TeSI FastICPix – final presentation

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The FastICPix – TESI Team

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Content

- Identification of areas with potential for high interest in FastICPix technology
- Specific applications inside mentioned areas to demonstrate social and economic impact
- Fields where FastICPix will likely have limited potential applicability
- Detailed information on found insights, interviews with experts, all relevant resources as well as contact details are included in the full report

Initial problem identification

FastICPix

- 2/3 Technology Readiness Level product
- Commercial applications
- R&D partnerships
- Funding

TeSI

- Social impact maximisation

Task

- Gather insights from industry to align FastICPix specifications with identified needs (idea screening, concept testing)
- Build comprehensive report and collect contact leads that will allow the project to move forward

We went through a process guided by Design Thinking and rigorous research in order to deliver actionable insights

Discover	Define	Develop	Deliver
Explore the possible & define ambition	Idea Screening & Concept Testing to develop Specs of applications for B2B	How can we draw attention to FastICPix?	How can we make FastICPix a reality
Find applications for FastICix	Confirm applications with Experts in the field	Develop a prototype that demonstrates the use	Develop an actionable insights gathered from research

In an unprecedented time, we had to put in one or the other additional Zoom meeting

- People contacted: 73
- E-mails sent: +150
- Hours worked: +780h
- Academic papers read: 54
- Days from beginning to end: 96
- Zoom / Hangouts calls made: ~30
- Intensive 2-day weekend sessions: 4
- Notes and resources collected on Google Drive: 1GB

Photon detection technologies

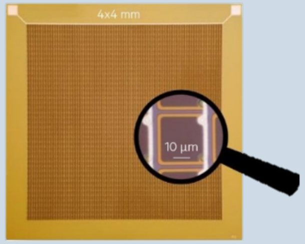
Amplification of Signal with Photomultipliers

Advantages

1. Using Photomultiplier Tubes

✓Scalable Sensor Area
✓Lower capacitance
✓Better sensitivity for different spectra
✓Better resolution

2. Using Silicon Photomultipliers



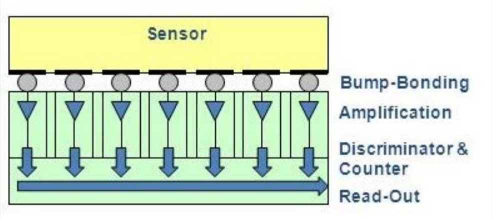
✓Higher PDE (Fill Factor)
✓More compact and robust
✓Lower bias voltage
✓Insensitive to magnetic field
✓Accurate photopeak resolution
✓Better time resolution

Only for small sensor areas!

What is FastICPix?

Implementation

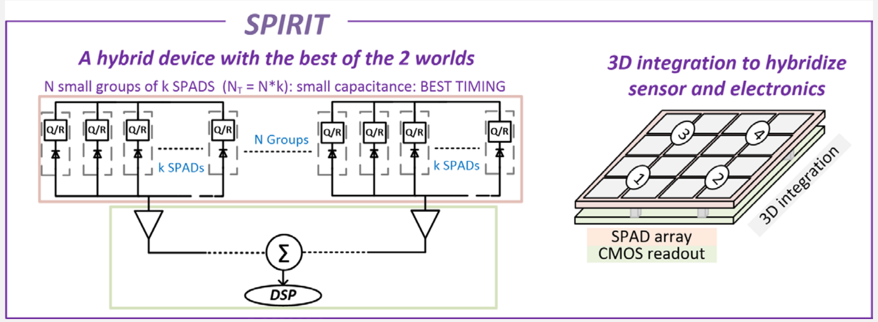
“New hybrid single photon sensor”



“Sandwich” of sensor with very short connections to the read-out chip.

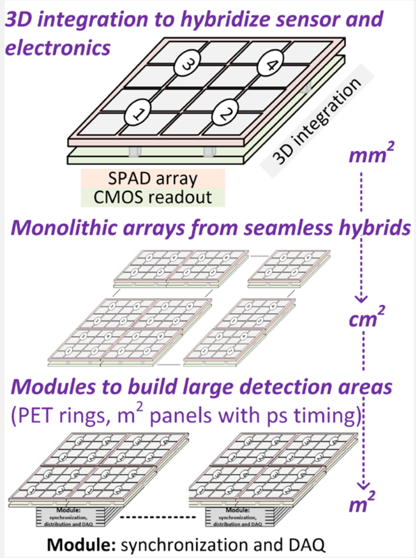
Sensor Concept

“Exploit optimal segmentation”



Active combination ***of small micropixel sub-arrays*** with ***ultrafast readout*** electronics (≤ 65 nm) using ***3D integration***

Adaptability and Scalability



FastICPix 3D integration of readout electronics and sensing area creates multiple key advantages over existing solutions

picosecond time resolution

adaptable & reconfigurable design

scalable sensor area without compromising performance

Low power consumption

High saturation threshold

Opportunities for FastICPix

LIDAR

FLIM

Mass Spectrometry

Opportunities for FastICPix

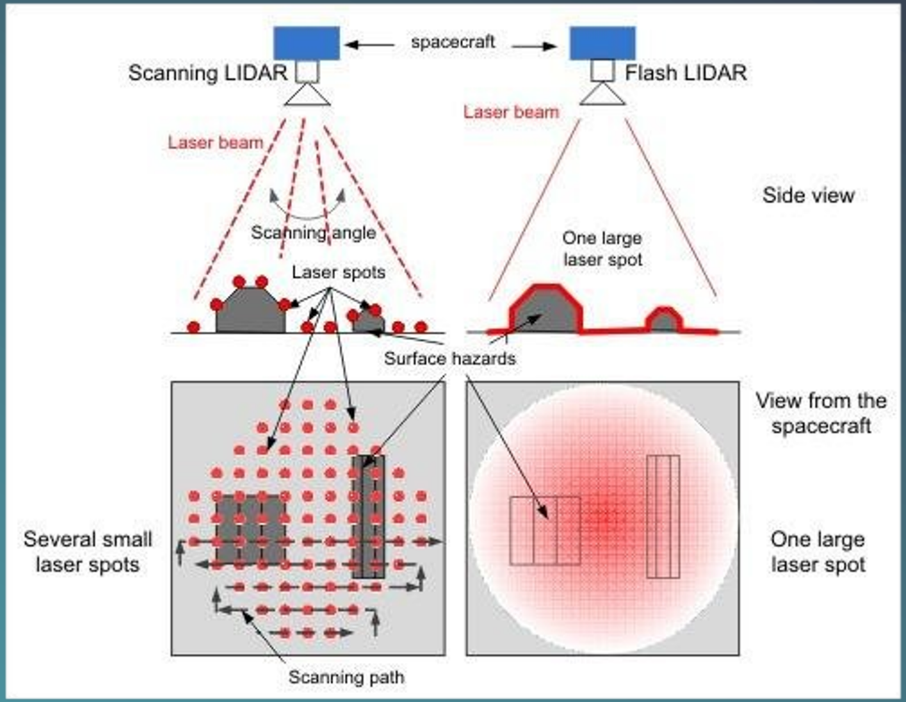
LIDAR

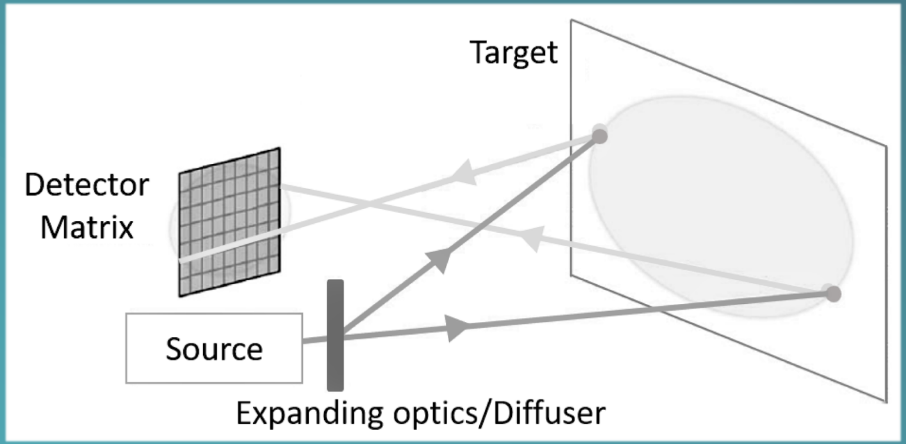
FLIM

Mass Spectrometry

LiDAR – FastICPix applications

- Flash Lidars – biggest potential for FastICPix
- Consultation with Professor Royo
- FastICPix advantage lies in scalability: potential large sensing area without loss of performance
  - ➢ Benefits: better time resolution, less tolerance in optics (consequent savings on costs)
- Dead time should be limited for FastICPix to be competitive solution





FastICPix with potential to significantly reduce costs of LiDAR systems in automotive industry

LiDAR in automotive highlights

Real time 3D collision avoidance, autonomous navigation, adaptive cruise control, hazard detection awareness

Bottleneck: cost of current LiDARs

FastICPix: large sensitive area, less lenses needed

To be verified: Compatibility of dead time with real world retro-reflectors

Autonomous driving market size: forecasts of 740,000 autonomous ready vehicles to be added in 2023 alone

→ multiple cameras on each driving car

Up to 90% decrease in fatalities by removing human error

Reduction in traffic jams and fuel emissions

Opportunities for FastICPix

LIDAR

FLIM

Mass Spectrometry

"Relevant for specific FLIM techniques"

Consultation with Experts

- Prof. Klaus Suhling, Kings College London

FastICPix Value Added

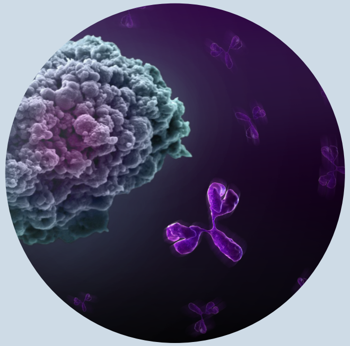
- Sensor area and time resolution not of highest importance
- Some techniques could benefit from the performance of FastICPix

FastICPix Applications

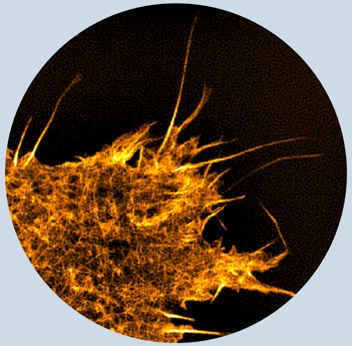
- Low illumination applications (eg. photosynthesis studies)
- Total Internal Reflection Fluorescence Microscopy
- Lightsheet Fluorescence Microscopy

These techniques are used for relevant applications

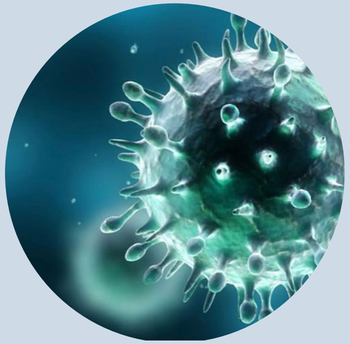
Immuno-oncology



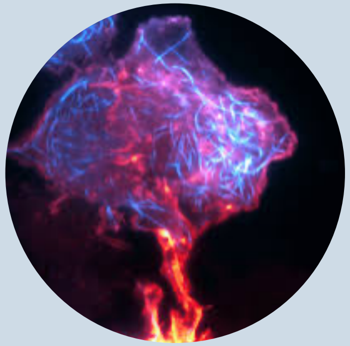
Neuroscience



Immunology



Live Cell Imaging



Opportunities for FastICPix

LIDAR

FLIM

Mass Spectrometry

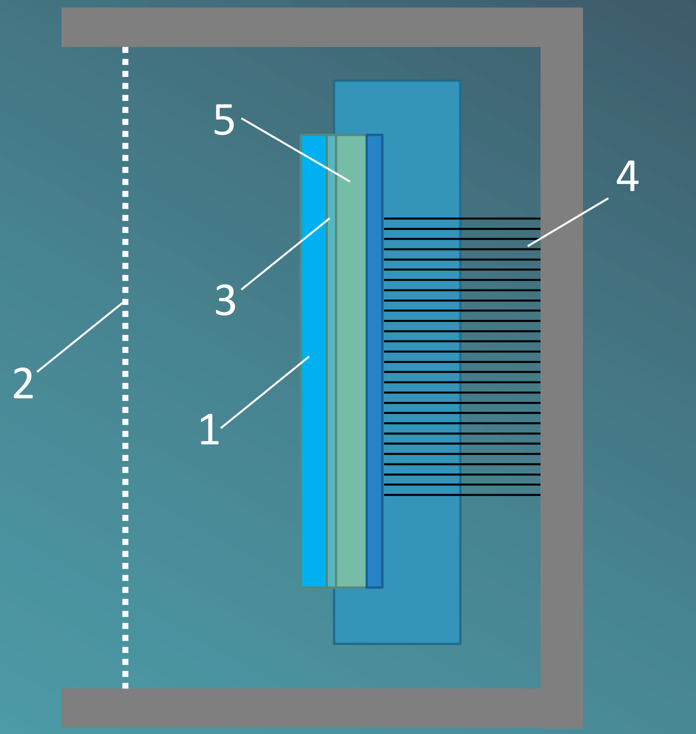
TOF MS – FastICPix

Consultation with Claire Vallance and Benjamin Winter

Coupling FastICPix sensor with a scintillator

Benefits of FastICPix

- Robustness (pressure resistance)
- Compact design and no need for vacuum
- Potential to avoid use of Microchannel Plate
- Improved detection accuracy
- Better mass resolution
- Shorter analysis time without sacrificing spatial resolution



1. Exalite Scintillator
2. Grounded grid
3. Charged Surface
4. Electrical Connections
5. FastICPix

Ambient Mass Spectrometry Imaging with FastICPix offers great potential in tissue diagnostics as it could improve the mass specificity, mass sensitivity & time of diagnosis

- Capability to image thousands of molecules in a single experiment without labelling or staining.
- Ability of FastICPix to operate under atmospheric condition enables minimal sample pre-treatment
- Improvements of signal-to-noise ratio, mass specificity and mass sensitivity
- Reduction in time to get results as it allows to capture the mass to charge ratio of the whole area
- Ability to reduce the size of the apparatus could allow *in-situ* or in doctor's office applications

These Improvements are directly playing into the hands of a growing histopathology market

$33 billion

Market size of anatomic pathology

6.1% CAGR

Growing focus of personalized medicine

Areas found incompatible with FastICPix

1

Quantum Random Number Generation

Dr. Lazaro (UPC) and Dr. Pruneri (ICFO)

Analog outputs from APD sensors, not compatible with digital SPAD readouts

FastICPix may find applications where QRG is obtained with photons

2

Multicore Fiber Optical Communications

Dr. Lazaro (UPC)

Optical communication use APDs in receiver end, hence FastICPix's SPADs are not compatible technology

3

Optical Coherence Tomography

Lucio Robledo (Haag Streit)

OCT works with analog APDs receivers, not digital SPADs outputs

The road ahead: two pathways

FastICPix
Standalone Solution

FastICPix
as part of a system

I. Multi-purpose sensor with pico-second time resolution and scalable sensor area

FastICPix
Standalone Solution

FastICPix
as part of a system

FastICPix as a standalone solution

- Standalone solution of a Photonsensor
- Licensing usage or selling of sensor technology to industry and independent researchers
- Produce versions of the sensor focusing on different aspects (time-resolution, spatial resolution, etc.)
- Gain awareness through competitions or research-agreements to counter Hamamatsu's overwhelming presence in academic literature

II. Early adaptions to specific use cases

FastICPix
Standalone Solution

FastICPix
as part of a system

FastICPix as part of a system, requires an ecosystem of partners

For each usecase, FastICPix is part of a larger architecture

Therefore you need to partner with experts in the respective fields

Find suppliers of the other parts and manufacturers for the final product

Build a finished prototype

Market the technology to the right Industry partners

Key Takeaways we want to share

Talking to Academia is hard – Talking to industry is harder

80%

Time spent on technology understanding

Multidisciplinarity was an advantage

Tech. Discovery vs. Design Thinking

Q&A

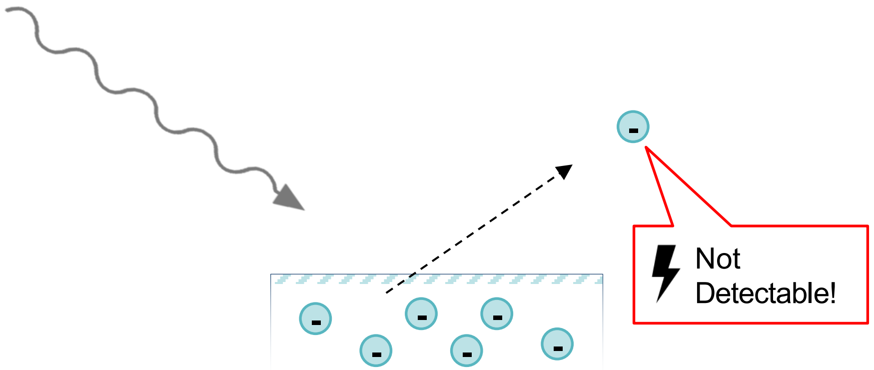
Thank you for your attention.

Back up library

Fundamentals of photon detection

Incoming Photon

Generation of primary electron using photoelectric effect



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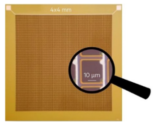

- ✓ Higher PDE (Fill Factor)
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- ✓ *Better time resolution*

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Fluorescence Lifetime Imaging Fundamentals

Fundamental Physics

- Fluorescence is the emission of light by a substance that has absorbed light
- Molecules remain in an excited state prior to returning to the ground state by emitting a photon
- In FLIM the time that a molecule remains excited (time until photon is emitted) is measured and the information used to build an image
- The decay time is dependent on the molecule type, thus FLIM delivers a picture where molecules can be identified

Applications

- Local environment sensing
- Detection of molecular interactions
- Detection of conformational changes
- Discrimination of multiple labels or background removal
- Tissue characterization by autofluorescence

Essential Components

- Pulsed laser source (diode lasers or multi-photon excitation)
- Single photon sensitive detector
- Dichroic mirror (to separate fluorescence signal from excitation light)
- Objective (to focus the excitation light into the sample and collect fluorescence signal)
- TCSPC unit to measure the time between excitation and fluorescence emission