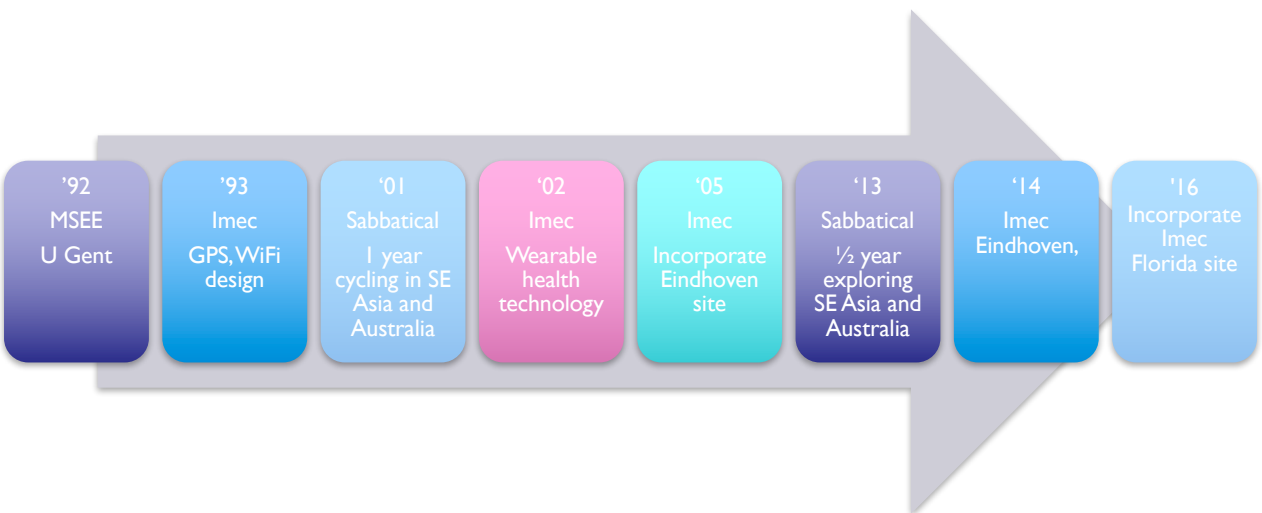




PHOTONICS IN THE MAGIC KINGDOM  
FAIRY TALES AND TALENT FAIRS

BERT GYSELINCKX  
IMEC USA

BERT GYSELINCKX



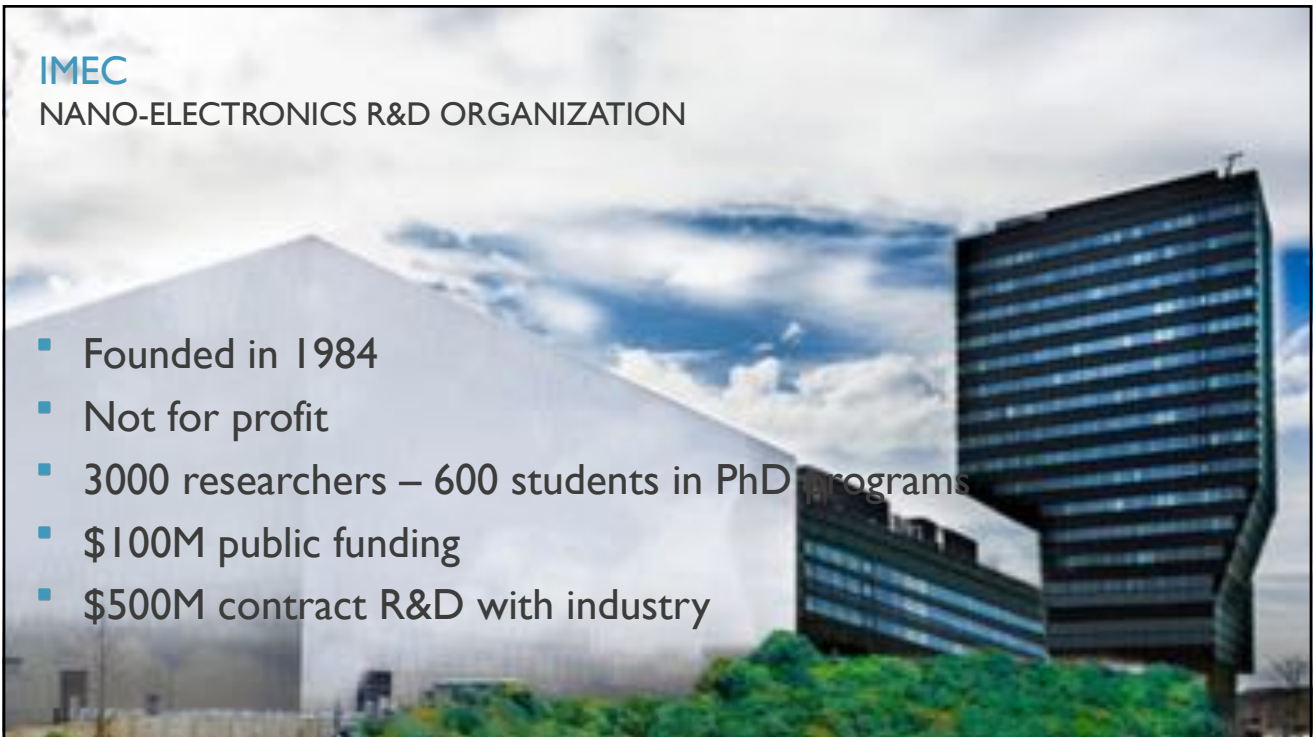




## IMEC

NANO-ELECTRONICS R&D ORGANIZATION

- Founded in 1984
- Not for profit
- 3000 researchers – 600 students in PhD programs
- \$100M public funding
- \$500M contract R&D with industry





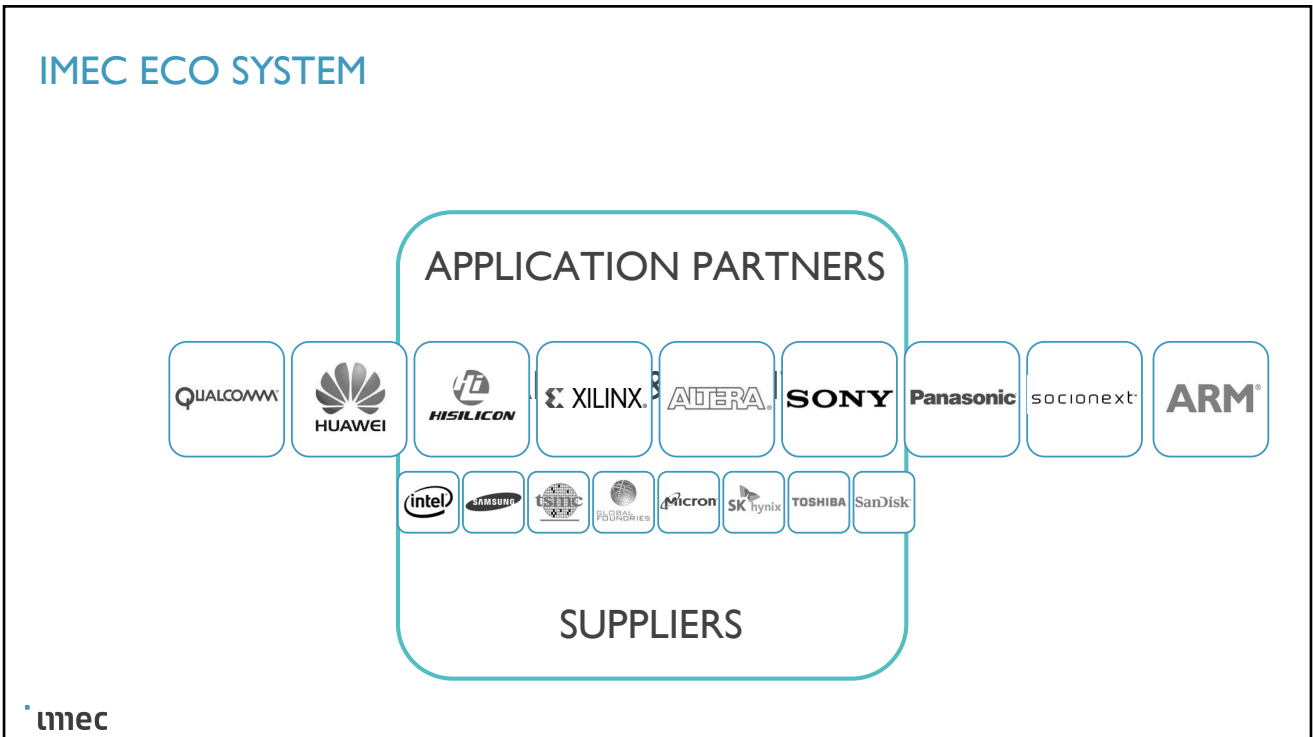
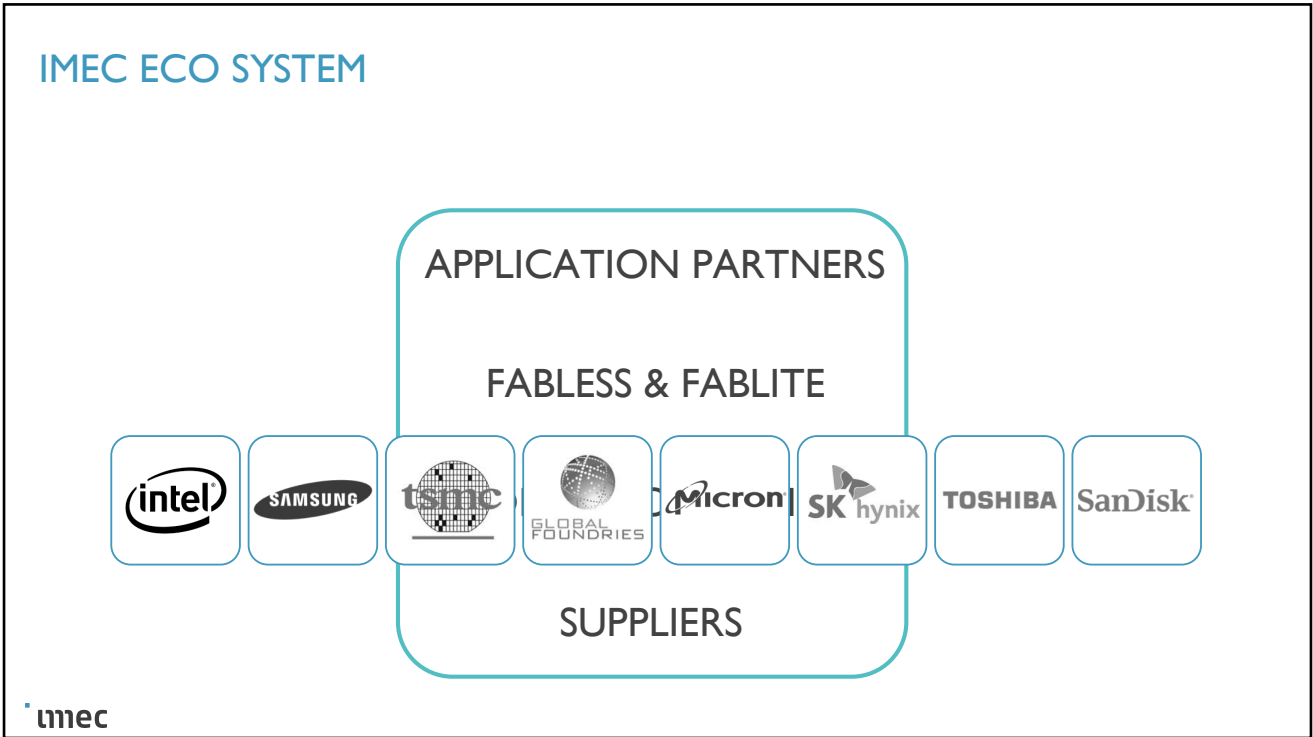
## IMEC ECO SYSTEM

APPLICATION PARTNERS

FABLESS & FABLITE

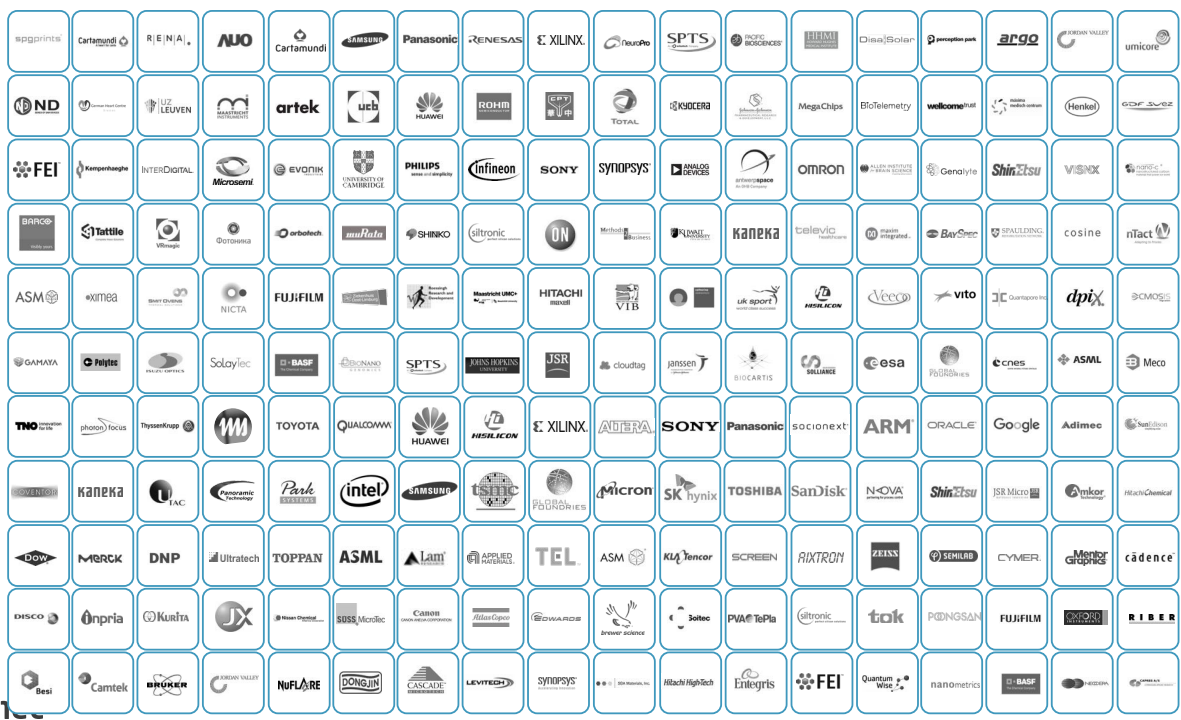
IDMS & FOUNDRIES

SUPPLIERS



# IMEC ECO SYSTEM

## APPLICATION PARTNERS








DESIGN CENTER  
FOR  
**HIGH FREQUENCY ELECTRONICS AND PHOTONICS**

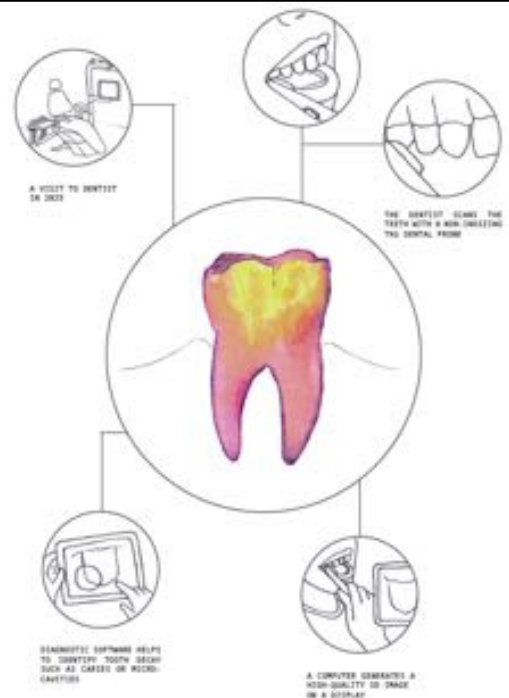


## THz DENTAL IMAGING PROBE

PART OF THE DENTAL INSTRUMENT SET, COMPLETING VISUAL INSPECTION



- Fully integrated handheld THz probe
- Targets early detection of tooth decay
- Non-ionizing imaging technique safe for regular use
- Generates a 3D high-quality image
- Characterizes material composition of tooth or decay




A VISIT TO DENTIST OR DENT

THE DENTIST SCANS THE TEETH WITH A NON-IONIZING THE DENTAL PROBE


DENTISTRY SOFTWARE HELPS TO IDENTIFY TOOTH DECAY SUCH AS CAVES OR MICRO-CAVITIES

A COMPUTER GENERATES A HIGH-QUALITY 3D IMAGE ON A DISPLAY

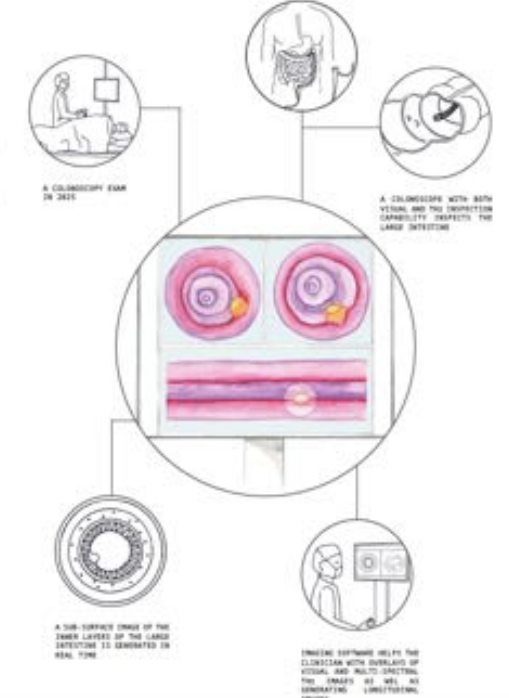


## MULTI-SPECTRAL THz COLONOSCOPY

A FIBER INTEGRATED THz SCANNER FOR INSPECTION OF THE LARGE INTESTINE



- Non-ionizing THz imaging
- Sub-surface imaging of the inner layers of the large intestine
- Analyzing the intestinal wall in a wide frequency range from 0.3 to 2THz
- Fully integrated with visual camera allowing visual and THz image fusion




A COLONOSCOPY EXAM IN DENT

A COLONOSCOPE WITH BOTH VISUAL AND THE INSPECTION CAPABILITY INSPECTS THE LARGE INTESTINE

A SUB-SURFACE IMAGE OF THE INNER LAYERS OF THE LARGE INTESTINE IS GENERATED IN REAL TIME

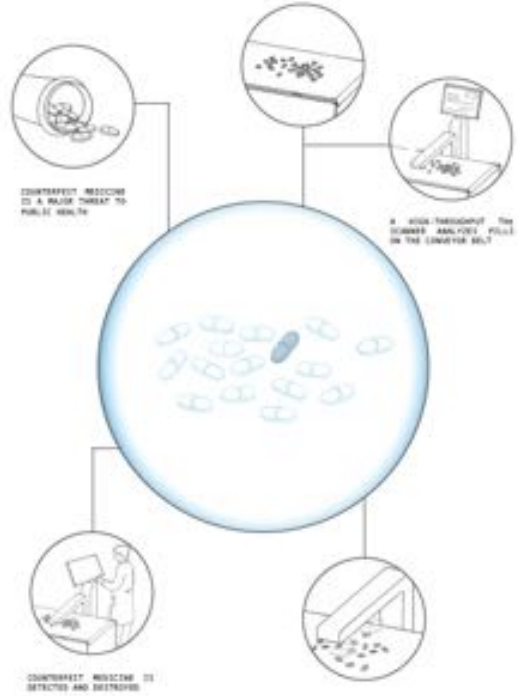
PROBING SOFTWARE HELPS THE CLINICIAN WITH OVERLAY OF VISUAL AND MULTI-DIRECTIONAL THE IMAGES TO GET AN INTEGRATING CORRELATING IMAGES



### PHARMACEUTICAL COUNTERFEIT DETECTION A THz SCANNER FOR INLINE INSPECTION OF PHARMACEUTICAL PRODUCTS



- Powerful but non-ionizing Thz source
- Linear Thz detector array that is able to support high speed throughput
- Analyzing the sample in a wide frequency range from 0.3 to 3THz
- Affordable system thanks to newest semiconductor technology.

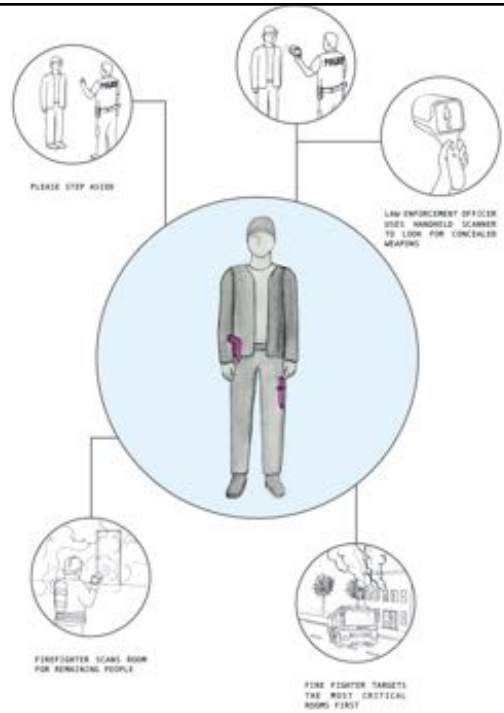


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### STANDOFF DETECTION HANDHELD STANDOFF DETECTOR FOR FIRST RESPONDERS AND LAW ENFORCEMENT



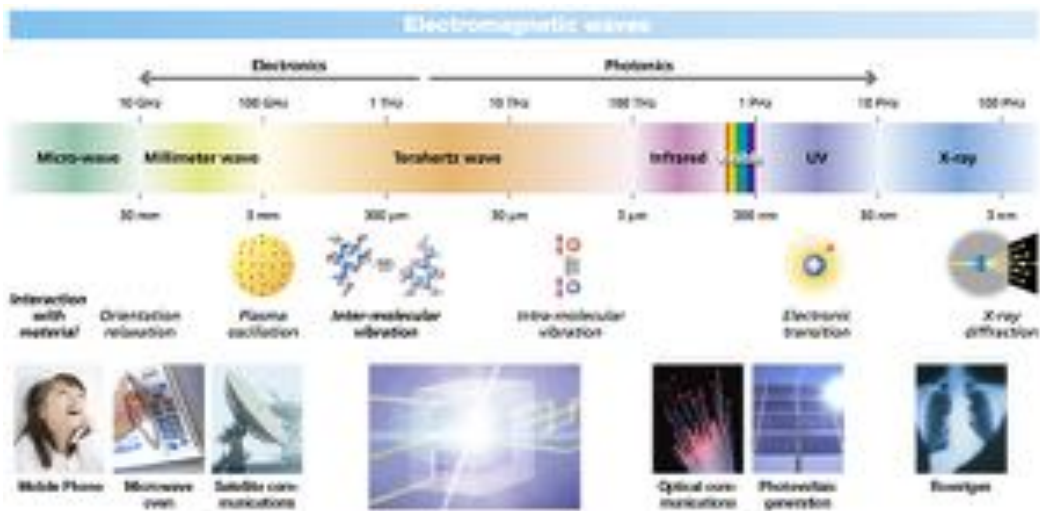
- Fully integrated handheld scanner
- Targets detection of hidden objects below clothes or behind walls
- Uses mm and THz waves
- Generates a basic image with sufficient resolution for detecting objects of interest



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# THz PHOTONIC INTEGRATED CIRCUITS

## THE TERAHERTZ DOMAIN AT THE JUNCTION BETWEEN ELECTRONICS AND PHOTONICS



Source: Advantest

### ADVANTEST 7500TS

THz WAVE SPECTROSCOPY AND IMAGING ANALYSIS PLATFORM

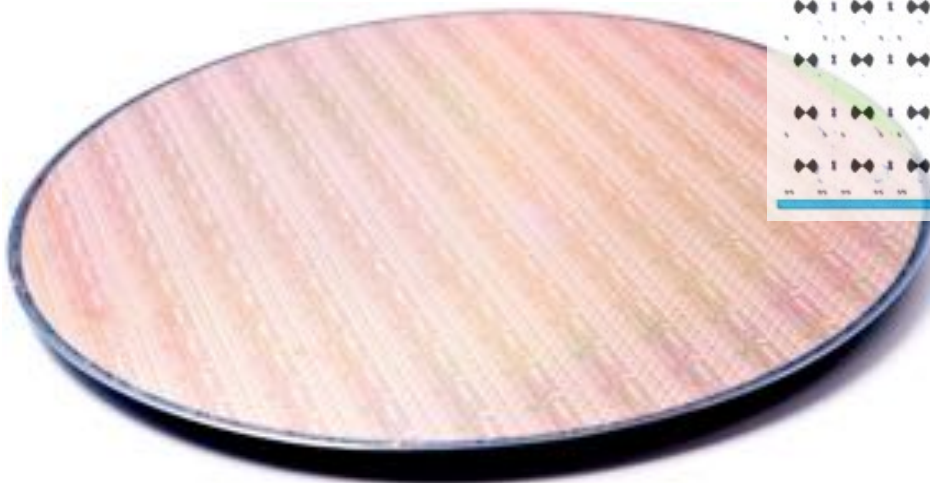


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### IMEC APPROACH

PHOTONIC INTEGRATION

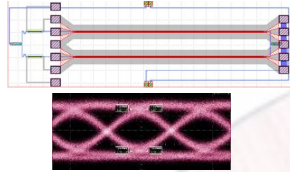


imec

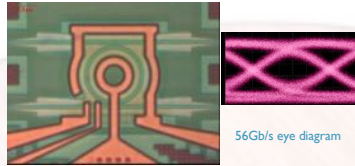
24

## IMEC'S Si PHOTONICS PLATFORM

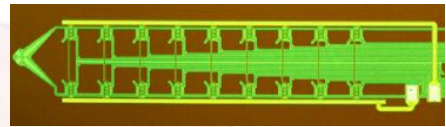
56G Silicon Mach-Zehnder Modulator



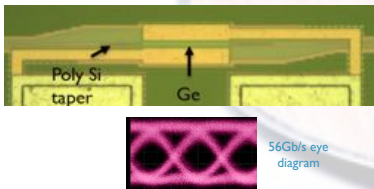
56G Silicon Ring Modulator



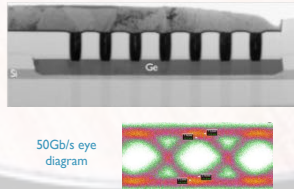
8+1-channel DWDM (De-)Multiplexing Filter



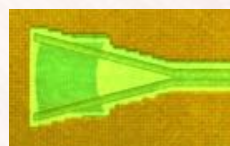
56G GeSi Electro-Absorption Modulator



50G Ge Photodetector



Grating Coupler



Edge Coupler



Philippe Absil et al. *Optics Express* 2015, 23(7), 9369–78.

## STATUS

### IMEC THZ IMAGING TECHNOLOGY



First scanned THz Image with imec emitter and Toptica detector



Scanning stage and optics



Two Toptica lasers



PCB + Batop silicon lens assembly



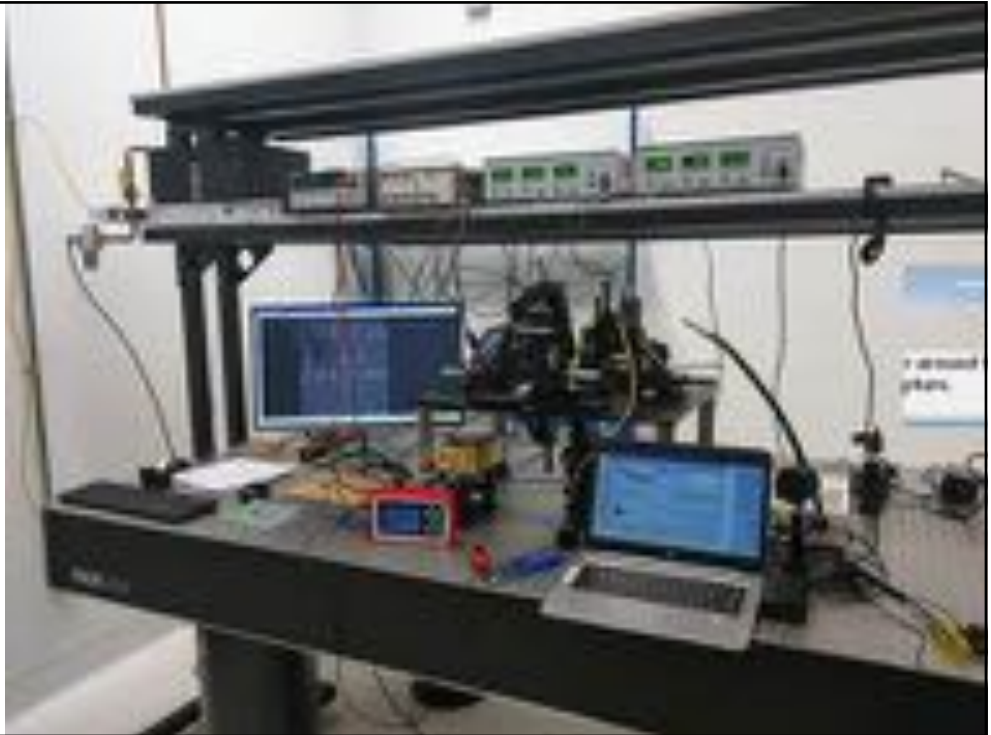
First single pixel photoconductive antennas on chip  
Second tape out with small 2D arrays in processing (June)



Imec Si Photonics with Ge option

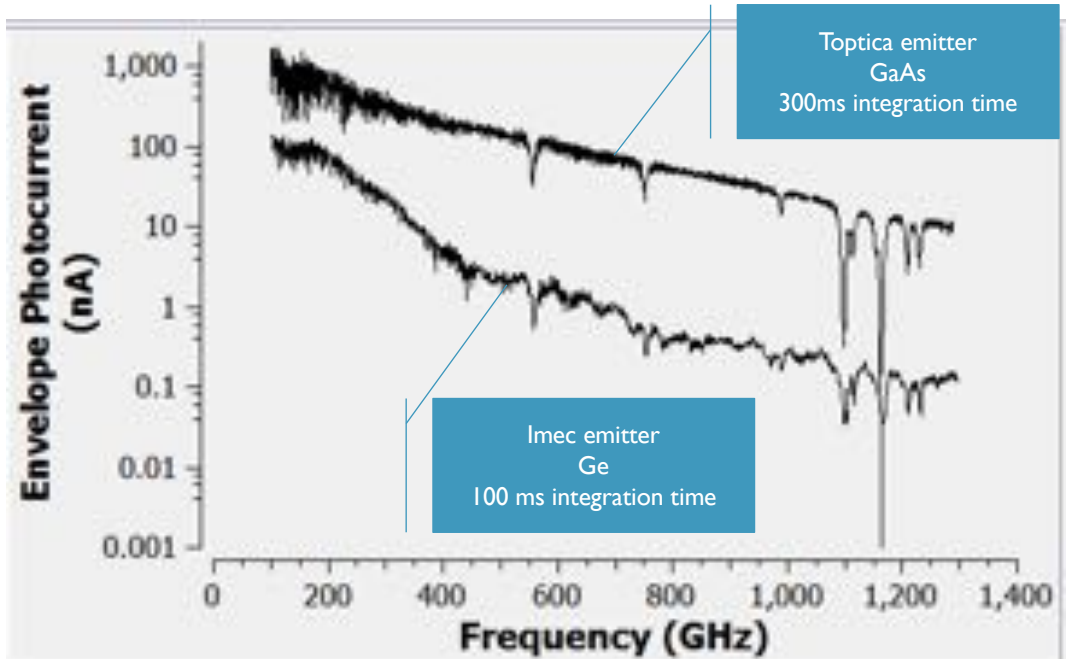


**STATUS**  
OPERATIONAL LAB



imec

**STATUS**  
EMITTER

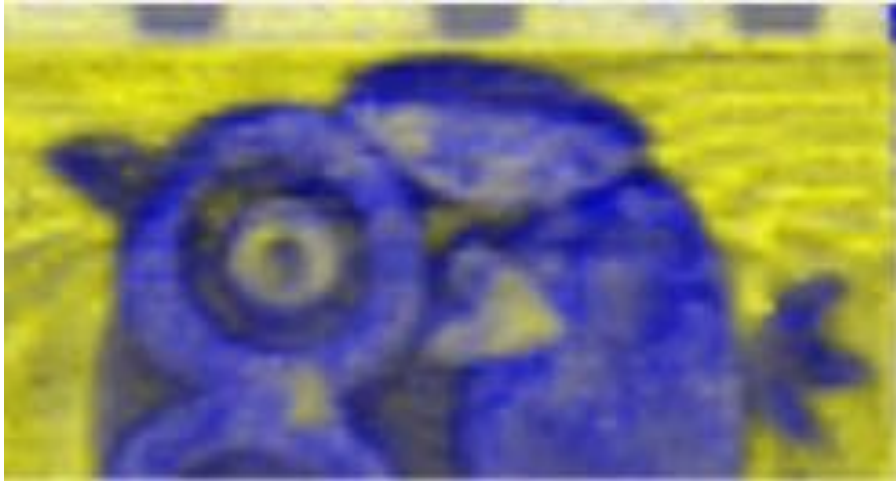


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### STATUS

THZ IMAGE WITH IMEC EMITTER AND OPTICAL DETECTOR

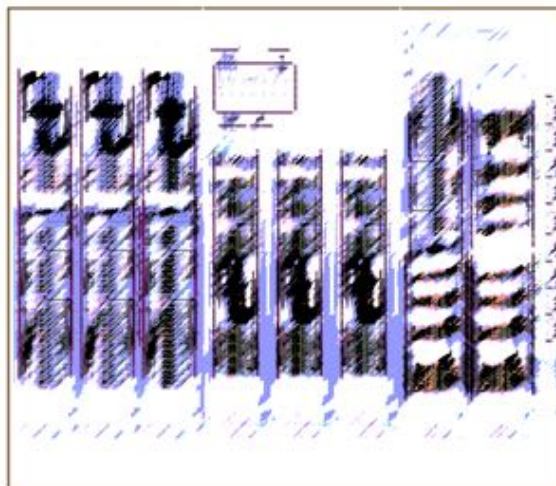


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### NEXT STEPS

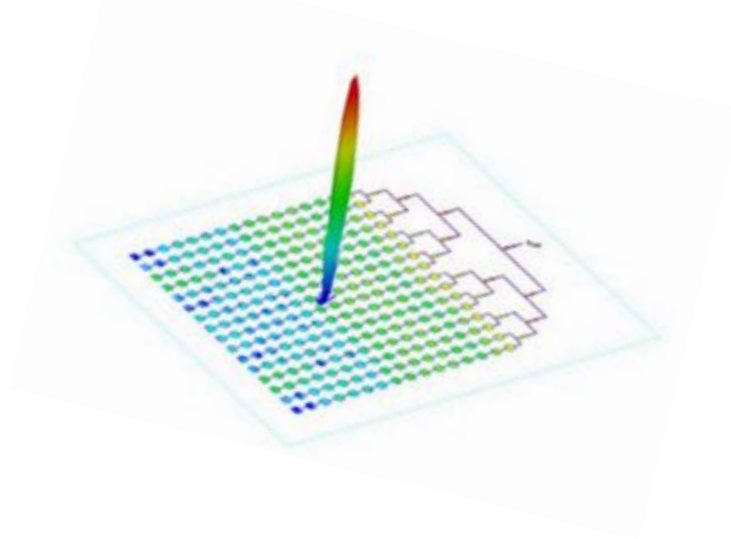
I.ARRAY ON PIC – EXPECTED SUMMER 2018



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## NEXT STEPS

### 2. BEAMFORMING THROUGH COUPLED PHOTOMIXERS

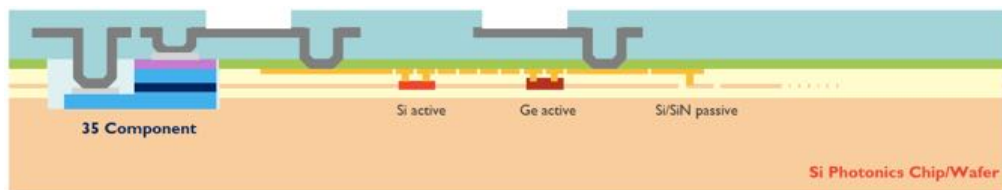


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## NEXT STEPS

### 3. LASER AND PIC INTEGRATION



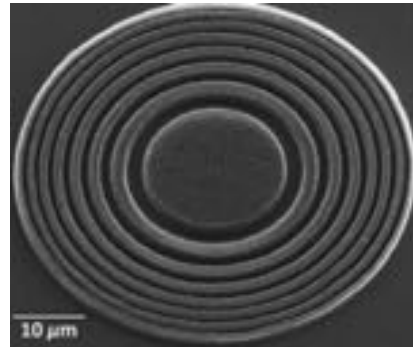
- PostDoc Alex Liles
- Collaboration with U Gent.

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## NEXT STEPS

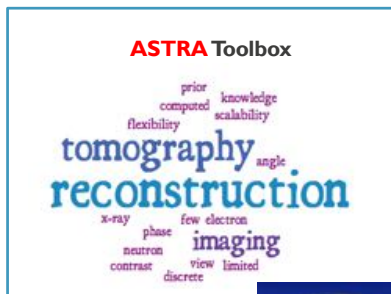
### 4. FRESNEL LENS ON CHIP



## NEXT STEPS

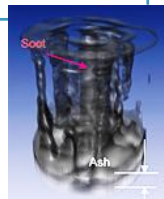
### 5. THZ TOMOGRAPHY WITH U ANTWERPEN

- **Goal:** Develop algorithms for 5D (3D volume + frequency + phase) terahertz tomography to enable imaging applications with imec hardware



#### imec spectrally coherent THz imager

- Steerable emitter array (fast scanning)
- Detector array: coherent, high SNR + phase information
- Integrated laser diodes: coherent excitation of emitter / detector



E.g. Non-Destructive Analysis of Ceramic Diesel Particulate Filters (Advantest)

# RF sensing and imaging

## mm-WAVE

### IMEC'S RADAR AND RF SENSING

ONE-STOP SHOP INCLUDING DATA FUSION, AND APPLICATION DEMOS

**New topic:**  
"Low-GHz RF sensing"

**Commercial products:**

- XETHRU
- vayyar.
- ANALOG DEVICES (ADF5904)
- ROHDE & SCHWARZ
- 30GHz ADI, ST, Infineon...
- Google Soli

**Applications:**

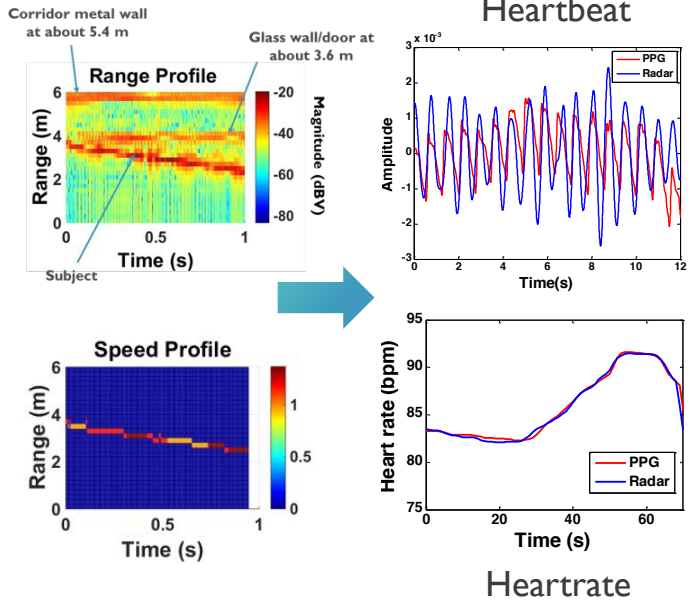
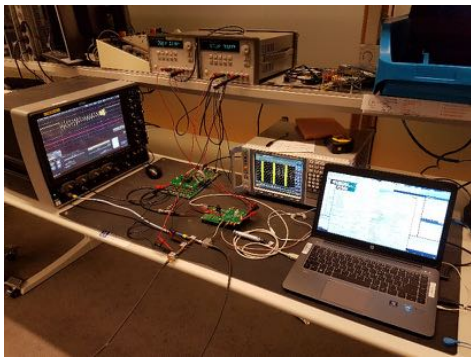
- Through-wall
- Respiration
- Occupancy
- Lighting
- Home & building automation
- Multicopter
- Robotics
- Smart cars

## LOW-GHz RF SENSING

### MEASURE HEART AND BREATHING RATE

Low-GHz radar prototypes

- 2.4GHz / 5GHz Doppler
- 7GHz FMCW



## 79 GHz CMOS SMART RADAR FOR AUTONOMOUS DRIVING

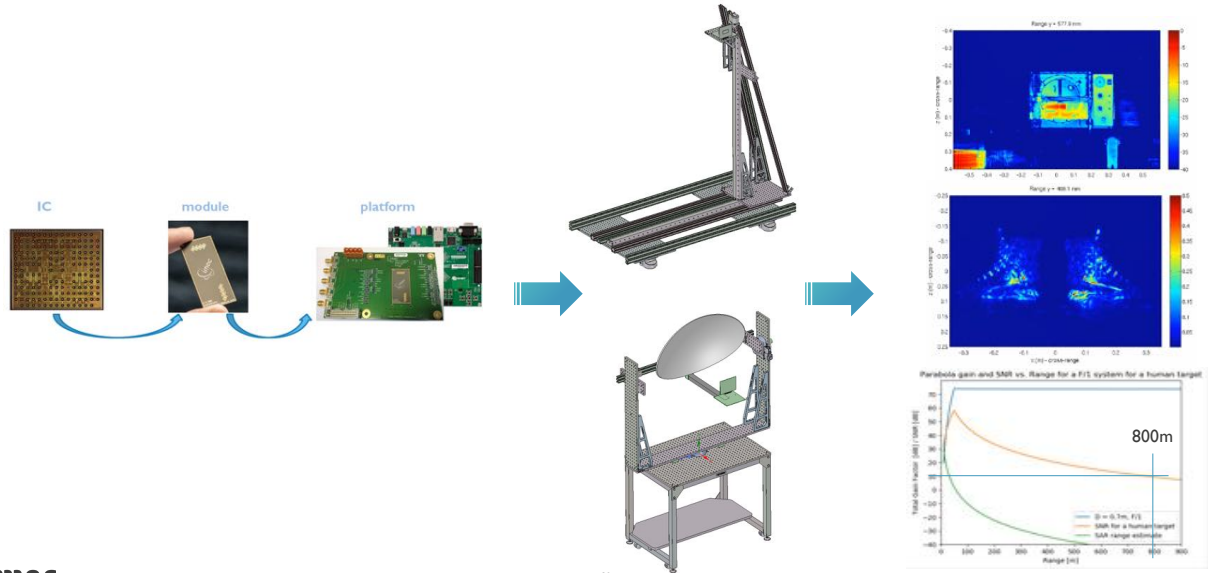
### COMPACT & PROGRAMMABLE

Front of module:  
4 transmit and 4 receive antennas  
in MIMO configuration

Back of module:  
2x 28nm CMOS radar SoC  
with 2 Tx and 2 Rx each



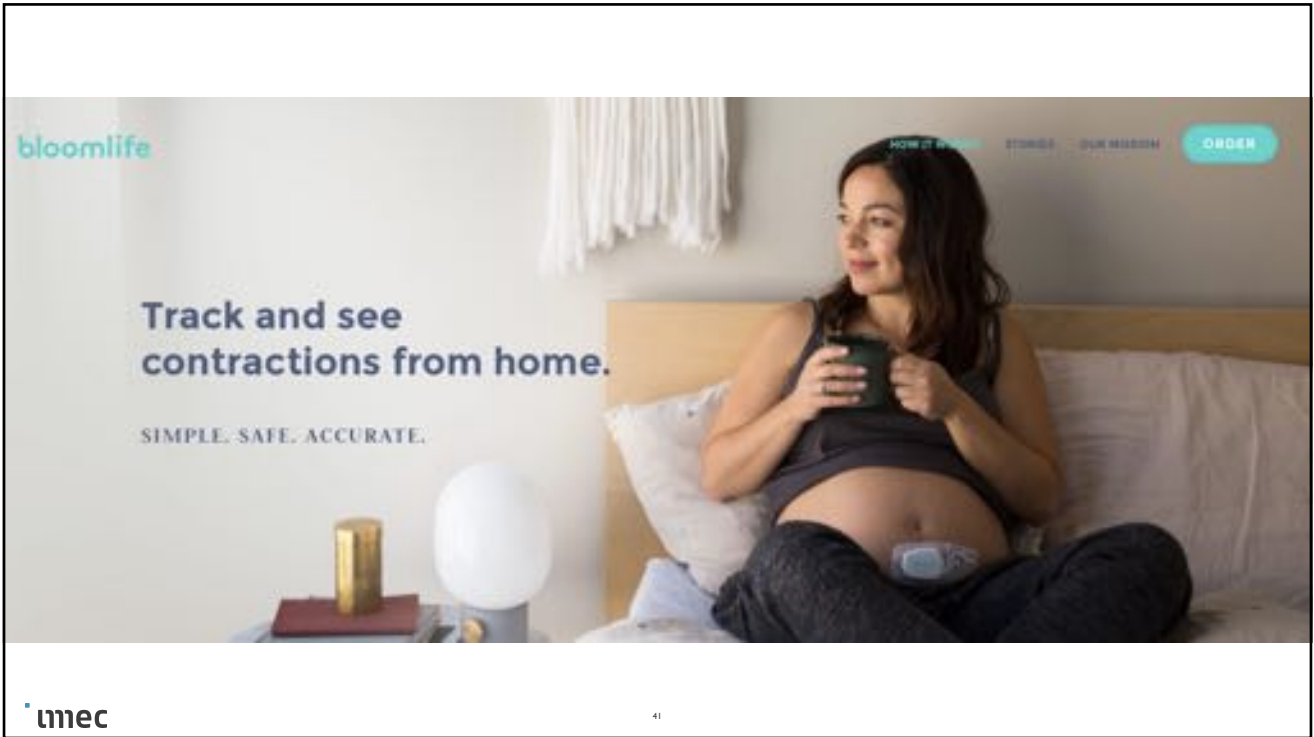
# mm-WAVE IMAGING TEST BEDS



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# VENTURING

40



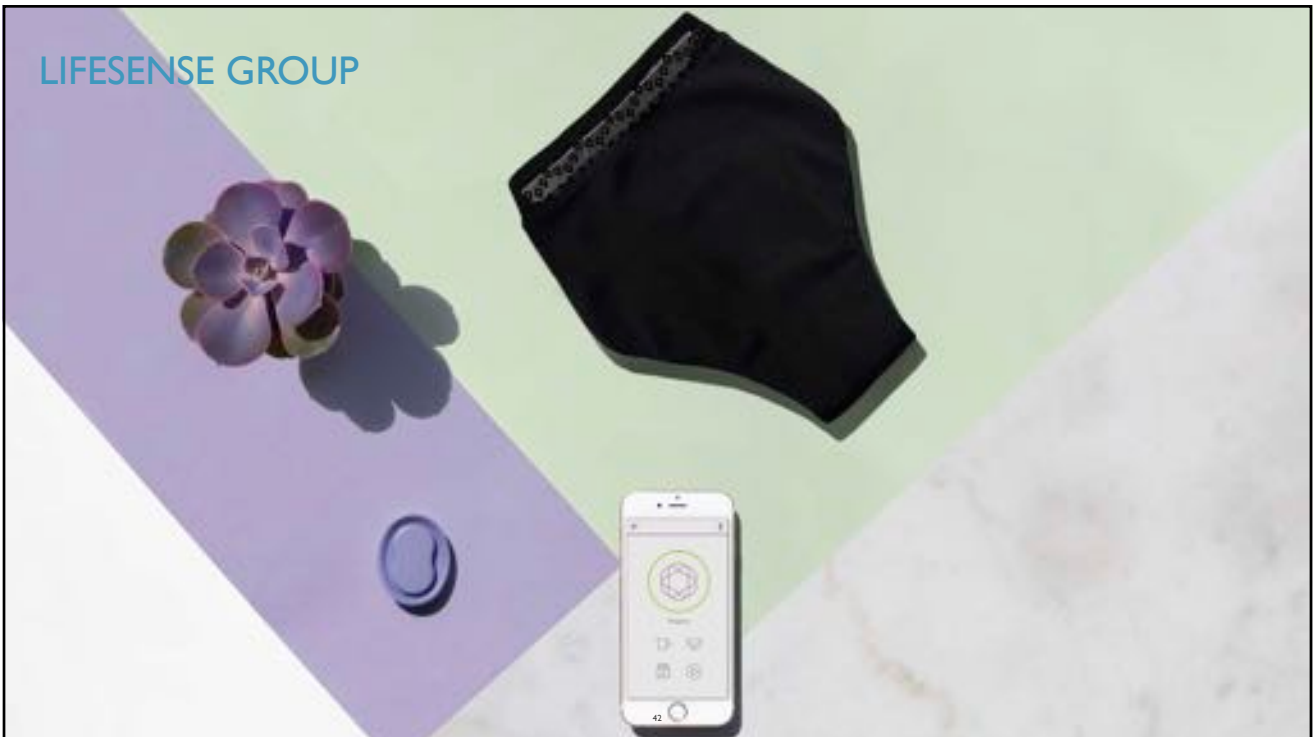
**bloomlife**    HOW IT WORKS    STORES    OUR MISSION    **ORDER**

**Track and see  
contractions from home.**

SIMPLE. SAFE. ACCURATE.

**imec**    41

The image shows a pregnant woman sitting on a bed in a bedroom, holding a smartphone. A small blue sensor is attached to her belly. The background includes a white lamp and a gold candle on a bedside table. The Bloomlife logo and navigation menu are in the top left, and the 'ORDER' button is in the top right. The main headline and sub-headline are centered on the left. The imec logo and the number 41 are in the bottom left corner.



**LIFESENSE GROUP**

The image features a purple orchid, a black sensor, and a smartphone on a background of purple, green, and white geometric shapes. The Lifesense Group logo is in the top left. The smartphone screen shows a circular interface with a green hexagon and several icons.

## WE ARE HIRING!

Payroll – PostDoc - PhD – internship



Computational imaging



Photonics design



Analog design



Digital design



Optical design



# JOIN THE FORWARD THINKERS



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## PROSTHETICS INTERFACES

POSTDOC MICROFABRICATION – POLYMER CHEMISTRY

# Faculty Cluster Initiative



APPLY  
NOW

OPEN  
CLUSTER  
POSITIONS

