Begi DVS Pre-processor & Light-field DVS.

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MEMBER OF BASQUE RESEARCH
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1.
DVS
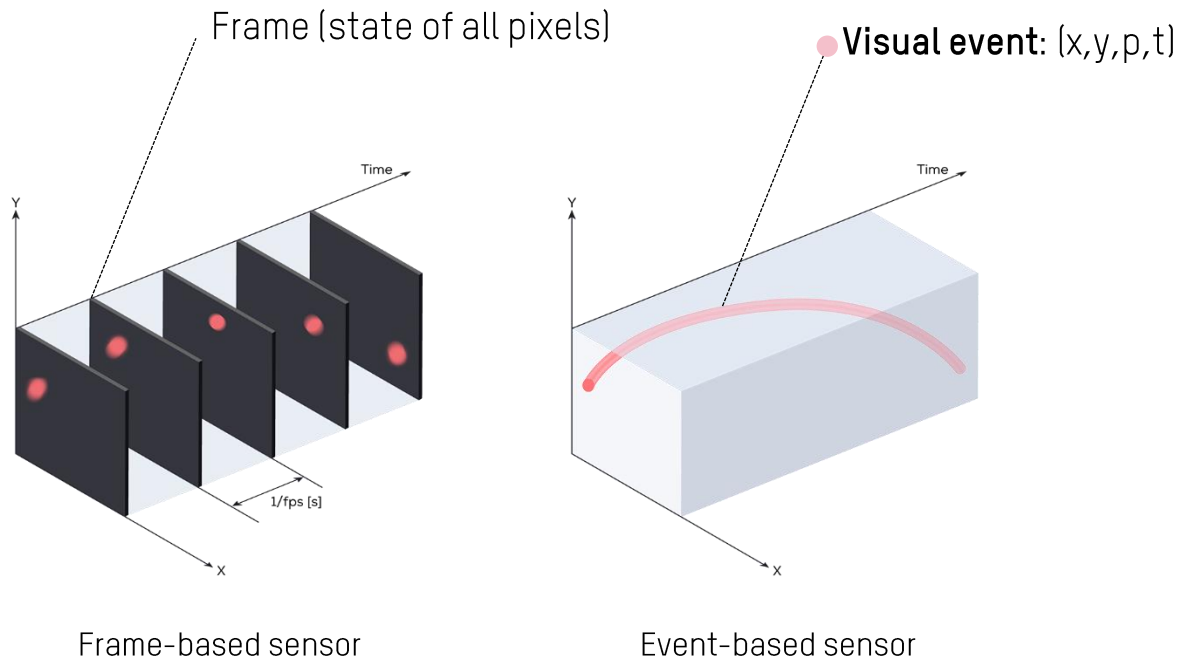technology.

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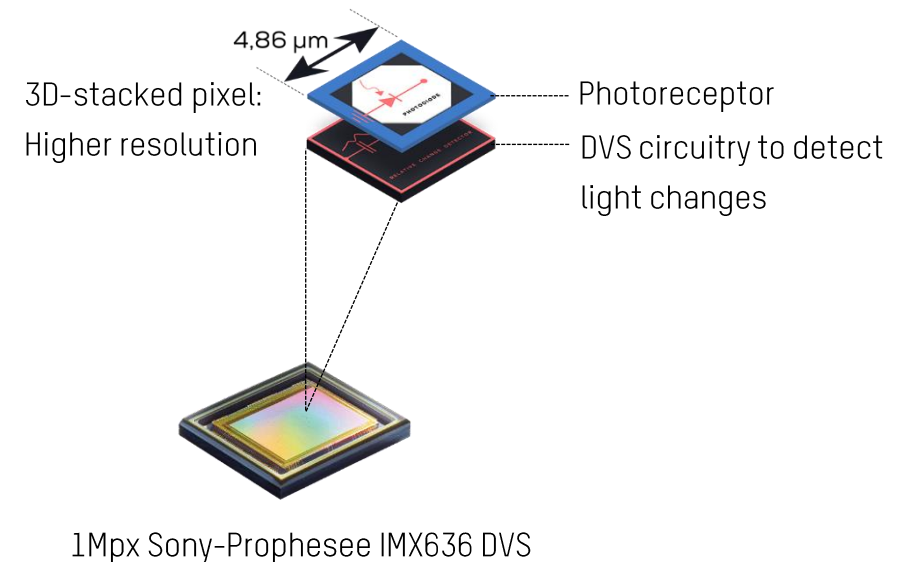
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Dynamic Vision Sensors (DVS) vs Frame-based sensors.

DVS pixels work asynchronously to detect **ONLY** significant changes in the incoming light: **visual events.**

- Sparse event-flows → Ultra-low latency, energy-efficiency and high dynamic range
- Enhanced efficiency when used with **event-driven processing paradigm**; e.g. Spiking Neural Networks (SNN)

... but mainstream AI is frame-based!!

Frame (state of all pixels)

Visual event: (x,y,p,t)

1/fps [s]

Frame-based sensor

Event-based sensor

4,86 μm

3D-stacked pixel: Higher resolution

Photoreceptor

DVS circuitry to detect light changes

1Mpx Sony-Prophesee IMX636 DVS

Credit figures: Prophesee

Events tend to accumulate around moving edges: **Easy to detect moving objects in cluttered scenarios**

High dynamic range >120 dB: pixels operate at their own luminosity level

High temporal resolution: eq. to 10,000 fps

High-sparsity in time & space

Low-power: 10 mW

https://rpg.ifi.uzh.ch/TimeLens.html

Credit: FlySight

https://rpg.ifi.uzh.ch/ERAFT.html
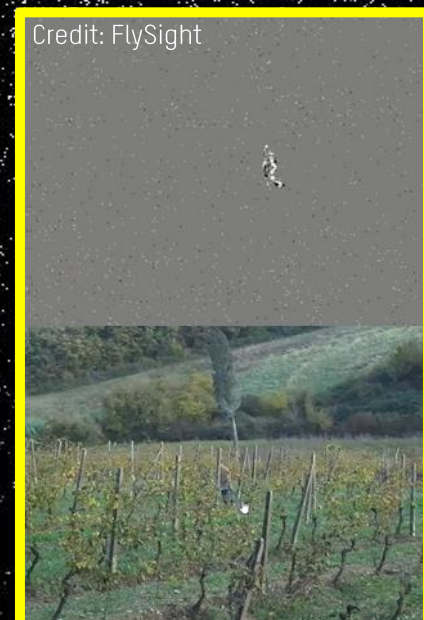
2.

About us.

We are the largest **technology center** (400+ engineers) of Mondragon Corporation (70k+ employees).

- **A team** (8 engineers) **committed to making event-based vision useful for industry** (focus on mobile robotics/UAVs & machine-tool)

- We coordinate the **NimbleAI** Horizon Europe research project (10 M€, 20 partners): www.nimbleai.eu Designing two pre-commercial DVS techs:

  - **Foveated DVS (DF-DVS)**: dynamic allocation of resolution – active vision
  - **Light-Field DVS (LF-DVS)**: passive, monocular, event-based 3D perception

- Our focus is on developing BEGI: a licensable **digital DVS pre-processor** to **bridge event-based vision (*efficiency*) and mainstream AI (*user base*)** while exploiting the new capabilities enabled by NimbleAI DVS tech. (largely in progress)

Begi

BEGI = EYE in Basque language

3.

Begi DVS
Pre-processor.

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BEGI pre-processor .

- **Industry-oriented pre-commercial IP**
  - ○ **Standard on-chip AXI** interfaces & memory-mapped registers (suitable for SoC integration)
  - ○ **Model-based algorithms, no AI-based!** → **Event filter**, **optical flow** & **depth estimation**

  In **multimodal DVS:** standard DVS (e.g., IMX636), DF-DVS & LF-DVS

  Out **standard data structures: depth-maps, time surfaces** & **frames** – configurable rates (100s fps)
  (for use by AI back-end processors running industry-grade AI models)
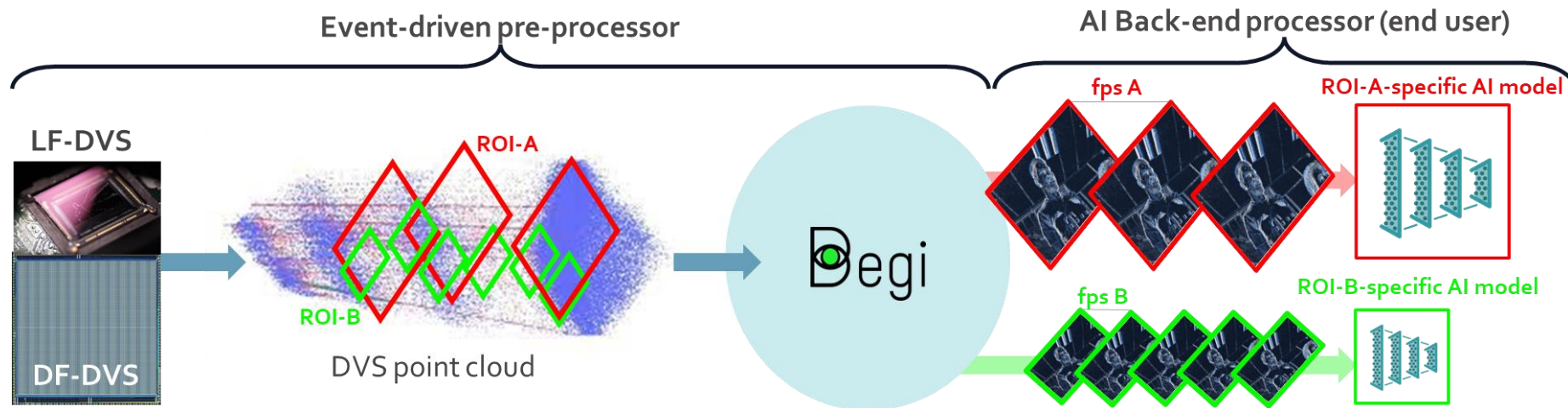
BEGI architecture.
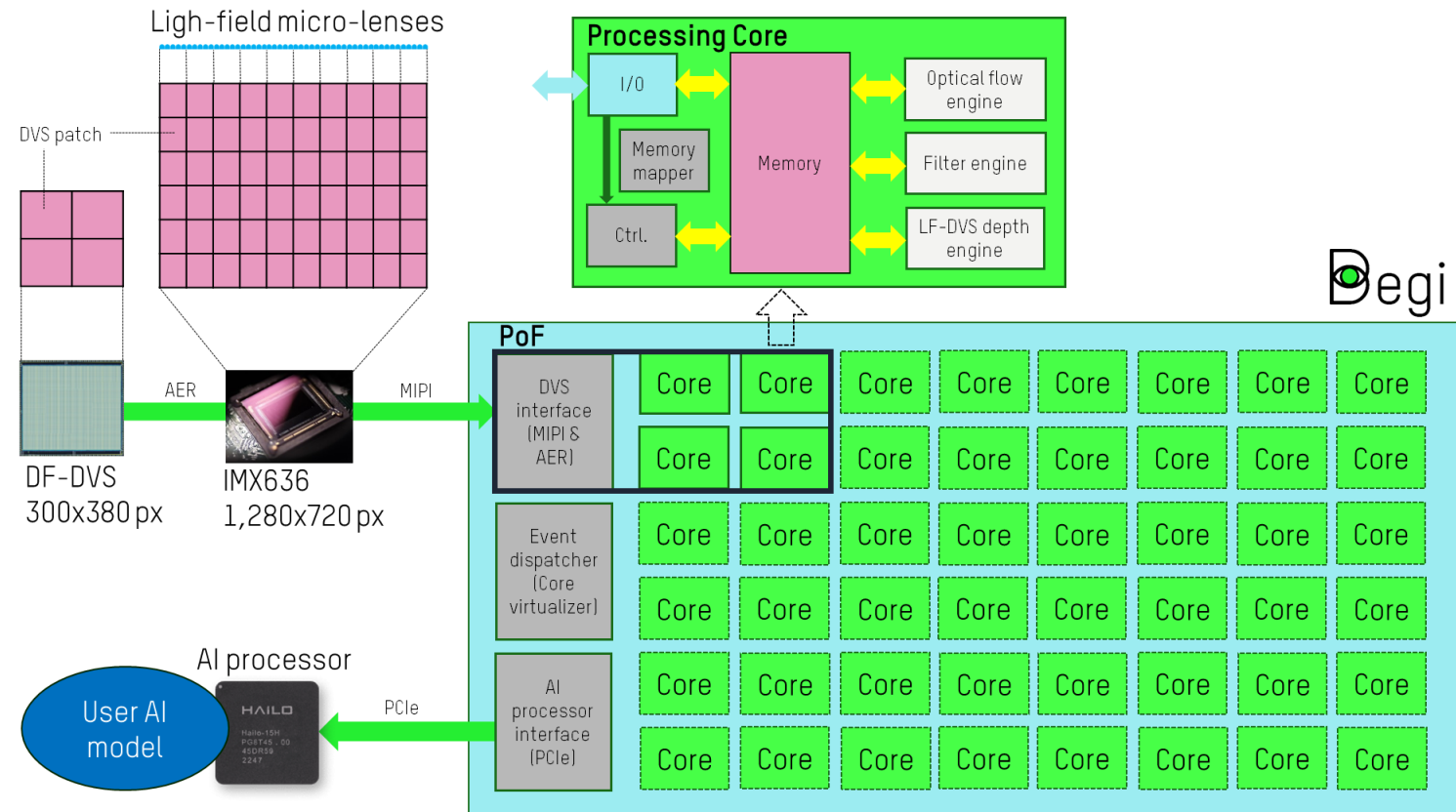
- **Customizable & scalable multi-core architecture**
  - ○ **Ultra-lightweight event-driven processing cores – time-driven outputs**
  - ○ **Spatial mapping**: microlens : voxel : DVS patch → Core (event dispatcher to virtualize cores & exploit sparsity)

    PoF low-res: 4 cores – expected to scale to 1 Mpx (IMX636)
  - ○ 3rd party AI cores can also be integrated

- **BEGI processing cores:**
  - ○ Model-based:
    more predictable inter-core traffic
  - ○ Specialized engines for event filtering,
    OF estimation and LF-DVS processing
  - ○ Configurable Ctrl.:
    post-silicon flexibility

- **PoF prototyped on FPGA** (Q4 2025)
  Silicon PoF expected by 2026/27

Ligh-field micro-lenses

DVS patch

DF-DVS
300x380 px

IMX636
1,280x720 px

AER

MIPI

Processing Core

I/O — Memory — Optical flow engine

Memory mapper — Memory — Filter engine

Ctrl. — LF-DVS depth engine

PoF

DVS interface (MIPI & AER) — Core Core | Core Core Core Core Core Core

Core Core | Core Core Core Core Core Core

Event dispatcher (Core virtualizer) — Core Core Core Core Core Core Core Core

Core Core Core Core Core Core Core Core

AI processor interface (PCIe) — Core Core Core Core Core Core Core Core

Core Core Core Core Core Core Core Core

AI processor

User AI model

HAILO

PCIe

Degi

BEGI algorithms .

SOTA accuracy w.r.t. algorithms @ 100+ fps (No GPU)

EPO App. No: 24383090.8

Lightweight event-driven optical flow

- Tracking moving ROIs – drive foveation in DF-DVS
- Motion-based region filter
- Motion-dependent adaptive time windows & guide fps decisions
- Potentially navigation

~50% removed events

With filter

RAW

EPO App. No: 24382617.9

Spatio-temporal event filtering

- Save energy & processing time
- Event flow control
- Required in stereo-matching to increase match ratio (preliminary match ratio increase in LF-DVS: ~30%)

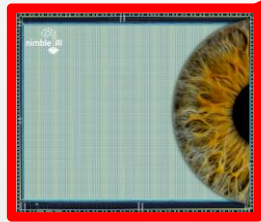## ongoing design of the LF-DVS-based 3D perception engine

Prophesee-Sony IMX636 DVS
(w/o Raytrix light-field micro-lenses – LF-DVS)

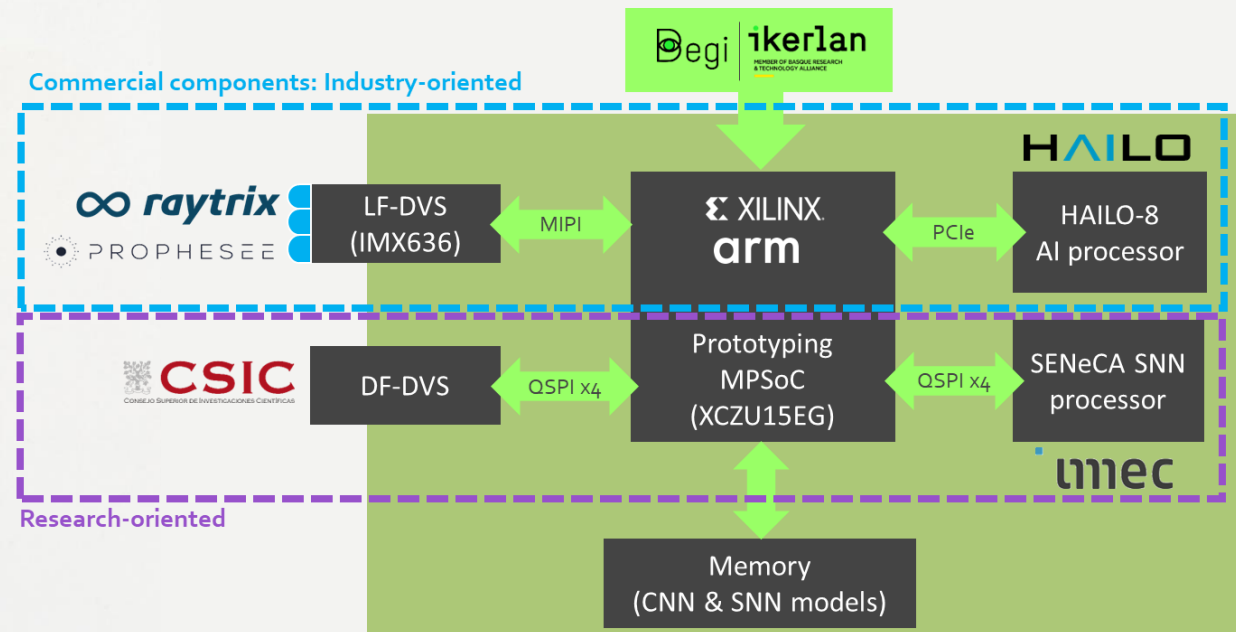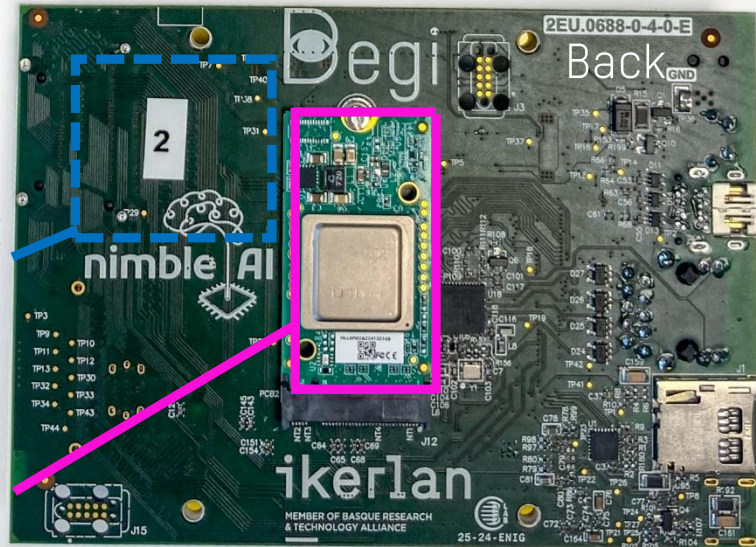BEGI-EVK.

Connector
for CSIC DF-DVS
(Q4 2024)

Front
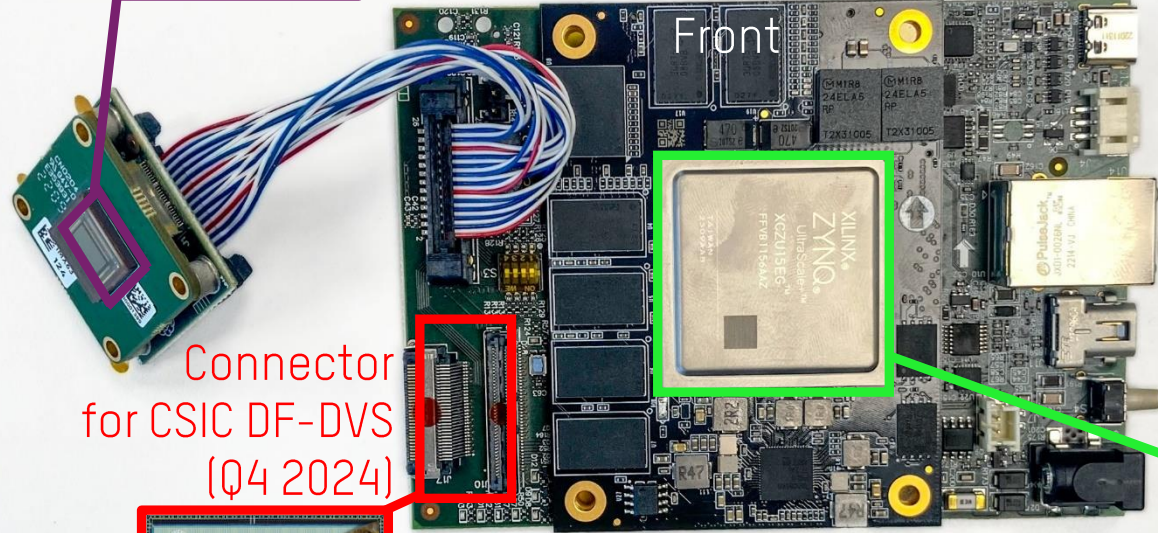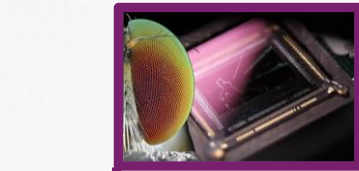
Xilinx MPSoC: Ikerlan
BEGI DVS pre-processor (Q4 2025)
w/o CEA, Codasip, Menta AI cores

- A PCB that integrates an FPGA hosting BEGI, along with DVS sensors and AI processors
- Linux & ROS support
- Test vision applications using live data
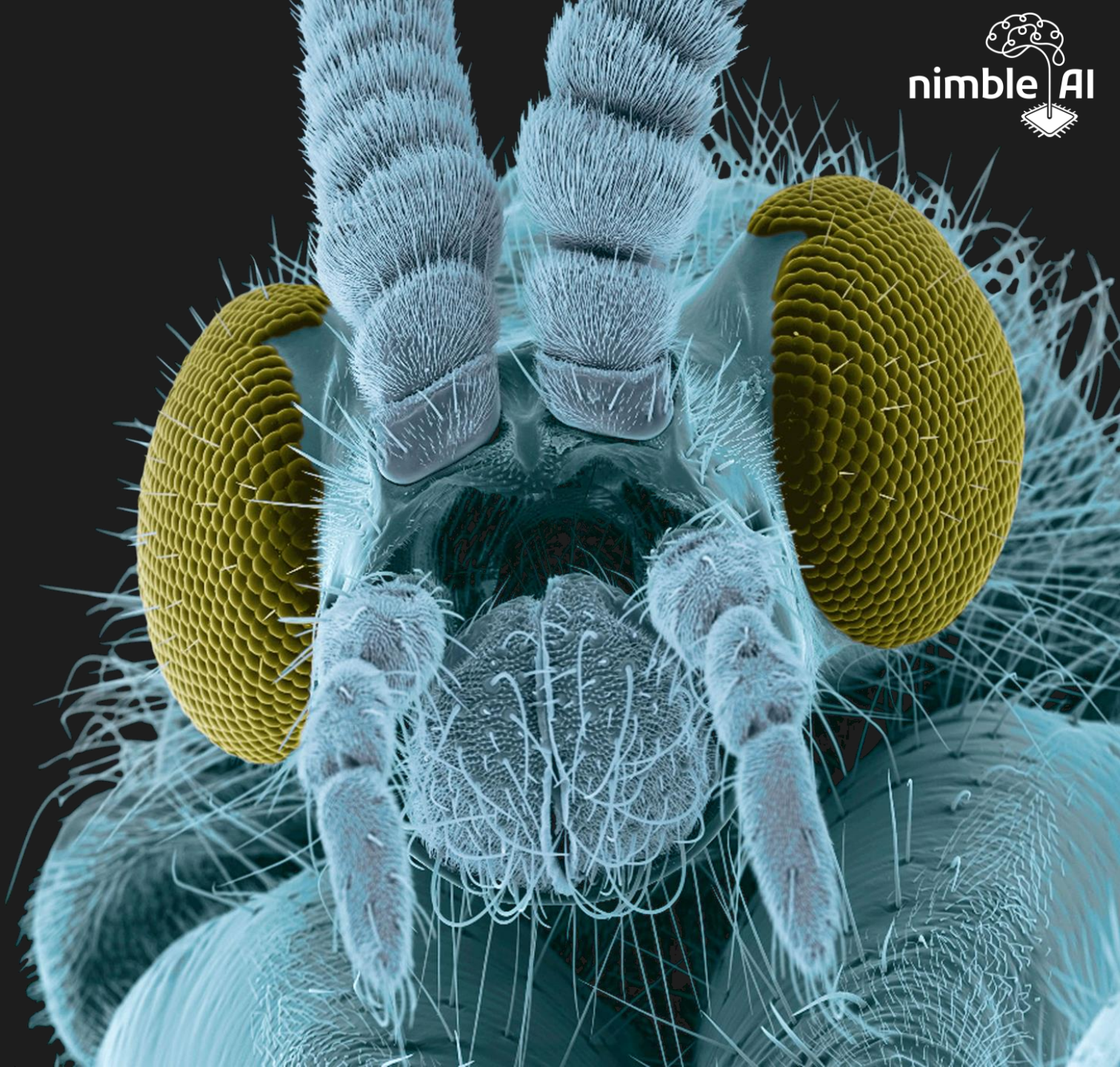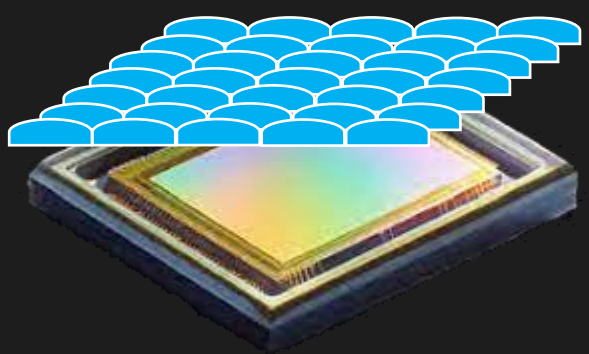- Available to interested parties in Q4 2025

Future slot
for Imec SENeCA SNN
processor (Q3 2025)

Back

PCIe slot:
HAILO AI processor

Commercial components: Industry-oriented

raytrix | PROPHESEE → LF-DVS (IMX636) ← MIPI → XILINX arm ← PCIe → HAILO-8 AI processor

CSIC → DF-DVS ← QSPI x4 → Prototyping MPSoC (XCZU15EG) ← QSPI x4 → SENeCA SNN processor
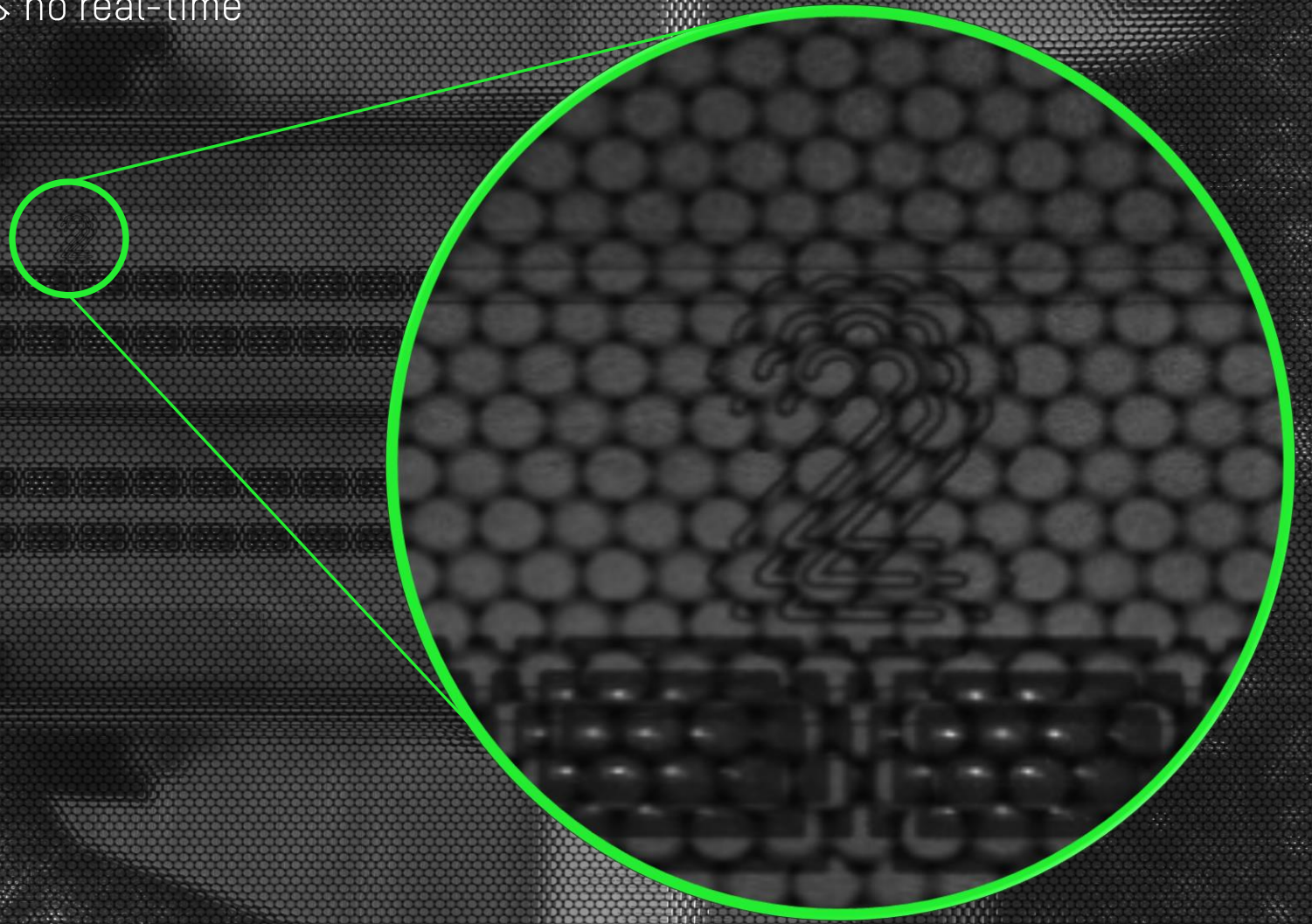
Research-oriented

Memory (CNN & SNN models)

4.
Light-Field
DVS.

Frame-based light-field: Depth perception.
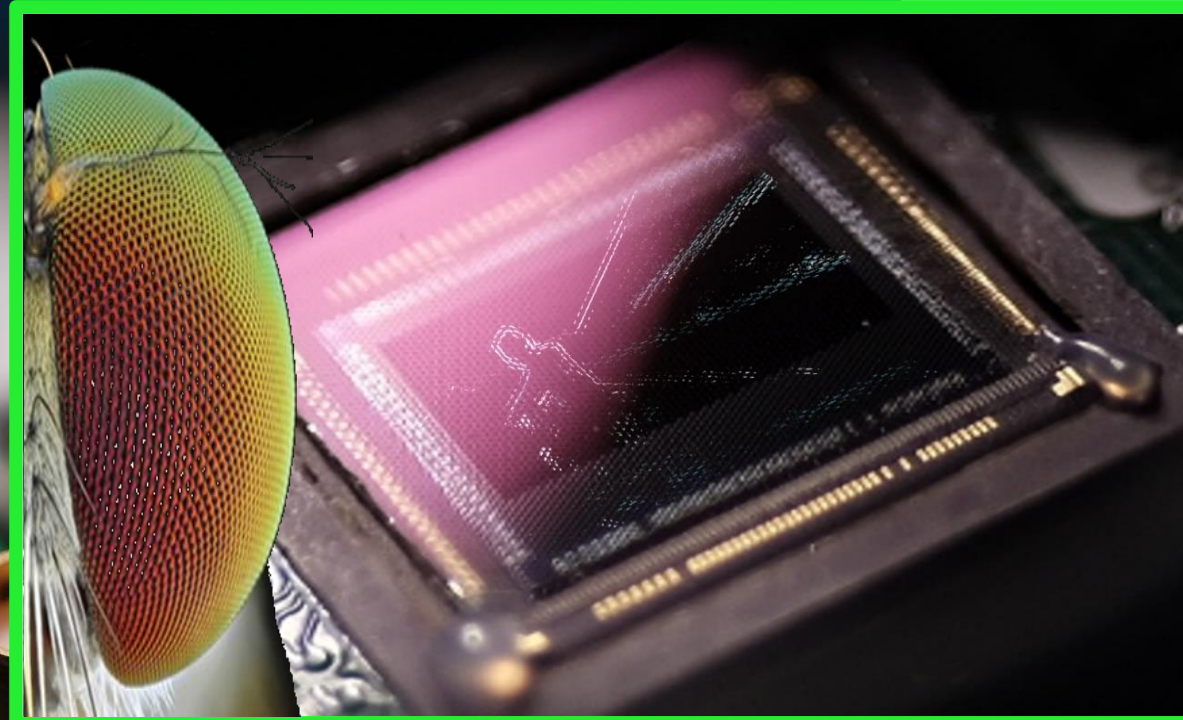
Computation/energy-intense: use of GPUs & no real-time

Our LF-DVSv1.0 PoF prototype.

Combines **efficiency of DVS** & **directional light capture** of light-field micro-lenses to achieve...

real-time, monocular, passive 3D perception with sub-ms latency!

... using
event-driven specialized accelerator
(currently in design)

Full-fledged commercial components	**Prophesee-Sony IMX636 & Raytrix micro-lens array** (1 microlens = 26 pixels diameter)
Operational range (optics-dependent)	PoF: 1 m; **expected: 10 m**
Depth accuracy	**~tens of mm**
Energy budget	Sensor**:** 10 mW Processing: few **tens of mW** with specialized event-driven accelerator
Latency	PoF: 6 ms; **expected: sub-ms**
Resolution	Near-VGA: **640 x 360 pixels**

Our LF-DVSv1.0 PoF prototype works!.

Raw events

Sub-aperture

Depth-map
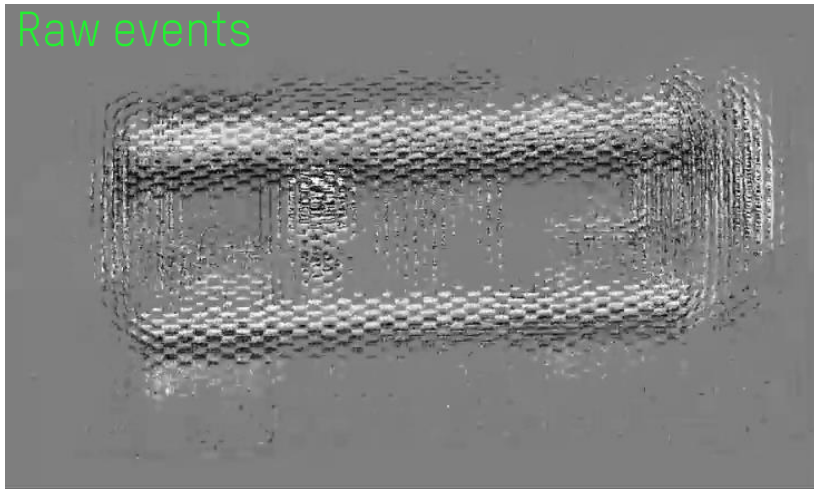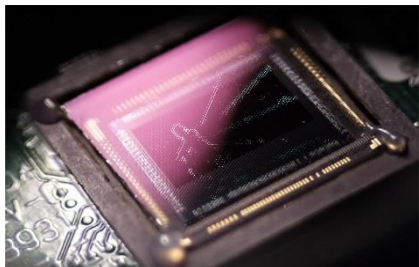
LF-DVS
events

x,y

z

Adapted Raytrix LF algorithms for frame-based sensors,
applied to time-surfaces created with BEGI-filtered LF-DVS events
(running on **GPU: 25% comp. & 75% comms → 160+ fps**)

Designing an ultra-efficient event-driven accelerator integrated in Degi
& LF-DVSv2.0 to extend the operational range and accuracy

SDK support for LF-DVS.
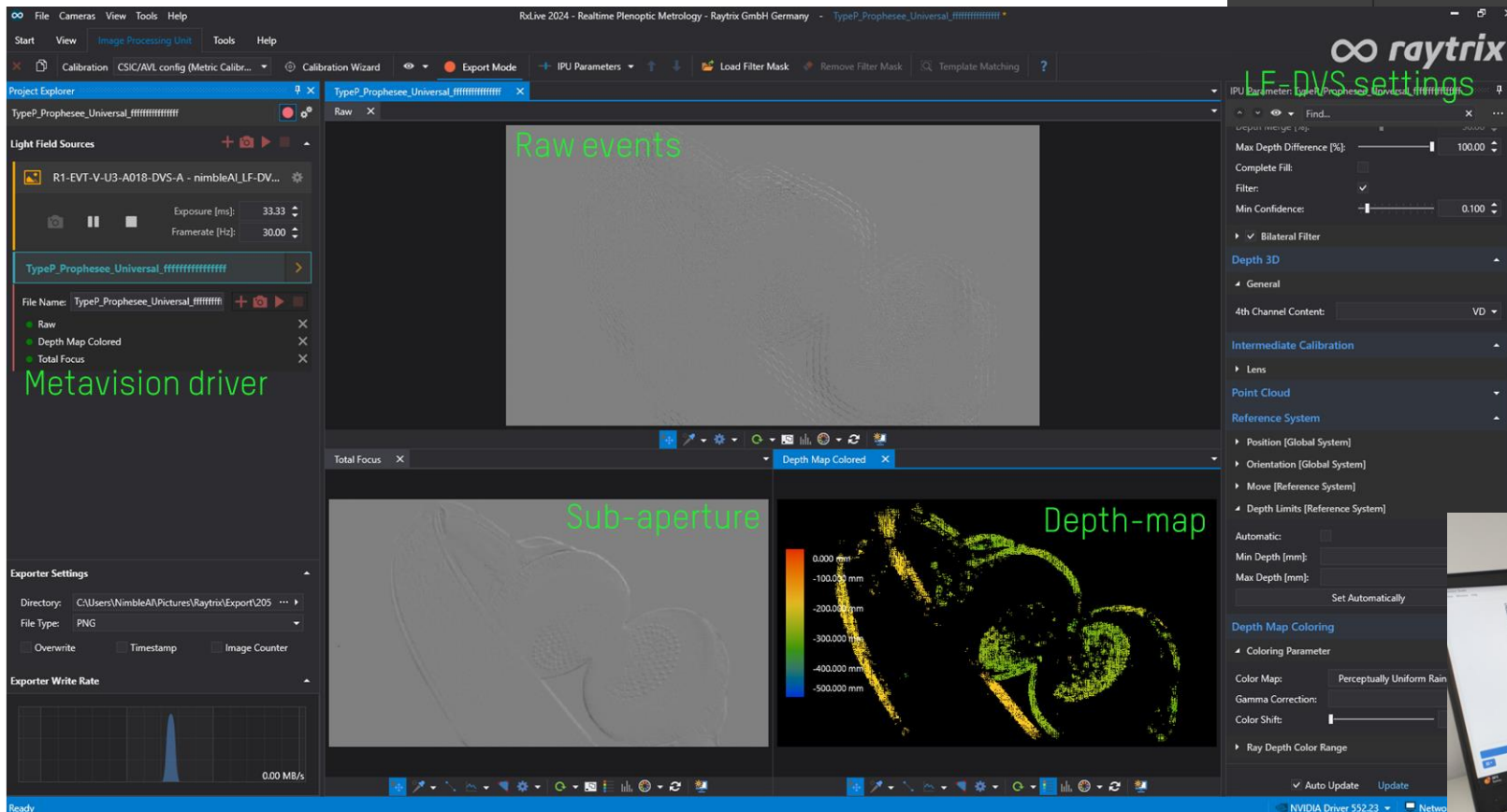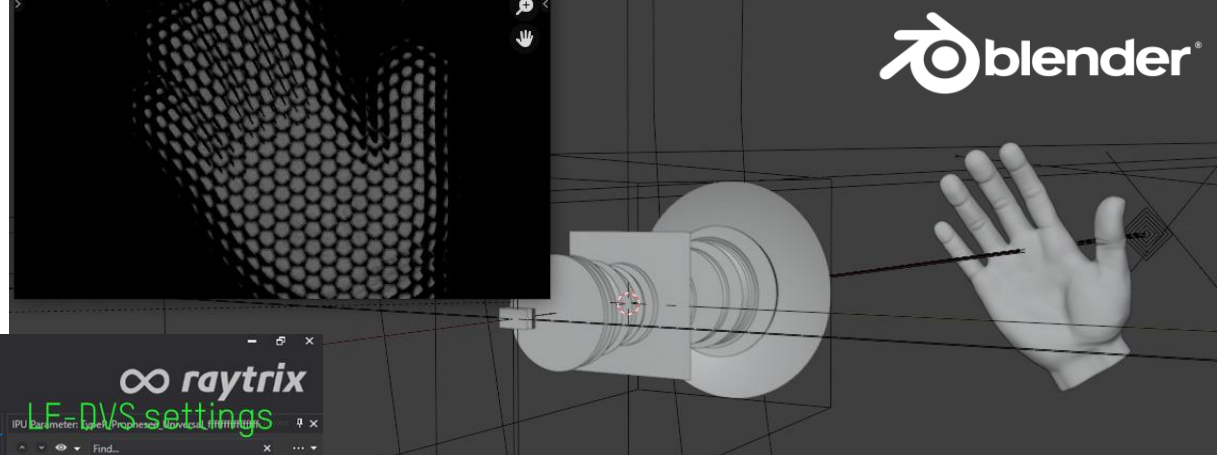
Blender LF and DVS models combined to generate synthetic event flows & ground truth in scenes with controlled motion and lighting conditions

Integrated in Raytrix RxLive with plugin for Prophesee Metavision and support for GPUs
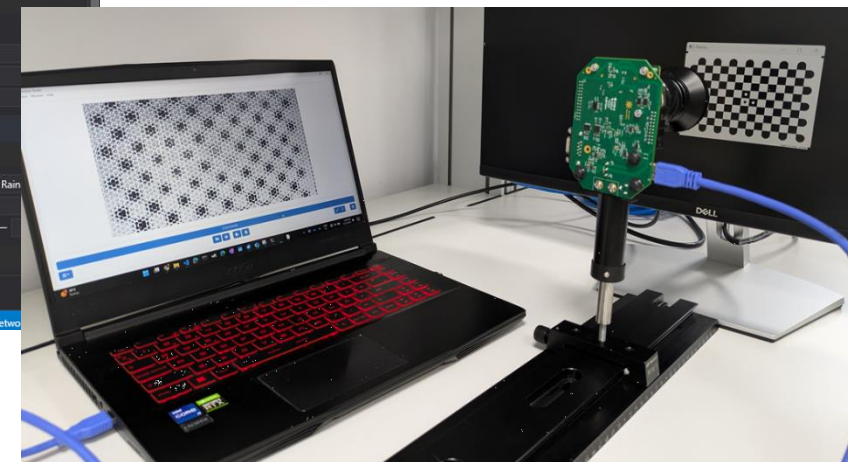
Support for automatic sensor calibration

Potential of LF-DVS & Roadmap.

✓ 2024:PoF

2025: FPGA-based BEGI prototype available for LF-DVS

2026/27: Optimized BEGI silicon available for LF-DVS

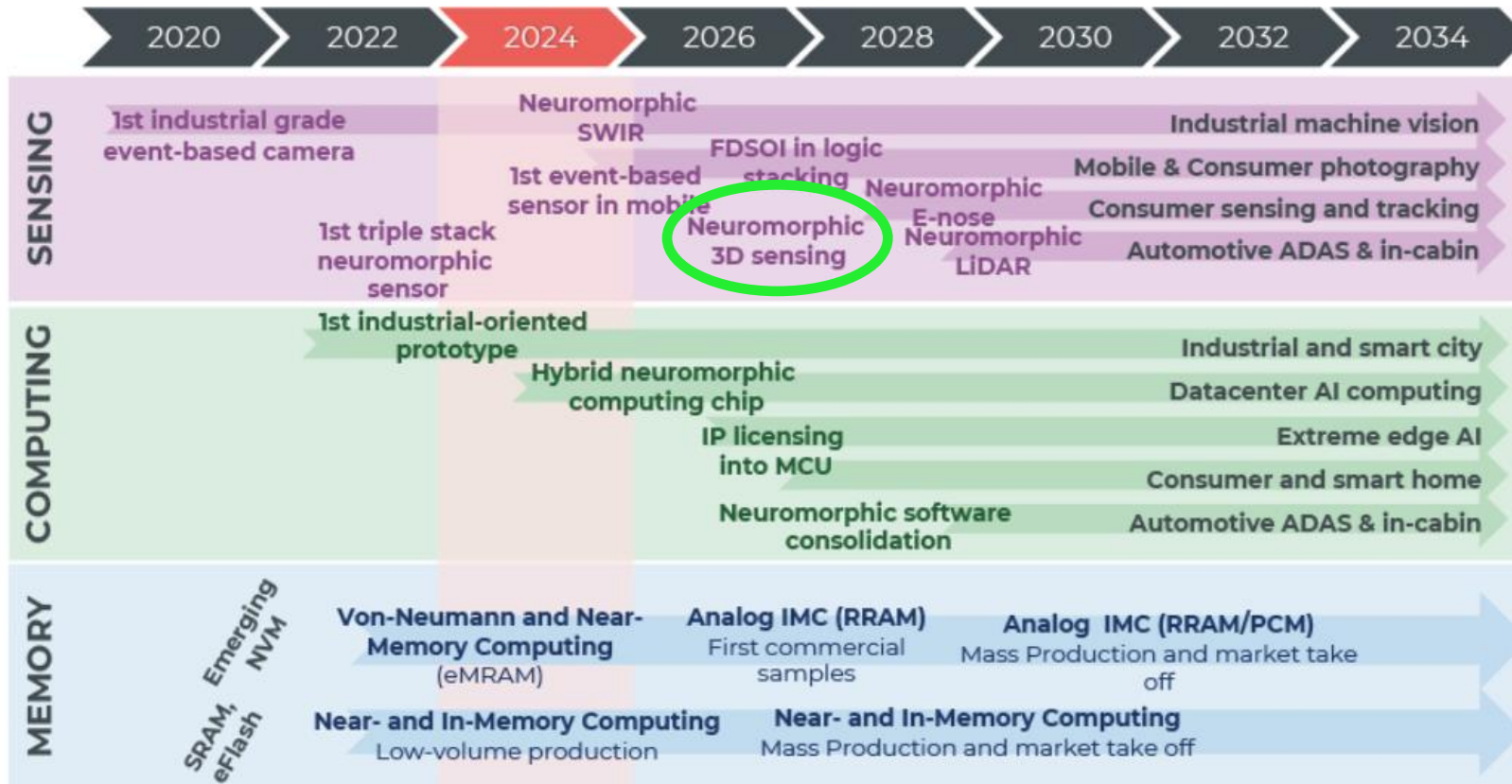*(Source: Neuromorphic Computing Memory and Sensing 2024, Yole Intelligence, April 2024)*

https://www.yolegroup.com/product/report/neuromorphic-computing-memory-and-sensing-2024

yole Intelligence

| 2020 | 2022 | 2024 | 2026 | 2028 | 2030 | 2032 | 2034 |

SENSING
- 1st industrial grade event-based camera
- Neuromorphic SWIR
- 1st event-based sensor in mobile
- 1st triple stack neuromorphic sensor
- FDSOI in logic stacking
- Neuromorphic 3D sensing
- E-nose Neuromorphic LiDAR
- Industrial machine vision
- Mobile & Consumer photography
- Consumer sensing and tracking
- Automotive ADAS & in-cabin

COMPUTING
- 1st industrial-oriented prototype
- Hybrid neuromorphic computing chip
- IP licensing into MCU
- Neuromorphic software consolidation
- Industrial and smart city
- Datacenter AI computing
- Extreme edge AI
- Consumer and smart home
- Automotive ADAS & in-cabin

MEMORY
- Emerging NVM
- SRAM, eFlash
- Von-Neumann and Near-Memory Computing (eMRAM)
- Analog IMC (RRAM) First commercial samples
- Analog IMC (RRAM/PCM) Mass Production and market take off
- Near- and In-Memory Computing Low-volume production
- Near- and In-Memory Computing Mass Production and market take off

OVERVIEW   TABLE OF CONTENT   DESCRIPTION   COMPANIES CITED

ABR, Accenture, Adesto Technologies, Aistartek, AI Storm, Alibaba, Alpsentek, Amazon, Ambarella, Ambient Scientific, AMD, AMT, Analog Inference, Anotherbrain, Antaïos, Apple, Applied Materials, ARM, Aryballe Technologies, Aspinity, Avalanche Technology, AWS, Axelera AI, Axis, Azure, BAE Systems, Baidu, Blumind, BMW, Bosch, BrainChip, Canon, CEA, Celepixel, Ceva, Cogito Instruments, Crossbar, d-Matrix, Dahua, Dialog, DTS, Empatica, ESA, Facebook, Fraunhofer, Fullhan, General Vision, GlobalFoundries, Google, Gorilla, GrAI Matter Lab, Groq, HPLabs, Gyrfalcon Technology, Hikvision, HLMC, Hprobe, Huawei, IBM, IMEC, Infineon, IniLabs, iniVation, Innatera, Insightness, Intel, Kalray, Knowm, Lenovo, Leonardo DRS, Lynxi, MediaTek, Mentium Technologies, Meta, Microchip, Micron, Mythic, NASA, Natural Intelligence, Nepes, Neurxcore, Nimble AI, Northrop Grumman, Numem, Numenta, Nuvoton, Nvidia, NXP, Oculi, Omnivision, Oppo, Opteran, Polyn Technology, Prophesee, Qeexo, Qualcomm, Quantum Ventura, Rain AI, Raytheon, Renesas, Robosensing, Samsung, SCD, Schneider Electric, Sensigent, Sigmastar, Smartnvy, Smartsens, SMIC, Socionext, Soitec, Sony, Snap Inc, Space Machines Company, Spin Ion Technologies, SpinEdge, STMicroelectronics, Summer Robotics, SynSense, Synthara, Syntiant, TDK, TetraMem, Tiandy, TSMC, Ultraleap, UMC, Uniview, Untether AI, Visionchip, Vision Research, Voxel Sensors, Weebit, Witmem, Xiaomi, Xperi, and more...

BEGI-powered lightweight UAVs...

Near-VGA LF-DVS processing chips consuming tens of mW
available for integration into miniature drones in 2026/27
(enable sub-ms 3D SLAM and 3D flow)

Begi

https://www.flir.com/products/black-hornet-4/

Thank you

Ready to co-design LF-DVS for your needs or help launch Degi?

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