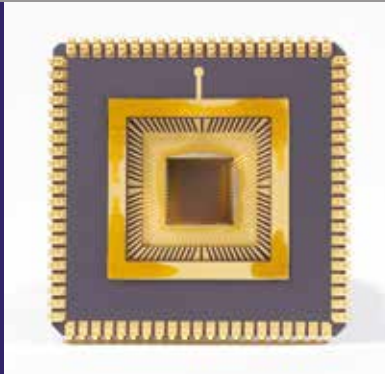




<sup>1</sup> TCAD Simulation of the ToF-LDPD-structure.

<sup>2</sup> ToF-sensor based on LDPD.

## LATERAL DRIFT-FIELD PHOTO-DETECTOR FOR TOF-IMAGING

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### Time-of-Flight-Imaging using the Lateral Drift-Field Photodetector

Nowadays, nearly every digital camera or mobile phone uses the pinned photodiode (PPD) as light sensitive detector fabricated in a low cost CMOS process. Driven by reaching higher and higher counts of megapixels (MP) this PPD is shrunk down to pixel sizes of  $1\mu\text{m}$  and below to provide two dimensional colour imaging. However, these pixel structures do not match the performance requirements - such as high dynamic range, responsivity, and high internal charge transfer speed - needed for special imaging applications (i.e. 3D imaging or low light imaging).

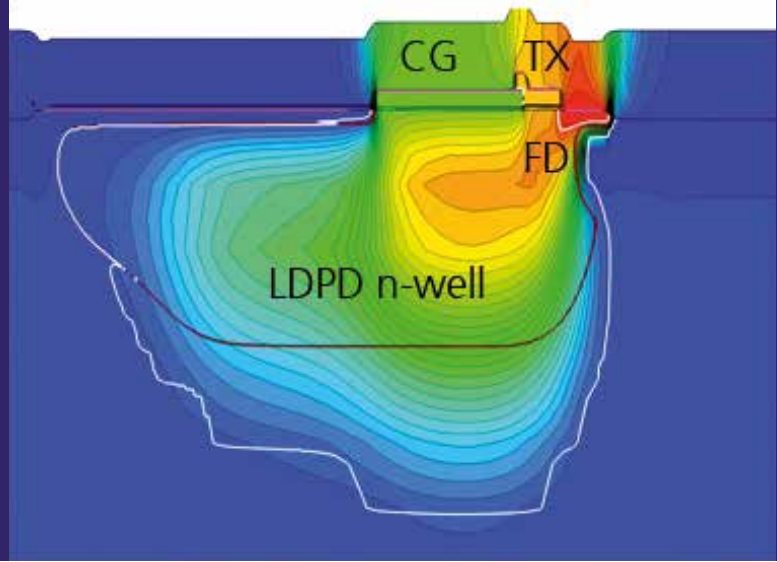
CMOS technology with a special non-uniform lateral doping profile to provide a drastically increased internal charge transfer speed compared to a conventional pinned photodiode. Inside this structure an internal electrical drift field enables transfer speeds of photogenerated charges in the nanosecond scale for a pixel size of  $40\mu\text{m}$ .

Based on this LDPD pixel structure Fraunhofer IMS has developed and fabricated a 3D Time-of-Flight (ToF) sensor with  $128 \times 96$  pixels.

This ToF-sensor reaches frame rates of up to 100fps and performs distance ranging up to 10 metres with a resolution of a few centimetres.

For this reason the Fraunhofer IMS has developed the so called Lateral Drift-Field Photodetector (LDPD) using its  $0.35\mu\text{m}$





### High speed charge transfer in the pixel achieved by

- increasing doping concentration in readout direction
- using a charge collection (CG) electrode building up an intrinsic lateral drift field

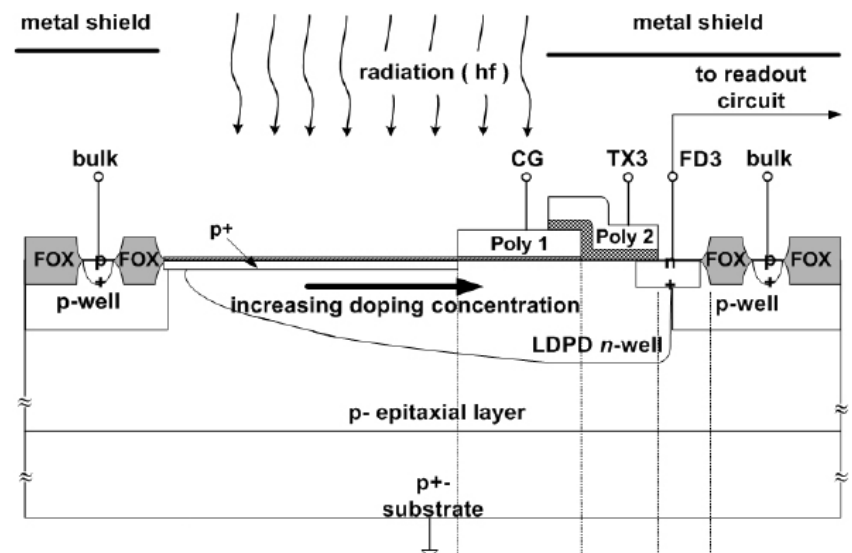
### In-pixel accumulation functionality

- 4 readout taps (floating diffusions, FD)
- low noise and non-destructive readout
- adjustable dynamic range
- Robust and efficient background light suppression
- High responsivity in NIR

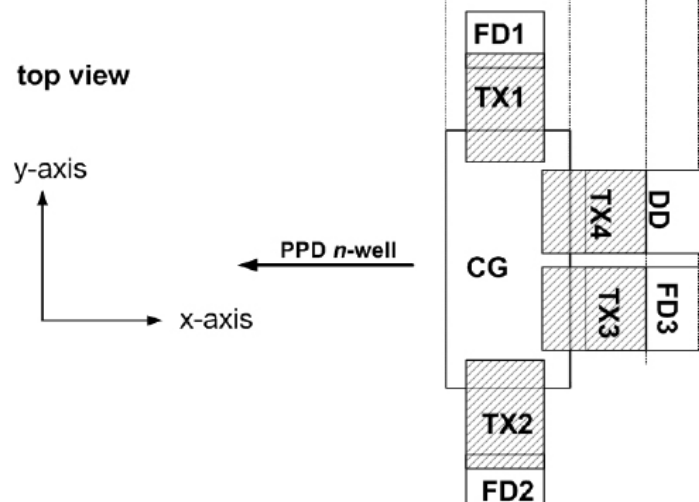
### 128x96 Time-of-Flight Sensor Based on the Lateral Drift-Field Photodiode

- 128x96 pixel array (SQCIF)
- Chip area: 6.45 x 6.45 mm<sup>2</sup>
- 0.35μm 2P4M CMOS process with modified n-well and high voltage option
- 4T pixel architecture with Lateral Drift-Field Photodiode
- Pixel pitch: 40μm
- Pixel fill factor: 38 %
- On-chip Correlated Double Sampling (CDS)
- 2 analog output channels (CDS mode)
- 3 analog output channels (direct output without CDS)
- Pulsed laser illumination (NIR)
- Laser pulse width: typ. 30ns
- Robust background light suppression
- Distance measurements up to 10m
- Depth resolution < 1 cm

### cross sectional view



### top view



3 Simulation of electrostatic potential.

4 LDPD pixel structure.