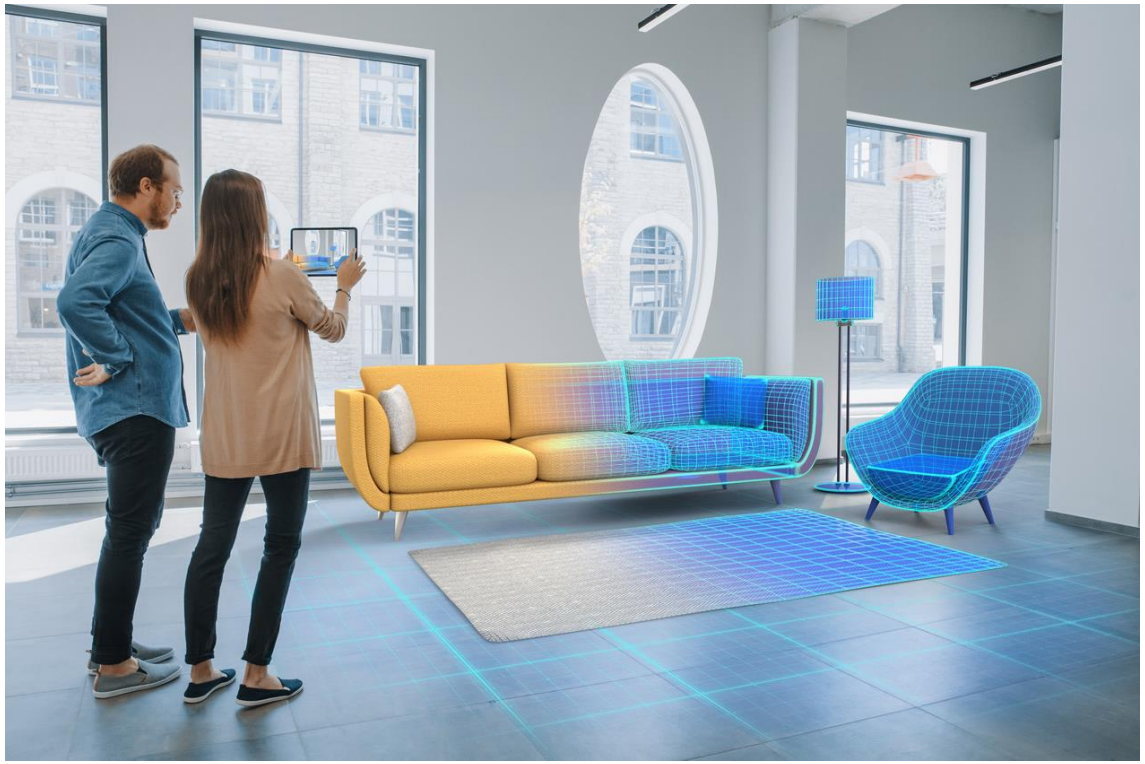




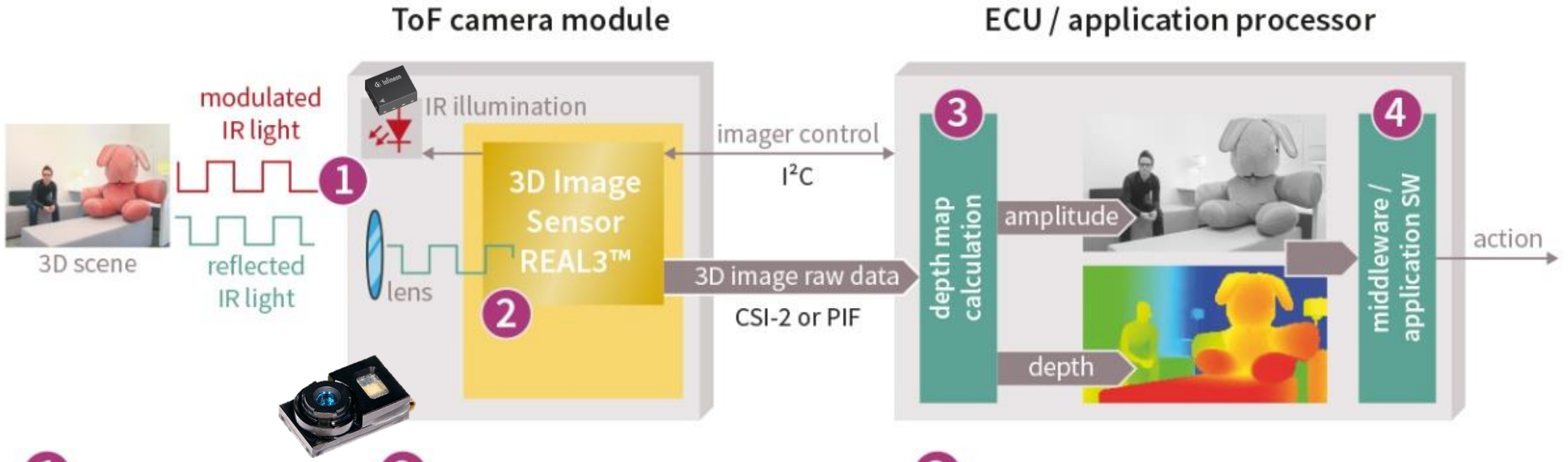
New Infineon FSI iToF imager with improved quantum efficiency

Christian Herzum, Vice President 3D-sensing
MWC 2023

pmd
IMAGINE YOU CAN

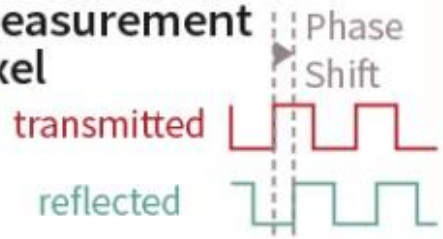
Infineon

Time-of-Flight (ToF) Principle – Depth and amplitude is measured in every pixel



1 Active illumination
- Modulated near infrared light
- 850 or 940 nm

2 Distance measurement in every pixel



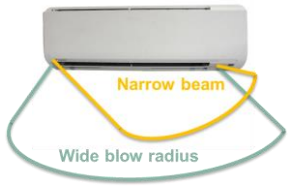
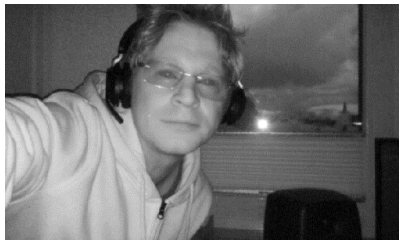
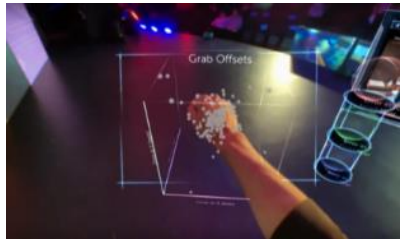
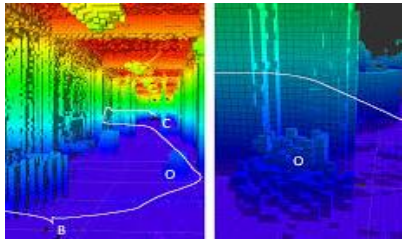
3 Processing
- Depth map calculation
- Calibration data
- Post processing

High quality depth map

4 Application algorithms

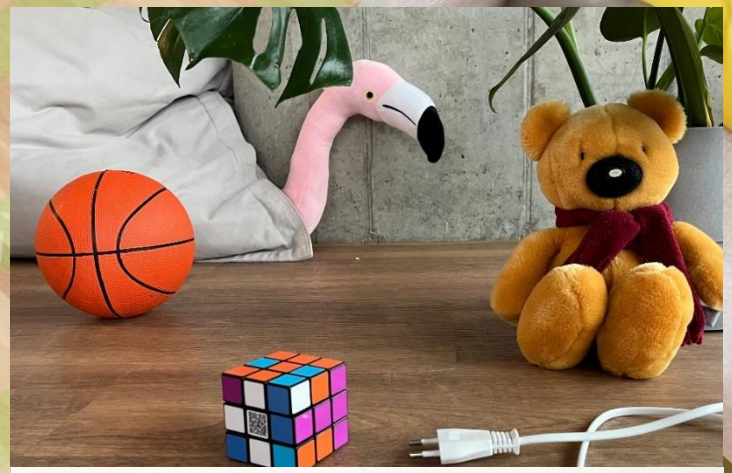
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Infineon REAL3™ Time of Flight – Versatile technology for wide range of consumer applications

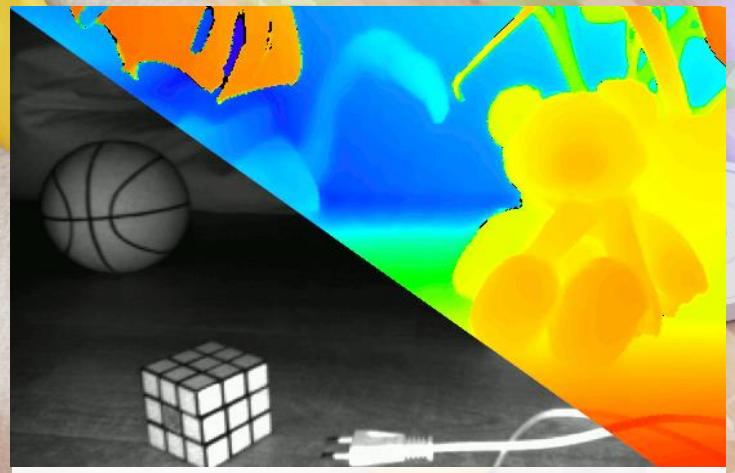
Mobile Phones	Face ID		Hand ID		Virtual Retail		Photography	
Smart Home	Smart Door		Presence detection		Monitoring		Night Vision	
Augmented- & Virtual Reality	Mapping		Control		AR Gaming		Segmentation	
Consumer Robotics	Companion		Drones		Collision avoidance		Navigation	

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Illustration of 3D Object Detection with ToF



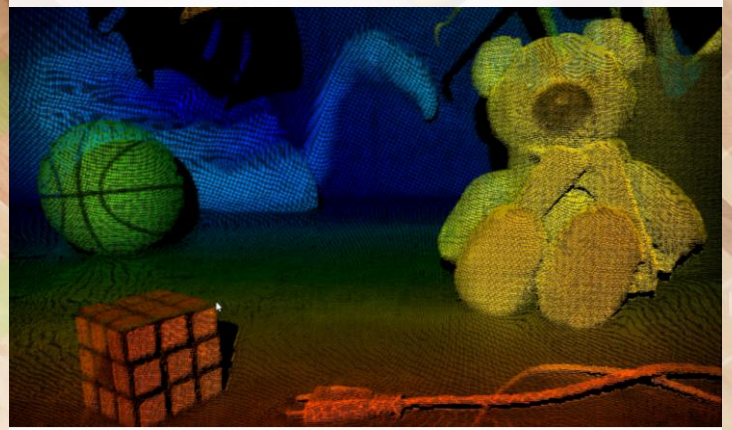
RGB (reference)



ToF 3D depth map/ IR image



ToF depth map & IR overlay

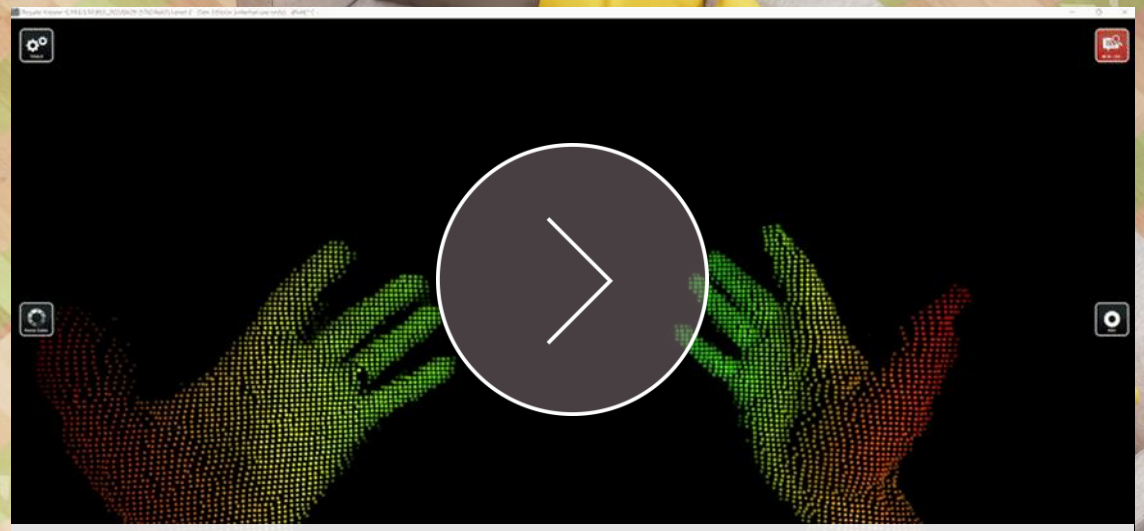


ToF depth color & IR point cloud

- ToF imagers provide different data simultaneously
  - Distance data
  - IR data
  - Metric x,y,z point cloud
- High resolution ToF data enables detection of small objects
- Easy registration with additional RGB based on IR output
- 2D image processing algos can be applied on IR data easily generating even more feature-rich results

Time of Flight

Human machine interface



Hand tracking – HQVGA resolution

- Dense 3D for hand and body tracking
- Enable safe interaction with your next generation service robot and companion robot
- Natural gesture interaction with Co-bot



Understanding human presence – (by Jungo)

- Using 3D & IR images allow robots to understand human intention; Does the owner interact with the robot? Is the robot interrupting the owner?
- Compare known silhouette vs. intruders

Best 3D Mesh with ToF – Instant initialization, better robustness, precise depth points



3D mesh improvements by ToF

- Metaverse requires correct 3D mesh information of the environment always and at any time
- 3D digitalization of large-scale and small-scale objects will be key to "populate" the Metaverse
- **ToF offers**
  - **Instant initialization**
  - **better robustness**
  - **less "flying" points**

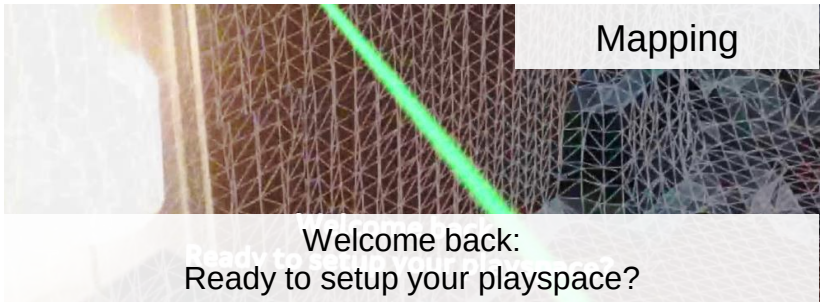
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Time of Flight is the enabler of immersive AR/VR experiences

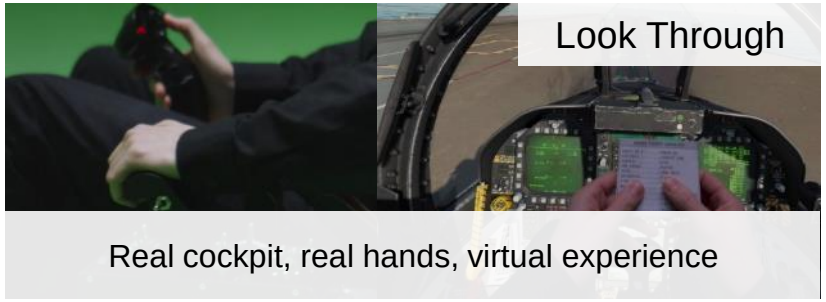
- Infineon and pmdtechnologies 3D depth-sensing technology for
  - **high resolution, low power** 3D mapping
  - in **wide FoV** augmented reality headsets

- **Magic Leap** 2 is using our technology to enable advanced cutting-edge industrial and medical applications (Link)

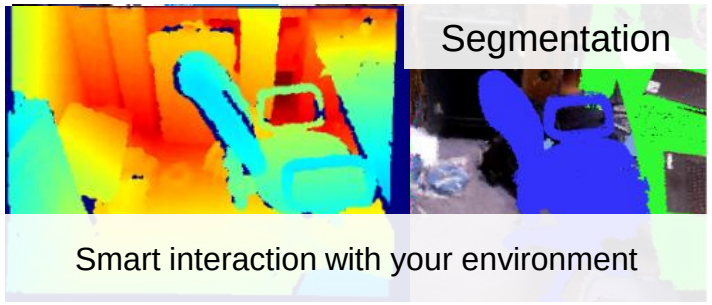




Welcome back:
Ready to setup your playspace?



Real cockpit, real hands, virtual experience



Smart interaction with your environment

Depth data for **robust 3D world** ● **Immersion** through **Environmental understanding**

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Ensure Secure Face Authentication with REAL3™ ToF



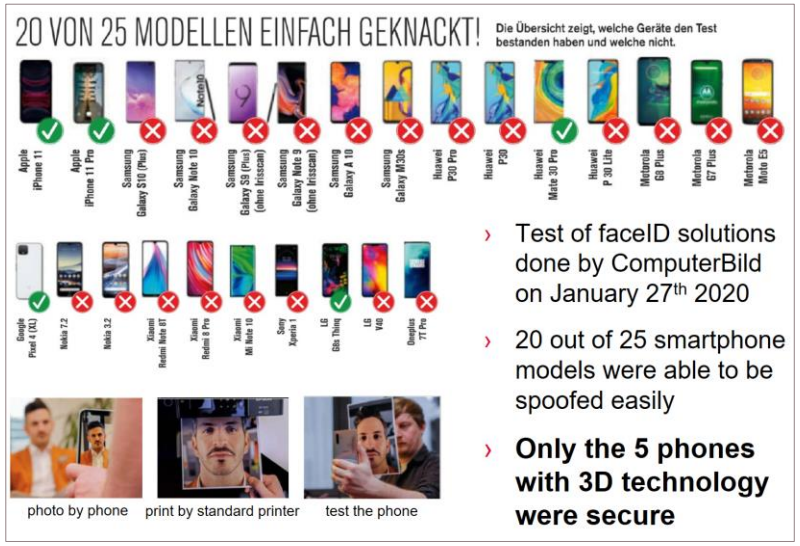




Front 3D ToF camera

Biometric Face unlocking (Android & iOS)

Secure Face payment



ArcSoft and pmd/Infineon achieving the world-first ToF-based Android Biometrical Class3 (Strong) Certified Under Display FaceID solution, using a **commercial** 400ppi **AMOLED display**

- **ArcSoft Face ID application, pmd/Infineon HW and depth pipeline. ToF Imager used IRS2976C (Test house: AntGroup)**
- Test to google specifications (https://source.android.com/security/biometric/measure)
- False Acceptance Rate: **0.000084% (FAR)**
  - Simulation test by using test data imported into the faceID algorithm library
  - Comparable to required test of 50000 unlock scenarios
- Total False Rejection Rate: **2.43% (FRR)**
  - Below the 10% requirement by google, averaged over the complete working distance
- Spoof Acceptance Rate: **0% (SAR)**

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Infineon ToF value proposition for smart doorlocks – New levels of security, assets protection and UX, at optimal power budget



ToF-powered Presence/Wake-Up Detection

- Presence detection (low light capability and wide FoV)
- Low Power Always-On Wake-Up Detection

ToF-based secured Face ID and Palm ID

- Secured, market-proven 3D Face-ID for user authentication
- Palm ID for added security and privacy. Increased user experience and touchless interaction.

ToF-assisted movement tracking

- Body tracking (face, eyes, head), for movement detection and tracking for intruder alert
- Low Light and Wide FoV

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Arima 6125: Secure face payment terminal – IRS2877C
Infineon REAL3™ Time of Flight (ToF) for secure payment



Infineon IRS2877C + IRS9102C Benefit

- High resolution 3D data for face and palm ID
- Most robust in the dark and bright sunlight
  - Patented SBI in every pixel
- Easy to integrate: Smallest VGA resolution imager with
- Hight efficency IRS9102C VCSEL driver
  - Best performance
  - Best 3D camera system BOM



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Advancements in indirect Time of Flight image sensors in front side illuminated CMOS

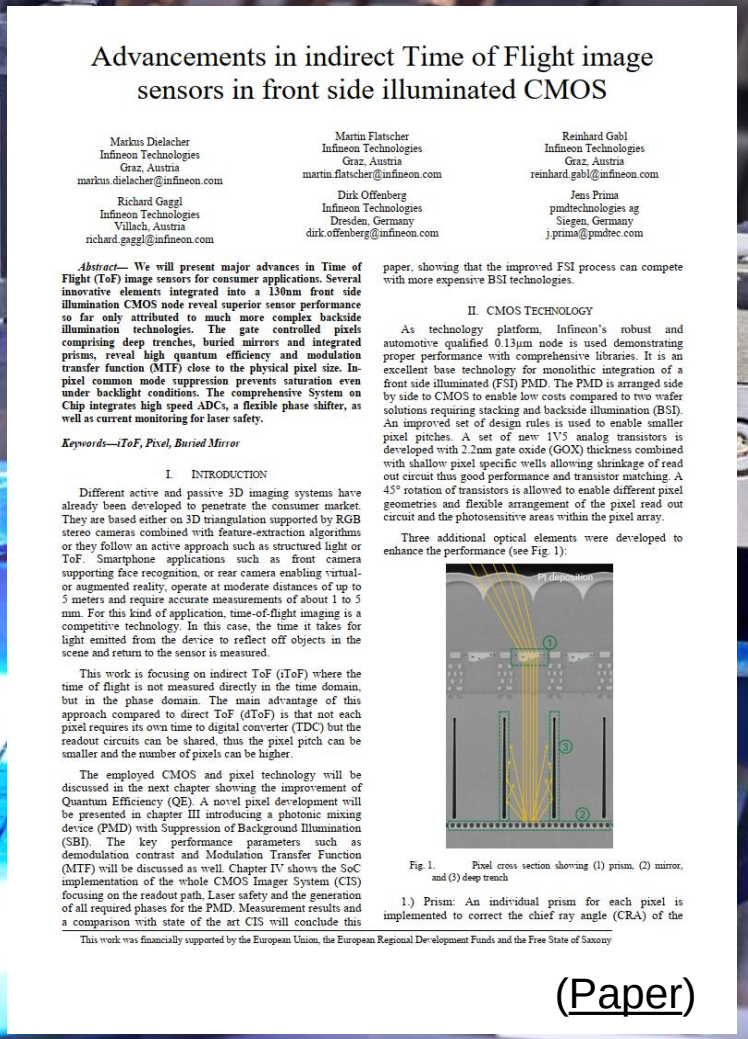
Continuous innovation and process technology improvement leading to new pixel generation:

EVO 3

Infineon REAL3™ process technology allows for advanced structures like thicker EPI layer, p-column and backside reflectors

The biggest performance jump jet defining a new imager

IRS2975C, IRS2976C



Advancements in indirect Time of Flight image sensors in front side illuminated CMOS

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***Abstract*— We will present major advances in Time of Flight (ToF) image sensors for consumer applications. Several innovative elements integrated into a 130nm front side illumination CMOS node reveal superior sensor performance so far only attributed to much more complex backside illumination technologies. The gate controlled pixels comprising deep trenches, buried mirrors and integrated prisms, reveal high quantum efficiency and modulation transfer function (MTF) close to the physical pixel size. In-pixel common mode suppression prevents saturation even under backlight conditions. The comprehensive System on Chip integrates high speed ADCs, a flexible phase shifter, as well as current monitoring for laser safety.**

Keywords—iToF, Pixel, Buried Mirror

I. INTRODUCTION

Different active and passive 3D imaging systems have already been developed to penetrate the consumer market. They are based either on 3D triangulation supported by RGB stereo cameras combined with feature-extraction algorithms or they follow an active approach such as structured light or ToF. Smartphone applications such as front camera supporting face recognition, or rear camera enabling virtual- or augmented reality, operate at moderate distances of up to 5 meters and require accurate measurements of about 1 to 5 mm. For this kind of application, time-of-flight imaging is a competitive technology. In this case, the time it takes for light emitted from the device to reflect off objects in the scene and return to the sensor is measured.

This work is focusing on indirect ToF (iToF) where the time of flight is not measured directly in the time domain, but in the phase domain. The main advantage of this approach compared to direct ToF (dToF) is that not each pixel requires its own time to digital converter (TDC) but the readout circuits can be shared, thus the pixel pitch can be smaller and the number of pixels can be higher.

The employed CMOS and pixel technology will be discussed in the next chapter showing the improvement of Quantum Efficiency (QE). A novel pixel development will be presented in chapter III introducing a photonic mixing device (PMD) with Suppression of Background Illumination (SBI). The key performance parameters such as demodulation contrast and Modulation Transfer Function (MTF) will be discussed as well. Chapter IV shows the SoC implementation of the whole CMOS Imager System (CIS) focusing on the readout path, Laser safety and the generation of all required phases for the PMD. Measurement results and a comparison with state of the art CIS will conclude this paper, showing that the improved FSI process can compete with more expensive BSI technologies.

II. CMOS TECHNOLOGY

As technology platform, Infineon's robust and automotive qualified 0.13µm node is used demonstrating proper performance with comprehensive libraries. It is an excellent base technology for monolithic integration of a front side illuminated (FSI) PMD. The PMD is arranged side by side to CMOS to enable low costs compared to two wafer solutions requiring stacking and backside illumination (BSI). An improved set of design rules is used to enable smaller pixel pitches. A set of new 1V5 analog transistors is developed with 2.2nm gate oxide (GOX) thickness combined with shallow pixel specific wells allowing shrinkage of read out circuit thus good performance and transistor matching. A 45° rotation of transistors is allowed to enable different pixel geometries and flexible arrangement of the pixel read out circuit and the photosensitive areas within the pixel array.

Three additional optical elements were developed to enhance the performance (see Fig. 1):

Fig. 1. Pixel cross section showing (1) prism, (2) mirror, and (3) deep trench

1.) Prism: An individual prism for each pixel is implemented to correct the chief ray angle (CRA) of the

This work was financially supported by the European Union, the European Regional Development Funds and the Free State of Saxony

(Paper)

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IRS2976C Time of Flight with EVO3 Technology in a nutshell & Preview on system benefits

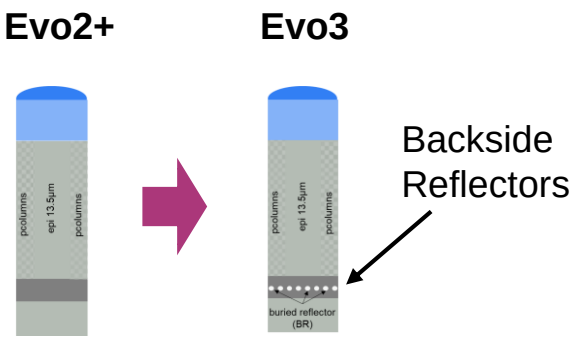
IRS2976C

REAL3™ Imager

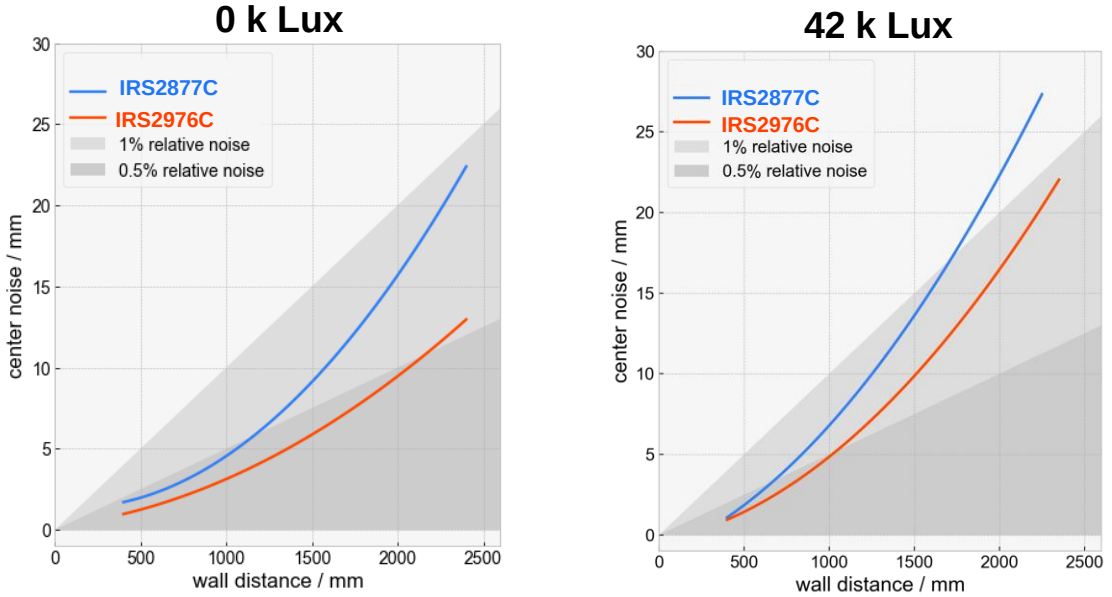


NEW

- **300k** upscaled **VGA** resolution 640 x 480
- **Smallest VGA imager**: 24 mm² → **1/4" image circle**
- Highly integrated system and **eye safety mechanisms**
  → **lowest module BOM** in combination with IRS9102C VCSEL driver
- **Latest Infineon EVO3 pixel technology**
  - Technology upgrade with 3D field engineering for best demodulation efficiency and optical reflector **boosting QE up to 30%.**
  - **Similar QE as BSI**, while maintaining the **cost advantage of FSI**



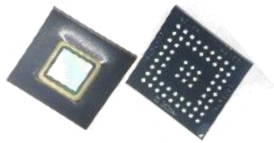
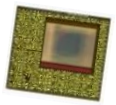
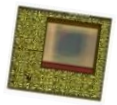
Face Authentication Application



- **IRS2976C refresh** provides **60% better** performance at 0 k Lux and **37% better performance** at 42 k Lux compared to **IRS2877C**
- IRS2976C allows for **drop in compatibility** and **easy upgrade** path from IRS2877C cameras for new **low power IoT face ID**

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REAL3™ ToF imager portfolio
Leading position in the industry

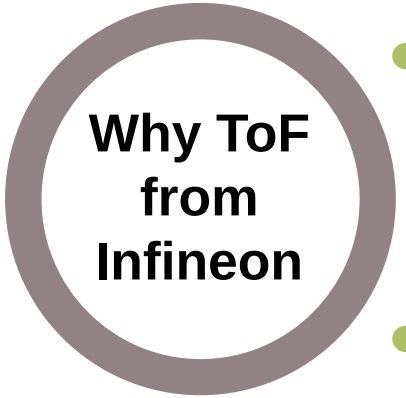
	ATV (-40°C to 105°C) ISO 26262 compliant	**Consumer** (20°C to 65°C)			
	 AS in Q1 2023	 2020	 2021	 2023	 2022
Imager	**IRS2877A & AS**	IRS2877C	IRS2875C	**IRS2976C**	**IRS2975C**
Special	9x9 LFBGA-65	bare die		Drop in for IRS2877C	Drop in for IRS2875C
eff. Pixel / Tech.	5 µm / EVO2+	5 µm / EVO2+	10 µm / EVO2	5 µm / **EVO3**	10 µm / **EVO3**
Status	A in production AS (FuSa) ES avail.	volume production	volume production	ES avail.	volume production
Resolution	**VGA** 640x480	**VGA** 640x480	**HQVGA** 224x172	**VGA** 640x480	**HQVGA** 240x180
Driver Support	IRS9103A in design	IRS9100C and IRS9102C VCSEL driver supported			
Applications	▪ Including Functional Safety ▪ Driver authentication ▪ DMS & OMS ▪ Obstacle avoidance ▪ Industrial Robotic	▪ smartphone user facing (ID) ▪ AR/VR HMD	▪ Robotic ▪ IoT ▪ Auto focus ▪ Drones	▪ smartphone under display ID ▪ Smart Access ▪ AR/VR HMD ▪ IoT ▪ Point of sales	▪ Smartphone auto focus and bokeh ▪ AR/VR HMD ▪ robotics ▪ industrial ▪ IoT



3D camera modules available from Infineon ODM partners

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Take Aways



Best price performance	Evo3 FSI technology combines **high QE** with low cost
Secure Face-ID	Fulfilling **strong biometric specifications**, also under-display
No decalibration, low power	mechanically robust for **lifetime calibration** (no bending); spot ToF **reduces power consumption**
Small formfactor	**Integrated eye safety** and **small VCSEL driver**
Low risk & high volume scalability	Infineon ensures **high volume availability** for ToF imagers with **dual foundry strategy** to reduce risk and ensure scalability

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