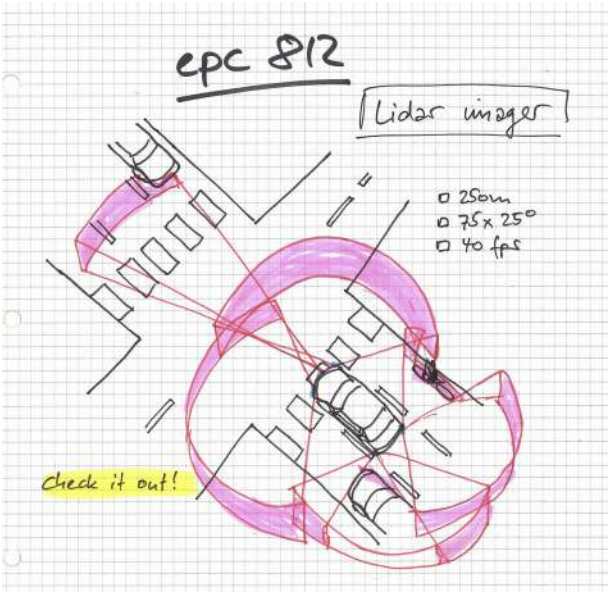
Match the TOF sensor with your car application

From driver-assistant systems to autonomous driving, this is the motivation for today's and tomorrow's sensor technology in the car industry. A part of this is and will be covered by TOF sensor technology. Solutions with cwTOF or pTOF will get such dreams feasible.

Keywords: Time-of-Flight, TOF, cwTOF, pTOF, LiDAR, driver-assistant systems, autonomous driving

Summary

The current generation of continuous wave Time-of-Flight (cwTOF) sensors requires frequency modulated illumination of a full image scene. Particularly in automotive applications which are calling for large field of views and/or larger distances, this approach is clearly limited by the available illumination power and the eye-safety aspect, despite the use of high sensitivity detectors. Therefore the scanning of the scene with pulsed emitters is required for achieving the needed field of view and distance for ADAS (LiDAR), so called pTOF sensor.



This Whitepaper compares cwTOF and pTOF application inside and around the car. Additionally, it explains the concept of direct pulse Time-of-Flight sensors and provide first data of a sensor chip from this new pTOF technology generation innovated by ESPROS Photonics.

The system concepts

The main principle of a sensor, based on the Time-of-Flight (TOF) effect, is sending out a light pulse, waiting until the echo reflected at the object comes back, and measuring the time between the start of the light and the return of the echo. The time multiplied by the speed of light is the traveling length. The distance camera to object is equally to half of this (forth and back).

This is the so-called pulsed TOF technology (pTOF). Refer to Figure 1. This has been used with narrow single beam systems for many years.

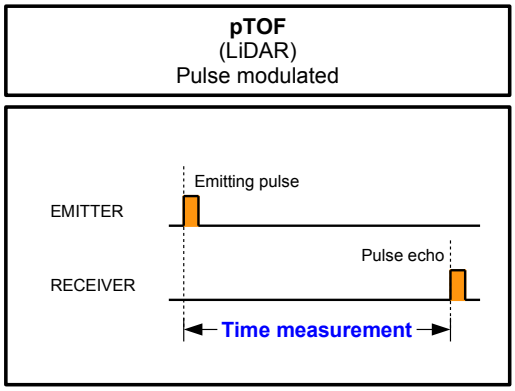


Figure 1: The pTOF principle

Instead of pTOF, there is also the possibility to send out modulated light with a continuous waveform and measuring the phase-shift between the emitted signal and the echo (cwTOF) as shown in Figure 2. The phase-shift is in fact a time-delay, so the same formula applies as for the pTOF system. This technology is used to

today often to illuminate a scenery for a pixel-field, instead of using a single beam.

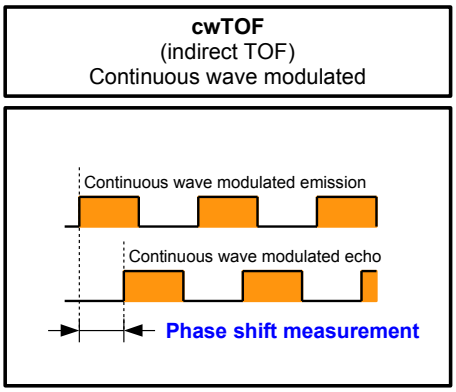


Figure 2: The cwTOF principle

Independent of the principle, the need of today's sensors is to monitor a scene, which means having an imager with a pixel-field and mostly a wide field-of-view (FOV). This leads us to the differentiation for the main USP's (unique selling proposition) and application areas:

cwTOF needs a power consuming continuous steady-state illumination defined by scenery size and operating distance, whereas pTOF uses short, strong pulses of light which consume only a fraction of this power. And there are more properties of importance which need to be taken into account for an application. Figure 3 compares different sensor technologies with a focus on the car applications.

Parameter	Requirement	Radar	Ultrasonic	cwTOF	pTOF (Imaging LiDAR)
Long range	≥100m				
Short range	0 .. 2m				
Spatial resolution	≤0.2°				
FOV horizontal	360°				
FOV vertical	≥25°				
Distance resolution	cm				
Weather condition	all weather				
Daytime	day & night				
Response time	>25 fps				
Safety	eye safe, ASIL				
Multiple sensors	no interference				
Cost	low				

Figure 3: Comparison of different sensor technologies

cwTOF in and around the car

As explained above, cwTOF sensors have an important role in near-field applications.

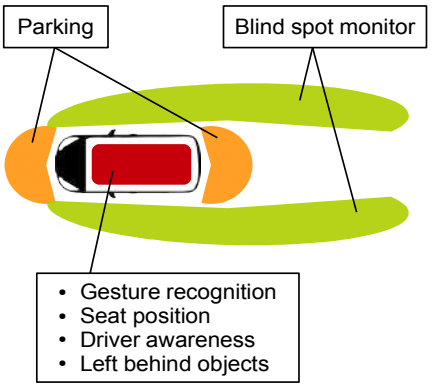


Figure 4: Using cwTOF in car applications

Using the vehicle as an example, in most cases we need high sensitivity of the sensor to guarantee eye-safety. A strong ambient-light suppression is mandatory for the wide variety of changing environmental light-conditions from full sunlight until the dark of the night. Possible application areas identified thus far are in-cabin monitoring and near-field sensing as shown in Figure 4.

Lets do an example for in-cabin monitoring for gesture recognition, seat position, driver awareness, left behind objects, etc.

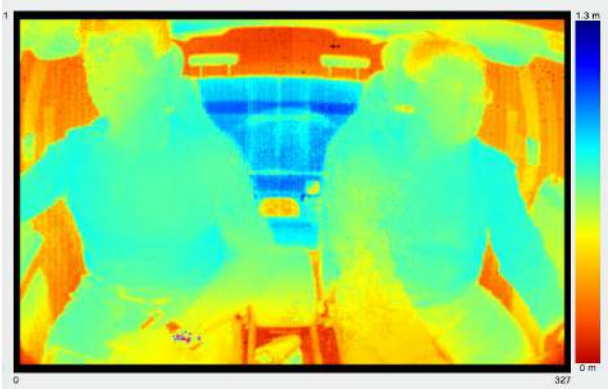


Figure 5: In-cabin monitoring: Distance image

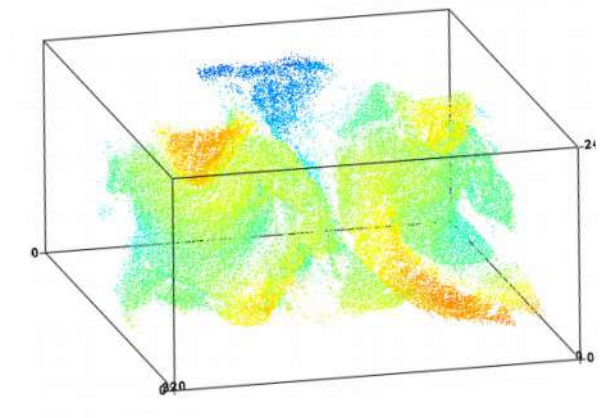


Figure 6: In-cabin monitoring: Point-cloud view

Typical parameters for a camera with ESPROS' epc660 chip are:

- Lens F# 1.4
- hFOV 94°
- vFOV 70°
- LED power 1W (cw)
- Frame rate 50 fps
- Wavelength 850 nm
- Range 6 m
- Sunlight >100 kLux

pTOF – the master of far-field

More tricky is to illuminate far-field sceneries as shown in Figure 7 and Figure 8.

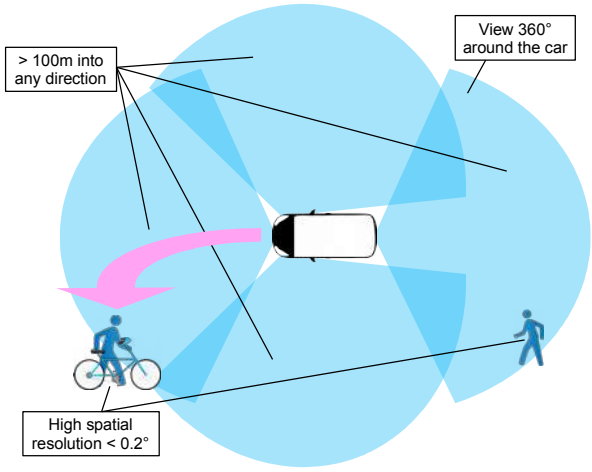


Figure 7: pTOF application-fields, top view: surrounding FOV

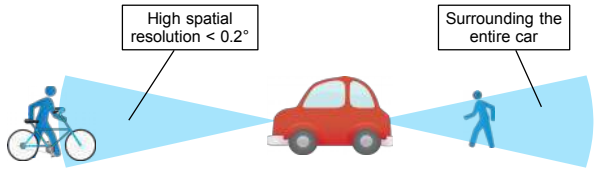


Figure 8: pTOF application-fields, side view: vertical FOV

Illumination power and eye-safety are not the only challenges in this situation: weather condition and multiple echos are of importance too for such applications.

With the main focus of such requests, ESPROS has invented a comprehensive pTOF technology based on the use of gated imaging with CCD for the distance measurement principle:

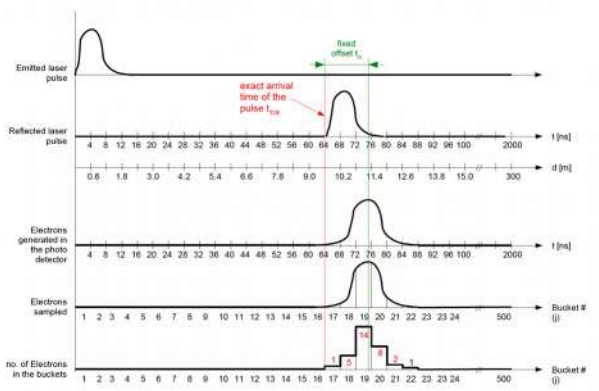


Figure 9: Signal shift by gated imaging with CCD for pTOF

Short-form description how it works:

- Sampling of arriving light pulses in time sequence into a fast CCD.

– A/D conversion of the CCD readout signal (samples).
– The pulse echo has a certain shape over several samples: Calculation of the exact pulse arrival time point out of the samples.
– The system can detect multiple echoes from one laser pulse.

A view to a realized implementation:

Imager parameters:

– QE	>70% @ 905nm
– Speed	6.5ns (FWHM)
– Sensitivity	20e-
– CCD sampling	250MHz
– CCD	450 stages (270m)
– Pixel pitch	45µm
– Pixel field	262 x 150 pixel
– Frame rate	> 100 fps (full 3D TOF)

Camera parameters:

– Lens	F# 0.8
– hFOV	50°
– vFOV	25°
– Laser power	300 W peak
– Laser pulse	5 ns
– Wavelength	905 nm
– Ambient light	100 klux on target

Results and conclusion

This Whitepaper shows the variety of possibilities to use TOF technologies in automotive applications. It explains the difference between the systems and lists their target use.

For the design and realization of such sensor systems, ESPROS offers a variety of cwTOF (see Figure 10) and pTOF imagers (see Figure 11) as well as cameras.

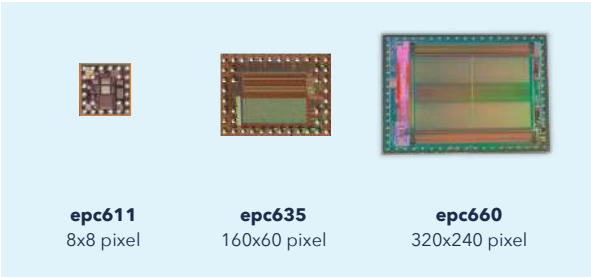


Figure 10: ESPROS cw TOF imager chips

All these products have a focus on the needs of the car industry: sensors with high sensitivity and powerful ambient-light suppression. For more details contact sales@espros.com .

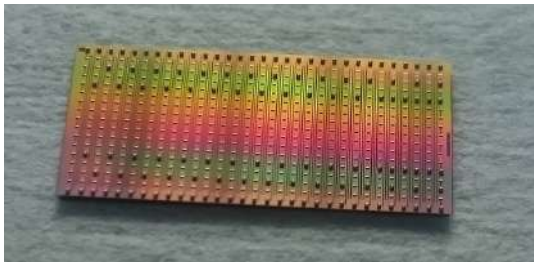


Figure 11: ESPROS p TOF imager chip

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