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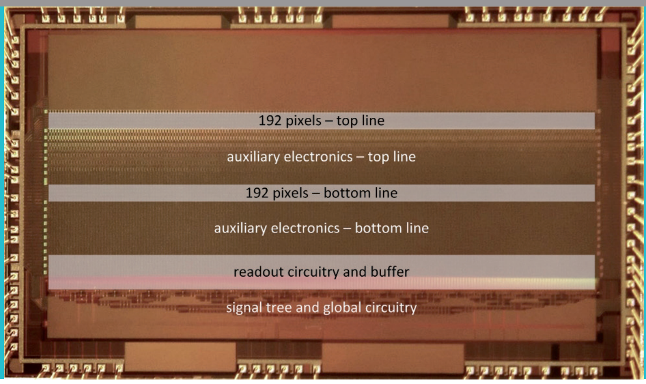

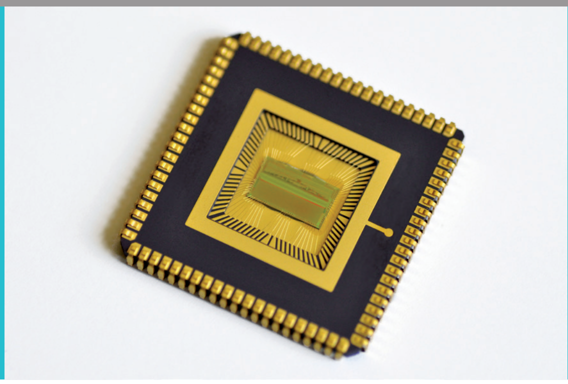

1 *Chip micrograph of CMOS LiDAR sensor SPADeye2*
2 *CMOS LiDAR sensor with package*

SPADEYE2 – CMOS LIDAR SENSOR

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Light Detection and Ranging

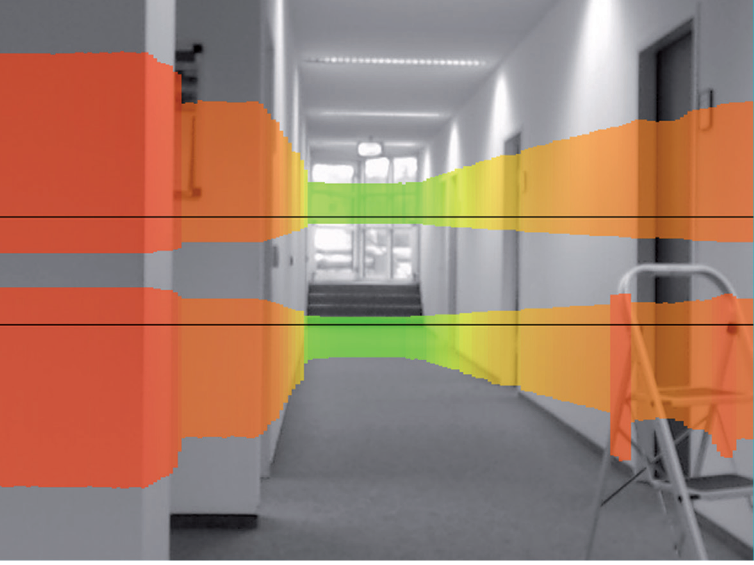
The 3D perception of the environment or objects is essential in many applications like automotive, industry, or security. In LiDAR (light detection and ranging) the distance is determined by measuring the time between the emission and the reception of a laser pulse. Since the velocity of light is known, the measured time can be directly translated into the distance of the object. In the direct technique the laser pulse time-of-flight is measured with a high precision electronical stopwatch. Like 2D image sensors flash LiDAR can use many single pixels to capture the scene with a high angular resolution.

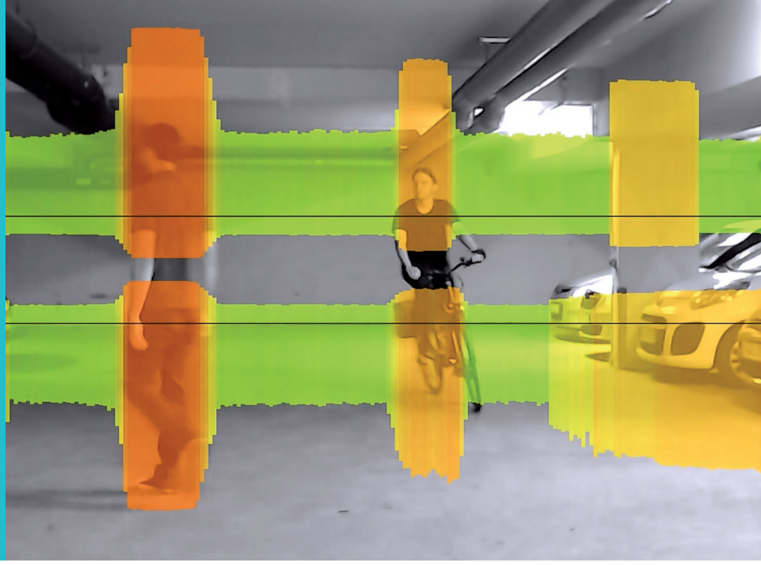
Sensor Overview

SPADeye2 is a 192 x 2 pixel dual line flash LiDAR sensor fabricated in an automotive certified 0.35 µm CMOS process. The chip integrated time-to-digital converter with a temporal resolution of 312.5 ps and a full scale range of 1.28 µs allows time-of-flight measurements in all pixels simultaneously. To minimize the required laser power and enable high accuracy time measurements the sensor employs fast and high sensitive CMOS single-photon avalanche diodes (SPAD) developed at Fraunhofer IMS. SPADs are avalanche photodiodes biased above the breakdown voltage. In the so-called Geiger regime a single photon can cause an avalanche breakdown which is detected by the signal processing circuitry. For single-photon counting or background light measurements the sensor also features an event counting mode.

Ambient Light Rejection

In outdoor applications like advanced driver assistance systems (ADAS) or autonomous driving background light of the sun is a serious impediment, since ambient photons can cause detections resulting in incorrect time-of-flight measurements. To improve the measurement quality SPADeye2 allows the detection of temporal correlated photons.





Photon coincidence detection improves the ability to separate between signal and background photons and allows an up to 66 % higher measurement range in high ambient light situations. To enable photon coincidence detection SPADeye2 uses four single SPADs in each pixel connected to a specific coincidence detection circuitry. For a maximum of flexibility the coincidence parameters are variable allowing a real-time adjustment of the background light rejection level to different environmental conditions.

Application benefits

SPAD-based LiDAR systems are applicable in many different applications. Due to their single-photon sensitivity they are suitable for automotive long-range applications like driver assistances (e.g. emergency breaking systems) or autonomous driving to detect obstacles in the driveway of the car. The direct time-of-flight measurement technique has the ability to differentiate between multiple objects in a single pixel. A shift in distance due to multiple reflection of the laser pulse, the so-called multi-path-effect, is avoided allowing the usage in safety-critical tasks. Mid-range LiDAR systems applied in the industry also benefit from the increased reliability of this technique. Due to the integration of the SPADs in a standard CMOS process the photon detectors can be integrated along with the electronics for SPAD control, data processing and readout on a single chip. Together with flash operation compact and cost-efficient LiDAR systems can be built which are desired in many applications.

SPADeye2 LiDAR Sensor Specifications

Chip dimension	9 mm x 5.2 mm
Technology	0.35 µm CMOS
Power supply	3.3 V / 31 V
Pixel count	192 x 2
SPADs per pixel	4
Pixel size (SPAD only)	40.56 µm x 52.4 µm
Fill factor	5.32 %
Line pitch	1 mm
Frame rate	52 kHz (@ 20 MHz readout)
Features	Timing and counting mode, variable coincidence

SPAD

Diameter	12 µm
Breakdown voltage	26 V (@ 300 K) + 37.8 mV/K
Operation voltage	31 V
Photon detection efficiency	2 % (@ 905 nm)
Dead time	20 ns
Dark count rate	10 cps (@ 300 K)
Dynamic range	134 dB

TDC

Temporal resolution	312.5 ps
Full scale range	1.28 µs
Architecture	Fully-parallel, DLL-based interpolation

Coincidence

Photon coincidence depth	1 to 4
Photon coincidence time	variable
Active SPADs	1 to 4

3 *Indoor measurement in hallway with color-coded distance*

4 *Indoor measurement in parking garage with color-coded distance*