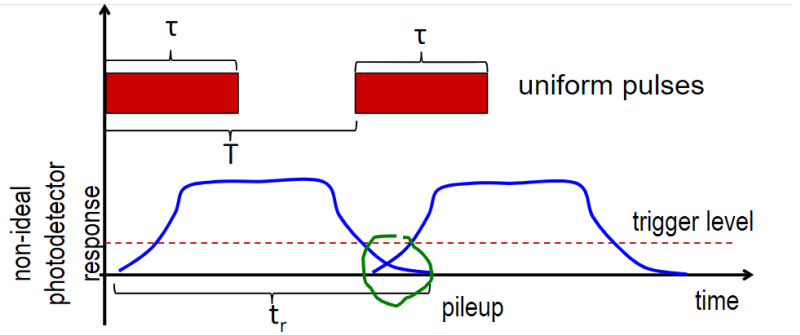
Δt: change in time

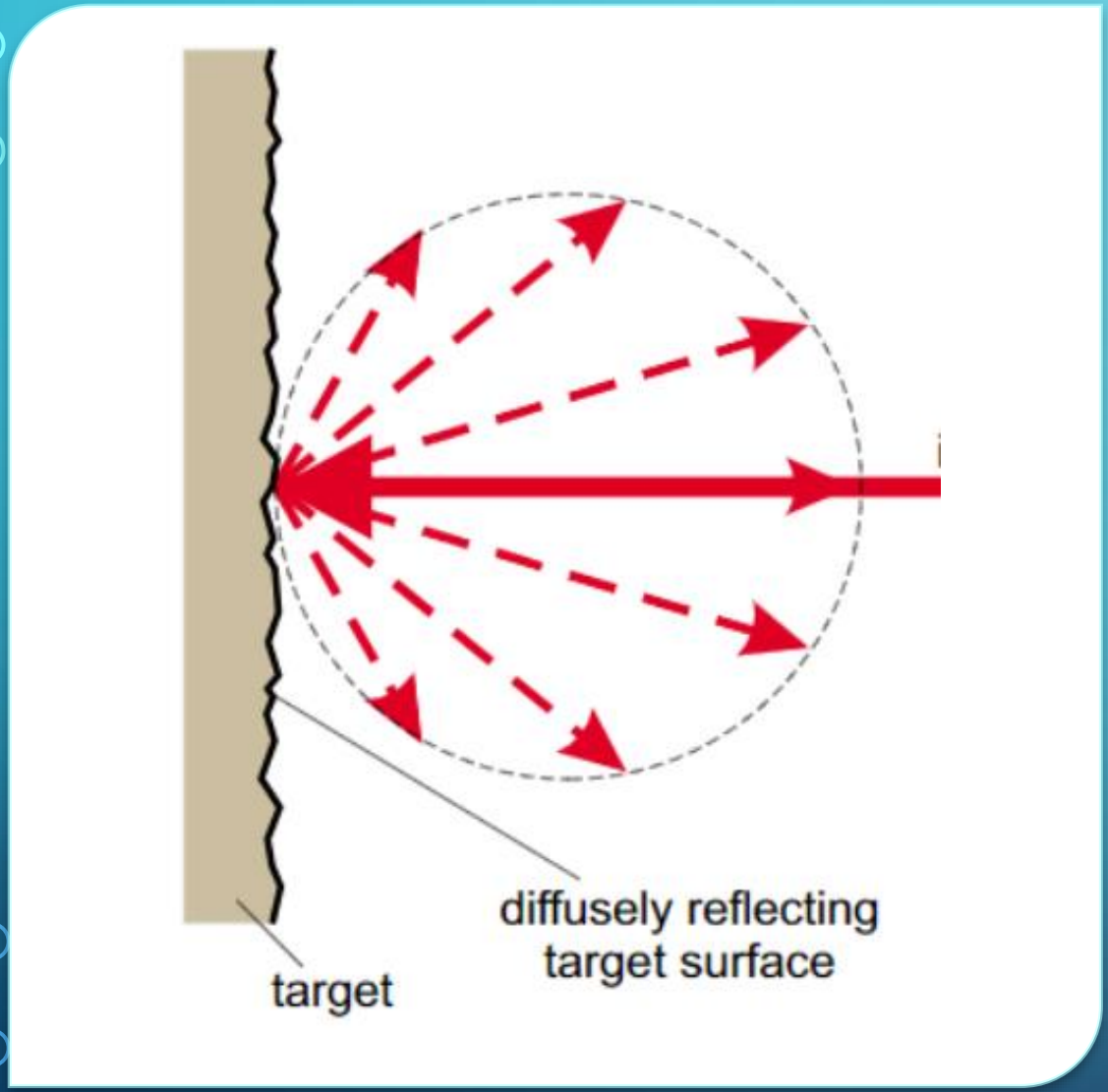
MAXIMUM AND MINIMUM DISTANCE

- Formula for maximum distance
- Minimum distance is fixed

$$R_{max} = \frac{1}{2}cT = \frac{1}{2}\frac{c}{f}$$

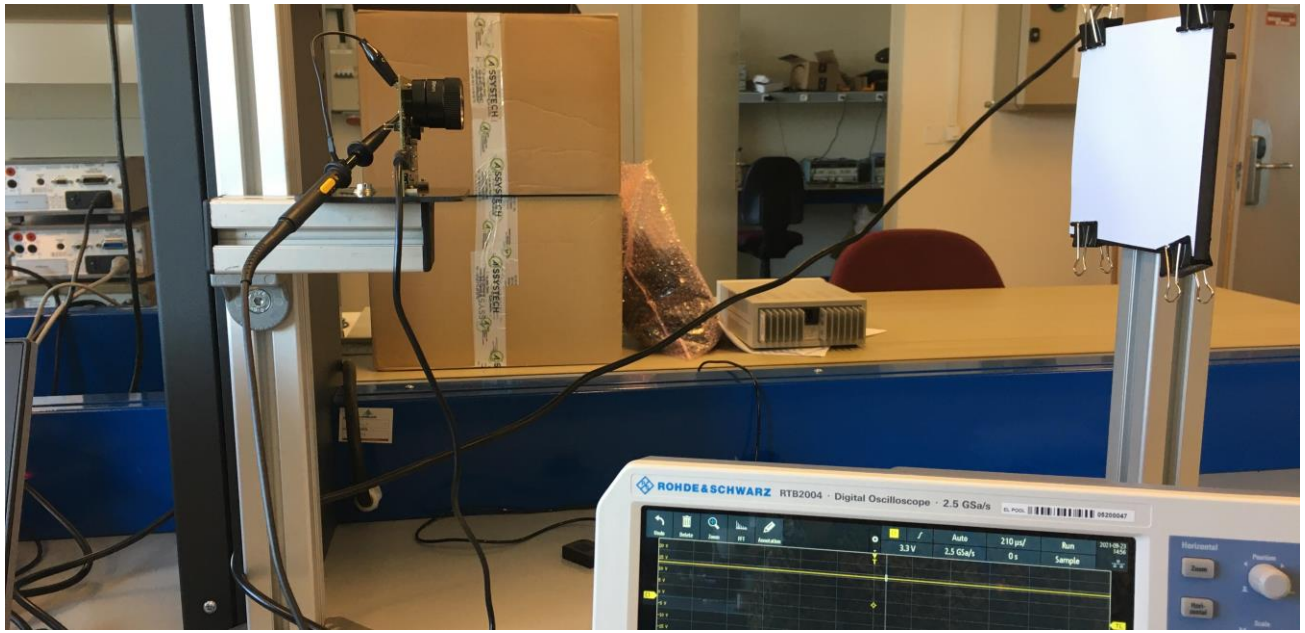






REFLECTION AND DIFFERENT SURFACES

- Reflection of different materials
  - Paper: up to 100%
  - Black plastic: 17%
  - Reflecting foil: 1250%
- Diffuse reflection
  - Shatters reflection
  - Lambert's cosine law
  - $I = I_0 \cdot \cos(\theta)$



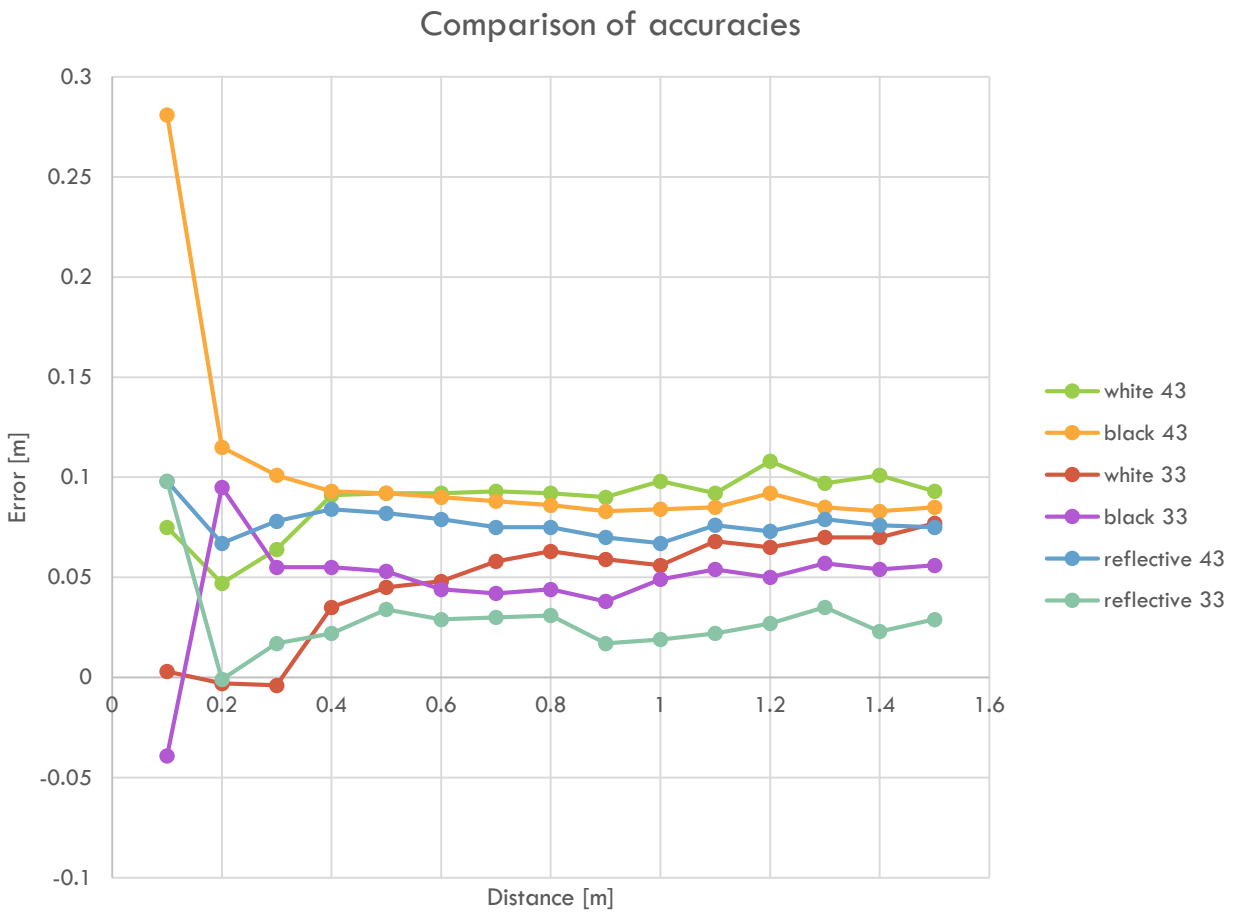
TESTING THE LIDAR

THE SETUP

- Moving it 10cm
  - SiPM bias voltage
  - Material
- Moving it 1cm
- Oscilloscope vs. Range Finder
- (Different materials)

(-43.0 V) bias voltage														
White paper					Black plastic					Reflective plastic				
Distance [m]		Time [ns]		Error [m]	Distance [m]		Time [ns]		Error [m]	Distance [m]		Time [ns]		Error [m]
Ruler	LiDAR	LiDAR			Ruler	LiDAR	LiDAR			Ruler	LiDAR	LiDAR		
0.1	0.175	1.17	75%	0.075	0.1	0.381	2.54	281%	0.281	0.1	0.198	1.32	98%	0.098
0.2	0.247	1.64	24%	0.047	0.2	0.315	2.1	58%	0.115	0.2	0.267	1.78	34%	0.067
0.3	0.364	2.42	21%	0.064	0.3	0.401	2.67	34%	0.101	0.3	0.378	2.52	26%	0.078
0.4	0.491	3.27	23%	0.091	0.4	0.493	3.29	23%	0.093	0.4	0.484	3.22	21%	0.084
0.5	0.592	3.94	18%	0.092	0.5	0.592	3.94	18%	0.092	0.5	0.582	3.88	16%	0.082
0.6	0.692	4.61	15%	0.092	0.6	0.69	4.6	15%	0.09	0.6	0.679	4.53	13%	0.079
0.7	0.793	5.29	13%	0.093	0.7	0.788	5.25	13%	0.088	0.7	0.775	5.17	11%	0.075
0.8	0.892	5.95	12%	0.092	0.8	0.886	5.91	11%	0.086	0.8	0.875	5.83	9%	0.075
0.9	0.99	6.6	10%	0.09	0.9	0.983	6.55	9%	0.083	0.9	0.97	6.47	8%	0.07
1	1.098	7.32	10%	0.098	1	1.084	7.23	8%	0.084	1	1.067	7.11	7%	0.067
1.1	1.192	7.95	8%	0.092	1.1	1.185	7.9	8%	0.085	1.1	1.176	7.84	7%	0.076
1.2	1.308	8.7	9%	0.108	1.2	1.292	8.61	8%	0.092	1.2	1.273	8.49	6%	0.073
1.3	1.397	9.31	7%	0.097	1.3	1.385	9.23	7%	0.085	1.3	1.379	9.2	6%	0.079
1.4	1.501	10.01	7%	0.101	1.4	1.483	9.89	6%	0.083	1.4	1.476	9.84	5%	0.076
1.5	1.593	10.62	6%	0.093	1.5	1.585	10.57	6%	0.085	1.5	1.575	10.5	5%	0.075
		Average:	17%	0.08833			Average:	34%	0.10287			Average:	18%	0.07693
		Without 0.1:	13%	0.08929			Without 0.1:	16%	0.09014			Without 0.1:	12%	0.07543

(-33.0 V) bias voltage														
White paper					Black plastic					Reflective plastic				
Distance [m]		Time [ns]		Error [m]	Distance [m]		Time [ns]		Error [m]	Distance [m]		Time [ns]		Error [m]
Ruler	LiDAR	LiDAR			Ruler	LiDAR	LiDAR			Ruler	LiDAR	LiDAR		
0.1	0.103	0.69	3%	0.003	0.1	0.0609	1.89	-39%	-0.0391	0.1	0.198	1.32	98%	0.098
0.2	0.197	1.32	-2%	-0.003	0.2	0.295	1.97	48%	0.095	0.2	0.199	1.32	-1%	-0.001
0.3	0.296	1.97	-1%	-0.004	0.3	0.355	2.37	18%	0.055	0.3	0.317	2.11	6%	0.017
0.4	0.435	2.9	9%	0.035	0.4	0.455	3.04	14%	0.055	0.4	0.422	2.81	5%	0.022
0.5	0.545	3.64	9%	0.045	0.5	0.553	3.68	11%	0.053	0.5	0.534	3.56	7%	0.034
0.6	0.648	4.32	8%	0.048	0.6	0.644	4.3	7%	0.044	0.6	0.629	4.19	5%	0.029
0.7	0.758	5.05	8%	0.058	0.7	0.742	4.95	6%	0.042	0.7	0.73	4.86	4%	0.03
0.8	0.863	5.76	8%	0.063	0.8	0.844	5.63	5%	0.044	0.8	0.831	5.54	4%	0.031
0.9	0.959	6.39	7%	0.059	0.9	0.938	6.25	4%	0.038	0.9	0.917	6.11	2%	0.017
1	1.056	7.04	6%	0.056	1	1.049	6.99	5%	0.049	1	1.019	6.79	2%	0.019
1.1	1.168	7.79	6%	0.068	1.1	1.154	7.69	5%	0.054	1.1	1.122	7.48	2%	0.022
1.2	1.265	8.43	5%	0.065	1.2	1.25	8.33	4%	0.05	1.2	1.227	8.18	2%	0.027
1.3	1.37	9.13	5%	0.07	1.3	1.357	9.05	4%	0.057	1.3	1.335	8.9	3%	0.035
1.4	1.47	9.8	5%	0.07	1.4	1.454	9.69	4%	0.054	1.4	1.423	9.49	2%	0.023
1.5	1.577	10.51	5%	0.077	1.5	1.556	10.37	4%	0.056	1.5	1.529	10.19	2%	0.029
		Average:	5%	0.04733			Average:	7%	0.04713			Average:	10%	0.0288
		Without 0.1:	6%	0.0505			Without 0.1:	10%	0.05329			Without 0.1:	3%	0.02386



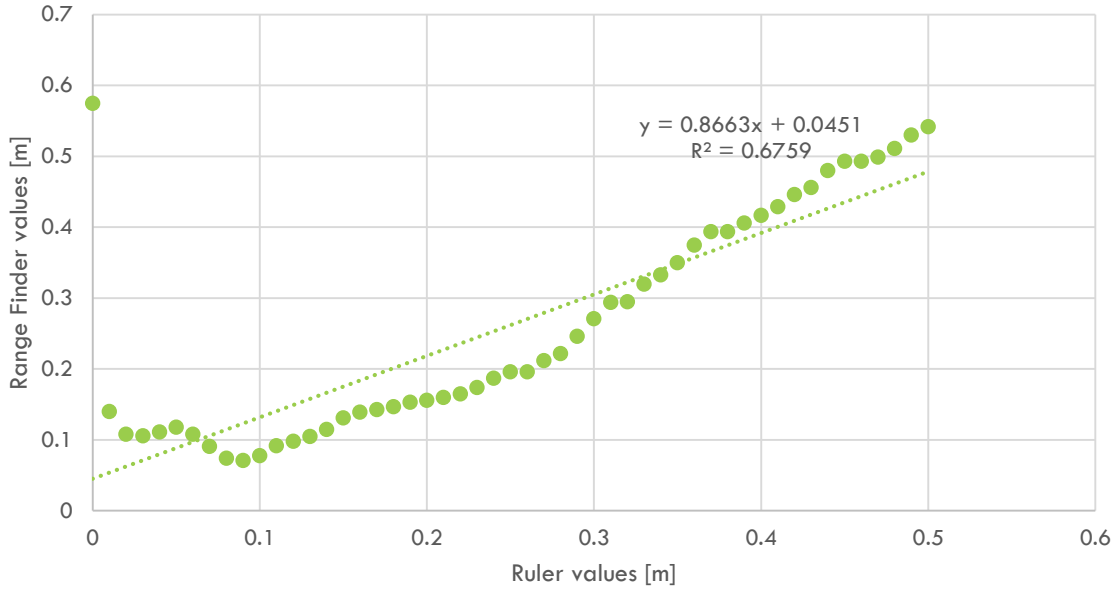
WHAT WE FOUND

- -33 V is better than -43 V
- The worst material to use was the black plastic
- The best material was the reflective tape

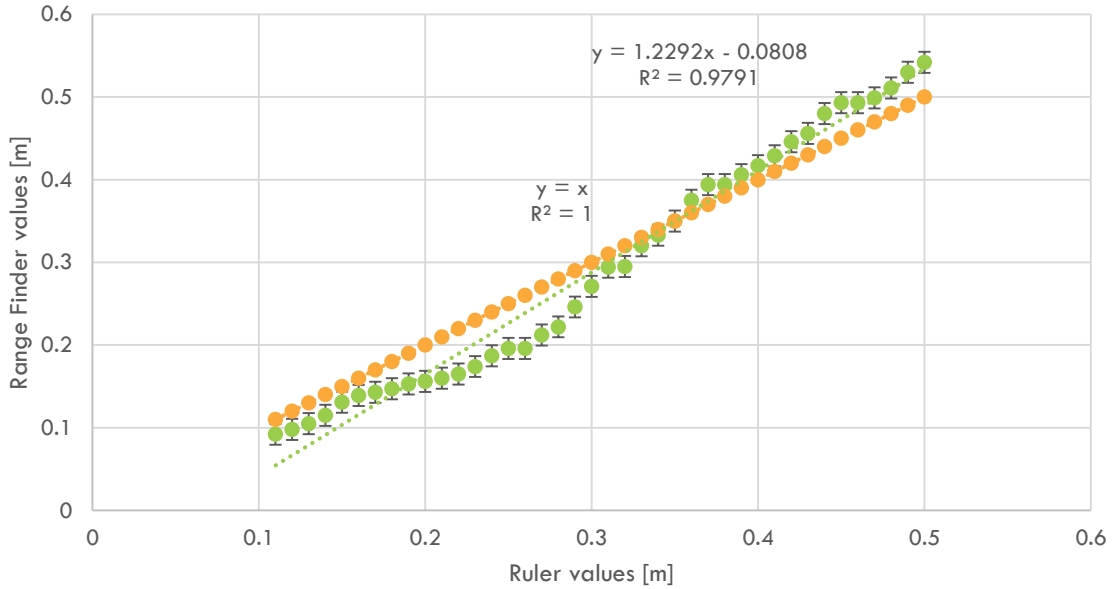
TESTING CM BY CM

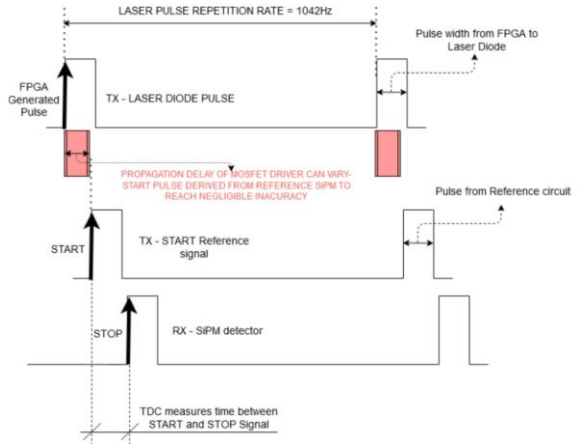
- Binning value – 0.0128m
- Calibration
- There is something wrong inside the chip

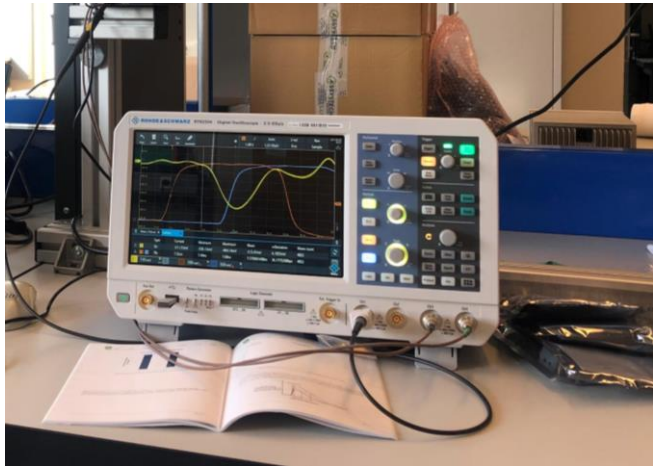
Trendline for the whole thing



Trendline from the given minimum at 0.11 cm







THE OSCILLOSCOPE

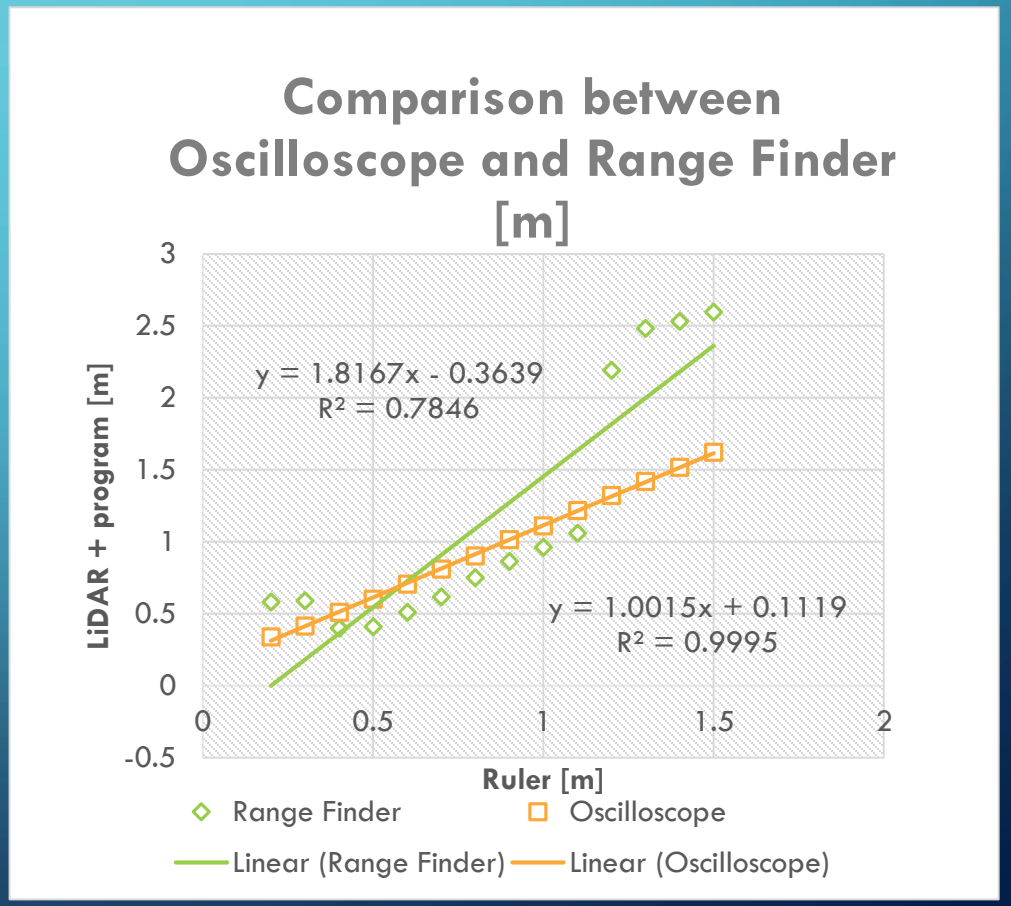
- Channel 1 – output of the sensor
- Channel 3 – start signal
- Channel 4 – stop signal

THE MYSTERIOUS AFTERSIGNAL

- Something else that reflects?
  - Black background
  - Tube
- Reflects forth and back
- Noise

COMPARISON BETWEEN THE OSCILLOSCOPE AND THE RANGE FINDER

-33.0 V SiPM bias power							
Ruler [m]	Range finder			Oscilloscope			
	Range finder [ns]	Range finder [m]	Error [m]	Oscilloscope [ns]	Oscilloscope [m]	Error [m]	
0.2	3.86	0.579	0.379	2.25	0.3375	0.1375	
0.3	3.92	0.588	0.288	2.75	0.4125	0.1125	
0.4	2.65	0.3975	-0.0025	3.4	0.51	0.11	
0.5	2.73	0.4095	-0.0905	4	0.6	0.1	
0.6	3.4	0.51	-0.09	4.7	0.705	0.105	
0.7	4.1	0.615	-0.085	5.4	0.81	0.11	
0.8	5	0.75	-0.05	6	0.9	0.1	
0.9	5.75	0.8625	-0.0375	6.75	1.0125	0.1125	
1	6.4	0.96	-0.04	7.4	1.11	0.11	
1.1	7.05	1.0575	-0.0425	8.1	1.215	0.115	
1.2	14.6	2.19	0.99	8.8	1.32	0.12	
1.3	16.54	2.481	1.181	9.45	1.4175	0.1175	
1.4	16.86	2.529	1.129	10.1	1.515	0.115	
1.5	17.3	2.595	1.095	10.8	1.62	0.12	
		Average:	0.330285714		Average:	0.113214	



CONCLUSION

- Their TDC is not ideal
- We want to install a new TDC anyway → perhaps their new picoTDC
- Test the TDC for bugs?