MICRO LED ARRAY FOR SMART LIGHTING SYSTEM AND AUTOMOTIVE HEADLAMPS APPLICATIONS

PHOTONICS AT DOPT

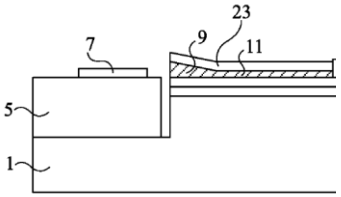
GaN LED ARRAY | Hani kanaan- BASEL | 12 /12/2016

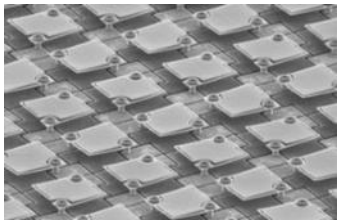
PHOTONICS AT DOPT

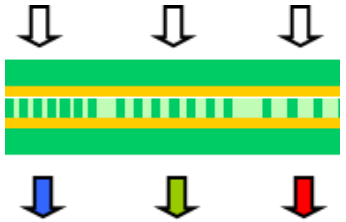
A FEW FIGURES

Created in 1978
300 researchers, engineers and PhD students

400 patents in portfolio
60 new/year







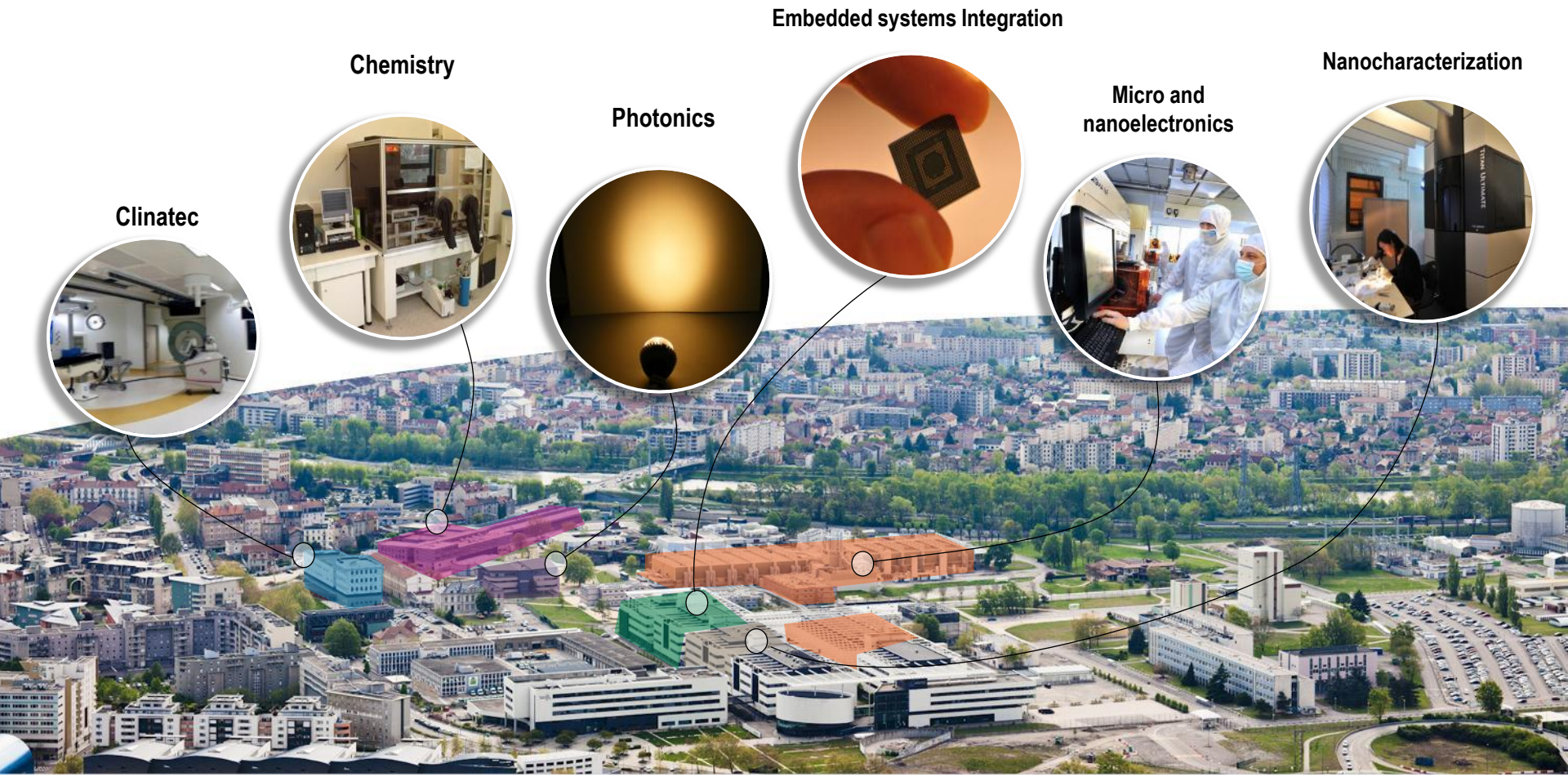
50-60 M€ budget
~10% for CAPEX

Dedicated clean rooms for III-V and II-VI materials on versatile substrate geometries up to 150 mm

Access to Leti clean rooms in 200 and 300 mm through many photonic processes and technology modules

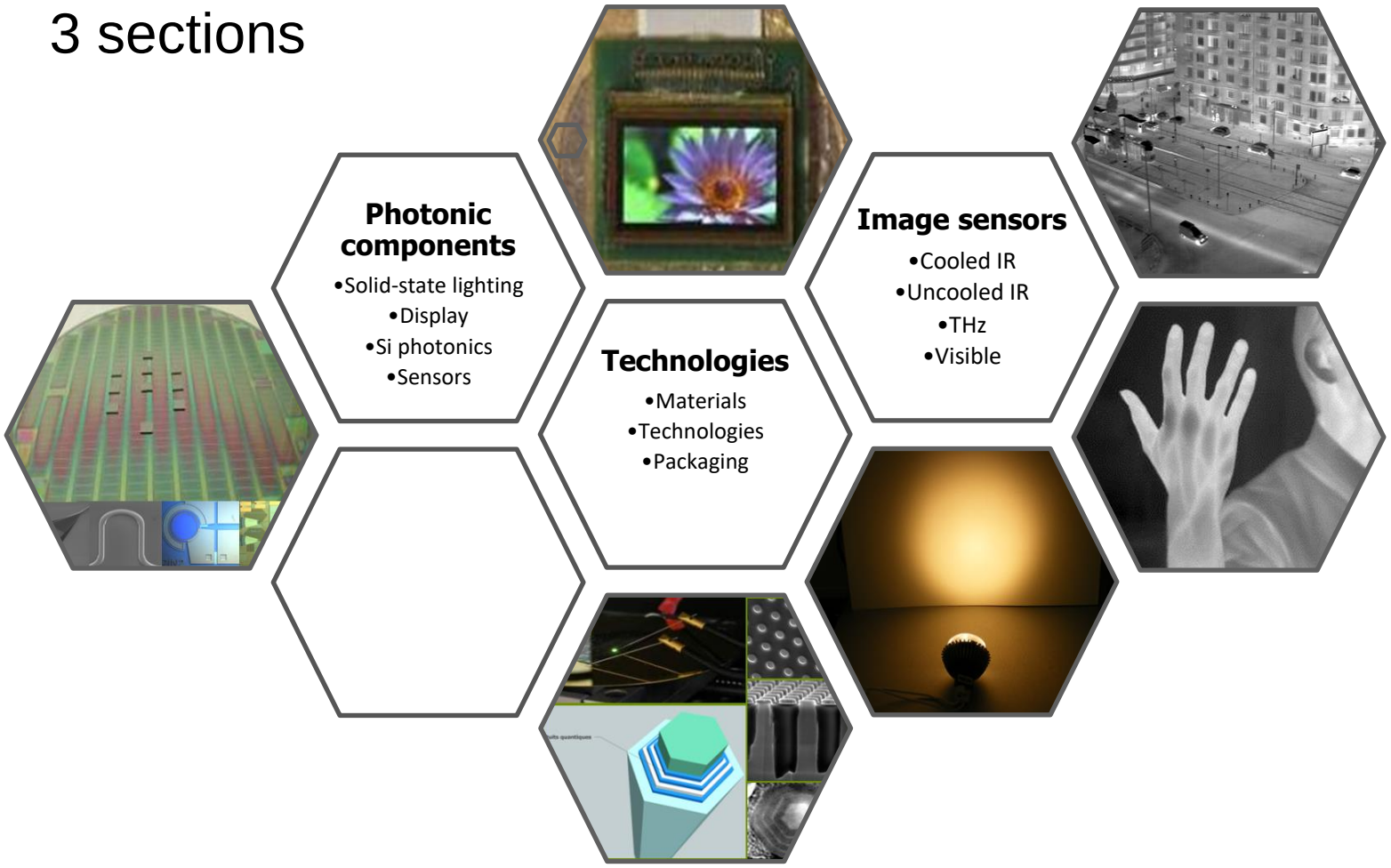
Electro-optical test and characterization facilities

RESEARCH PLATFORMS AT GRENOBLE



DOPT RESEARCH PROGRAMS

3 sections



Core competencies : component design and modeling, III-V and II-VI materials, fabrication technologies, characterization

SMART LIGHTING SYSTEM

What is ?

- lighting elements , detectors , electronics components , …

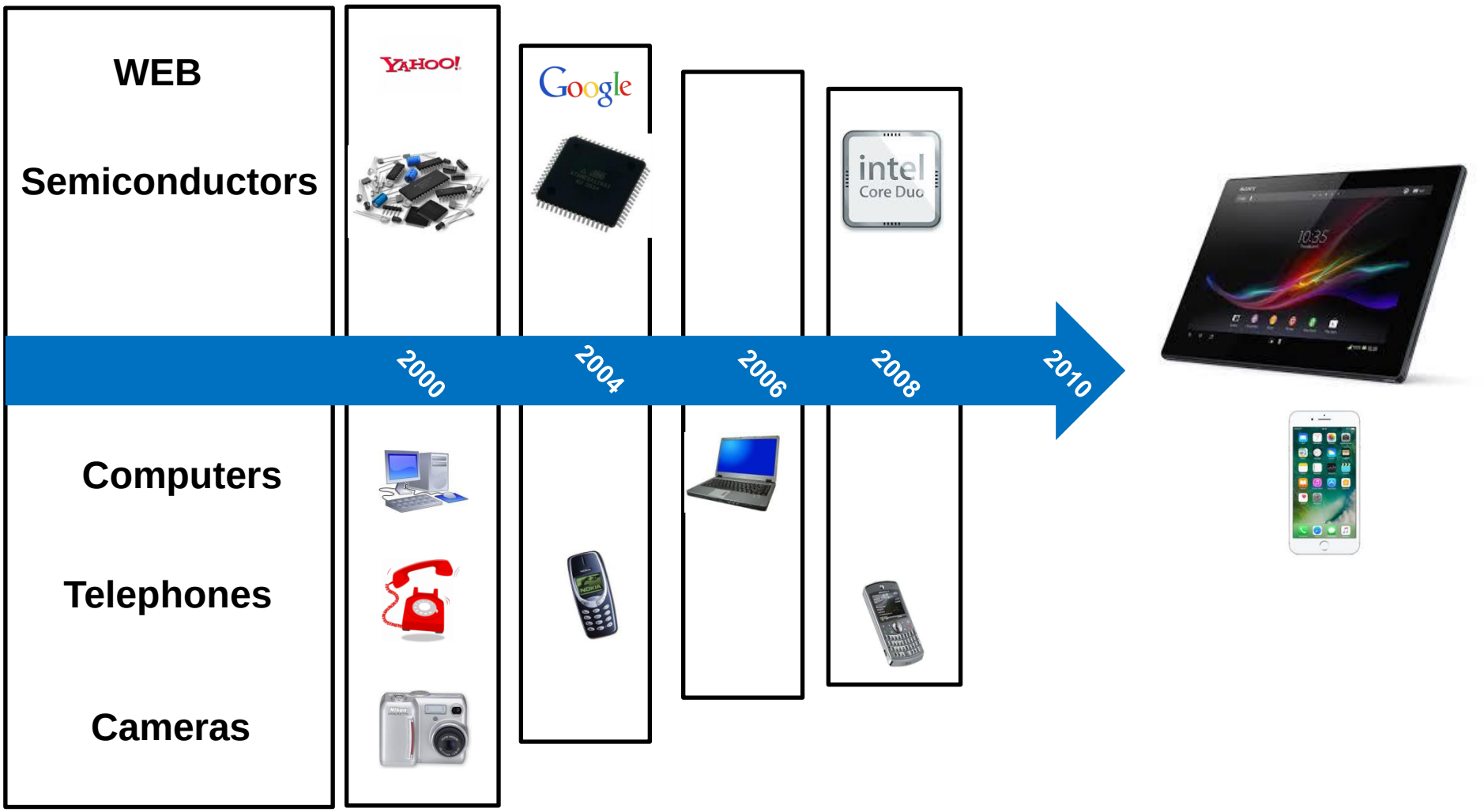
For what ?

- Automatic dimming, projection, daylight sensor, presence sensor, beam control, color control,
- cost reduction &/or functionality enhancement
- New business potential

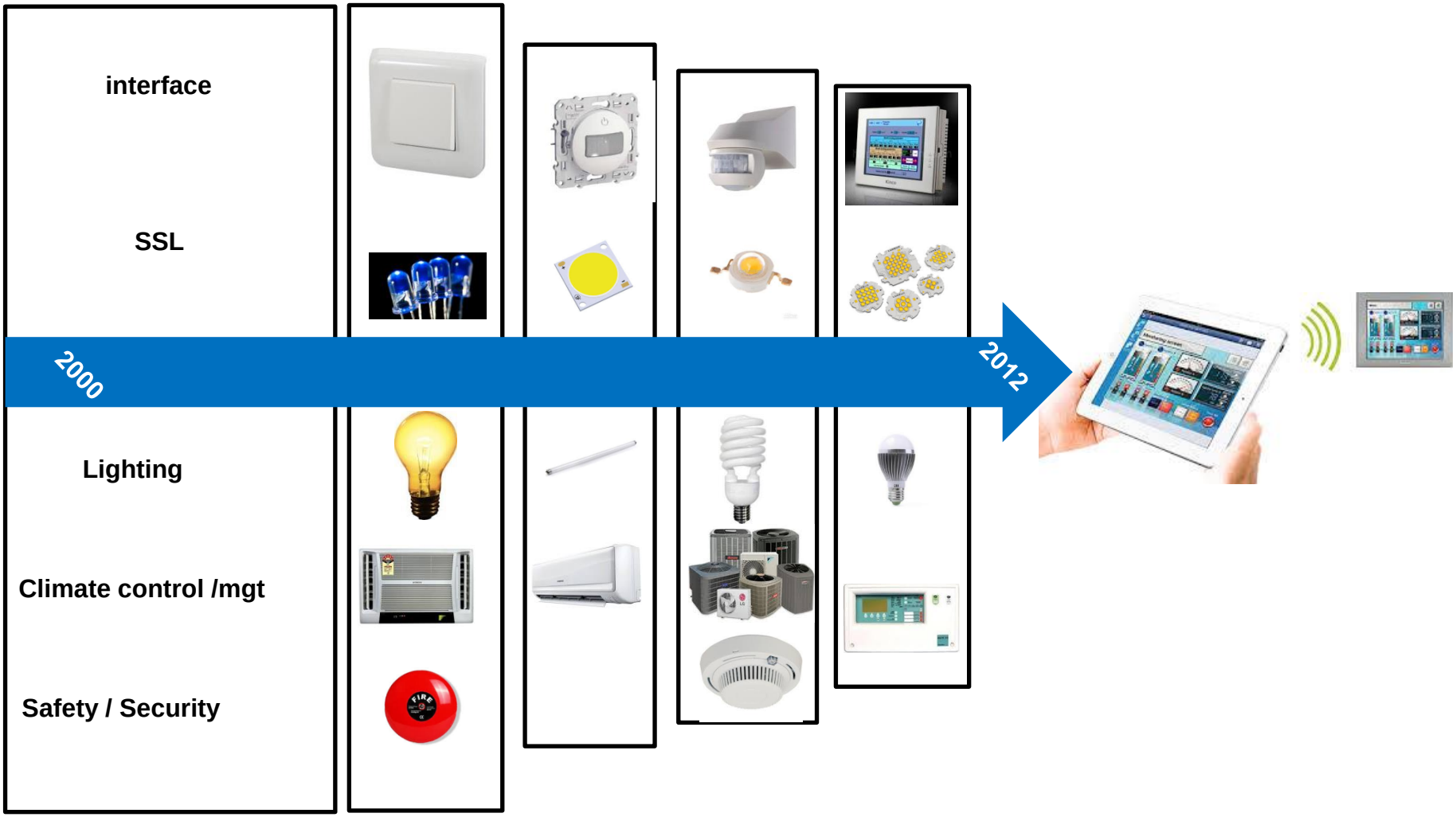
How to do it

- Sensor, imageur, light sources ,processor & Scenarri …

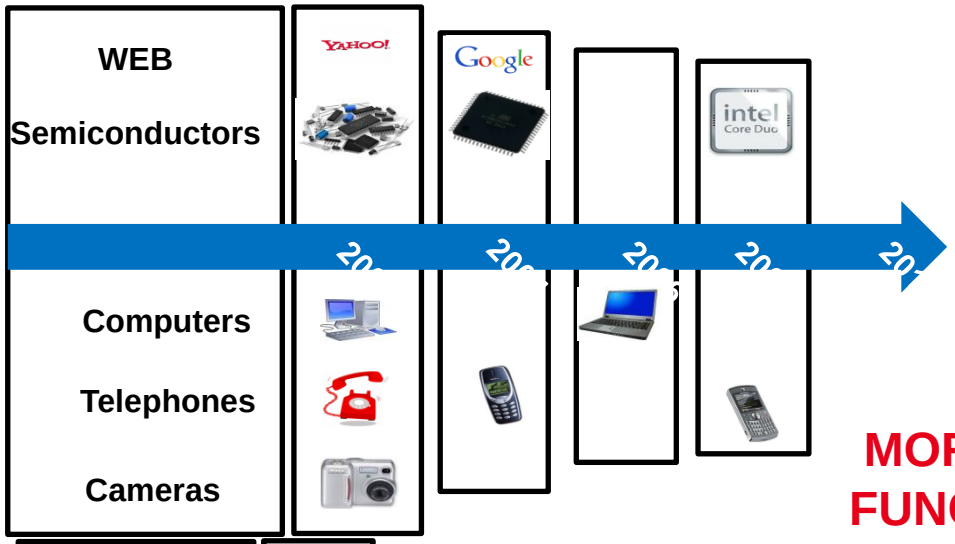
CONSUMER ELECTRONICS INDUSTRY CONVERGENCES



BUILDING INDUSTRY CONVERGENCE PROGRESS

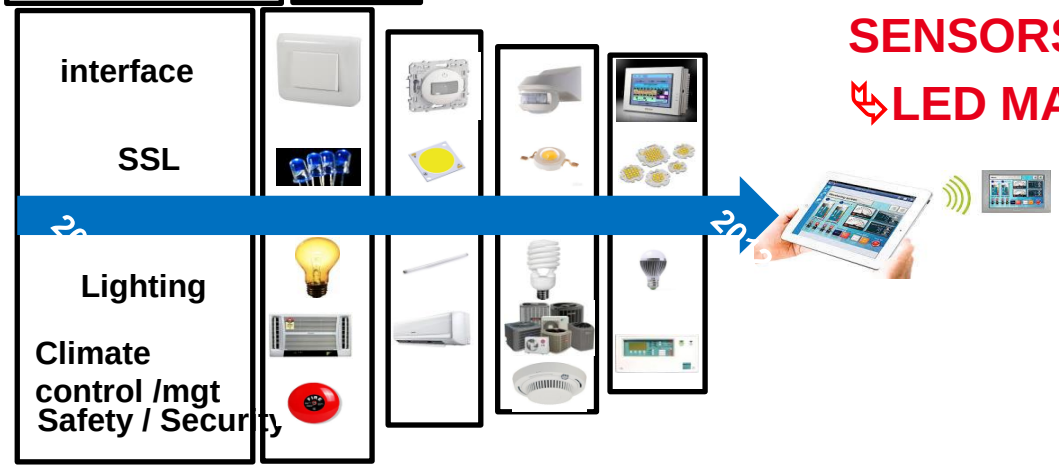


WHAT NEXT ?



MORE AND MORE INTEGRATION OF FUNCTIONALITY (LIGHTING, DISPLAY SENSORS…) IN THE SAME COMPONENT

↳LED MATRIX?



HIGH DENSITY LED ARRAY FOR ADAPTIVE STREET LIGHTING

Spacial & Dynamic control of light flux

WHY HIGHT DEFINITION LED GAN MICRODISPLAYS?

Head-mounted Displays
→see-through systems

Augmented reality

New applications /
New markets

↳ New requirements:
- system
- display

System requirement:
- **Compactness**
- **Field of view (immersion)**

Microdisplay requirement:
- **Image quality**
- **Compactness**
- **Low consumption**
- **High brightness**

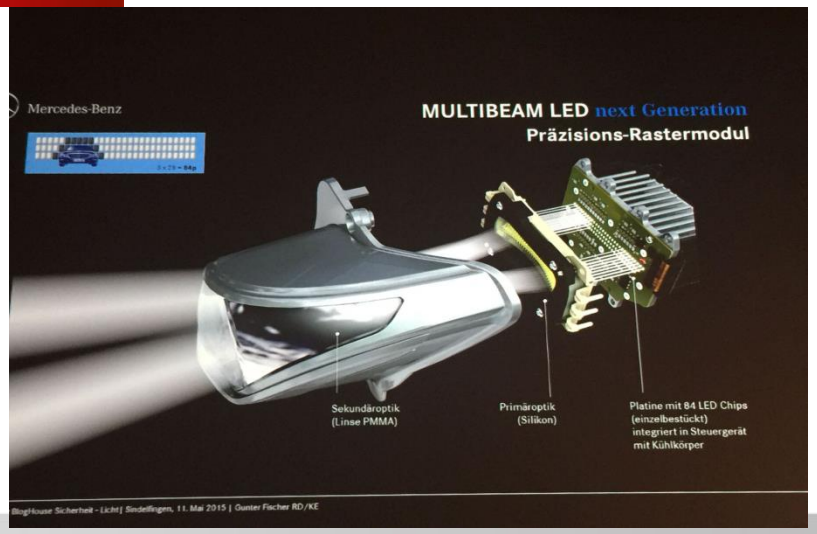
Emissive
OLED microdisplay:

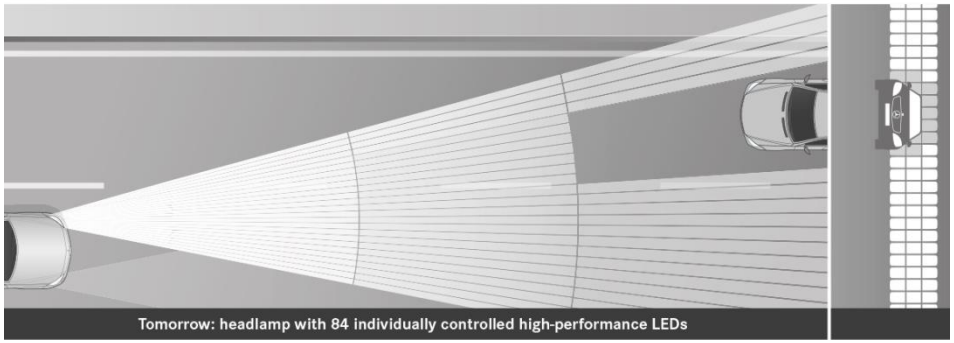
1000 Cd/m²

Need more..

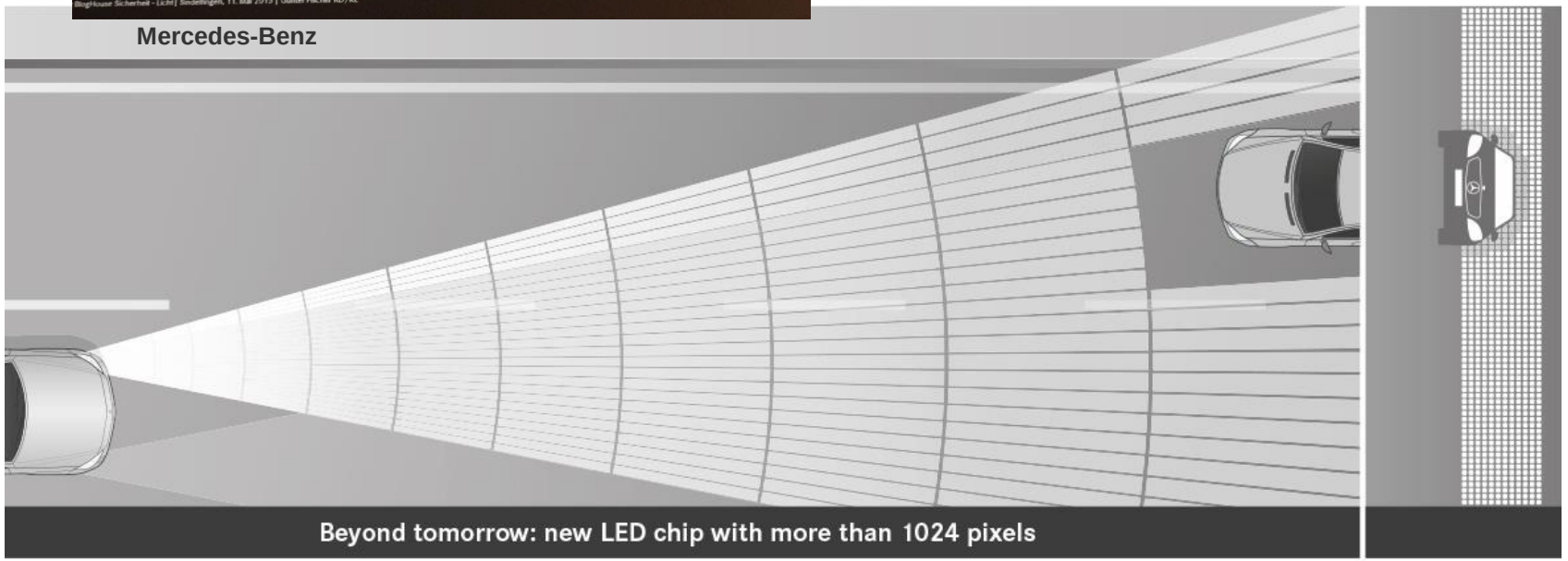
New display:
↳ LED GaN microdisplay

WHY HIGHT DEFINITION LED GAN ARRAY HEADLAMPS? STATE OF THE ART





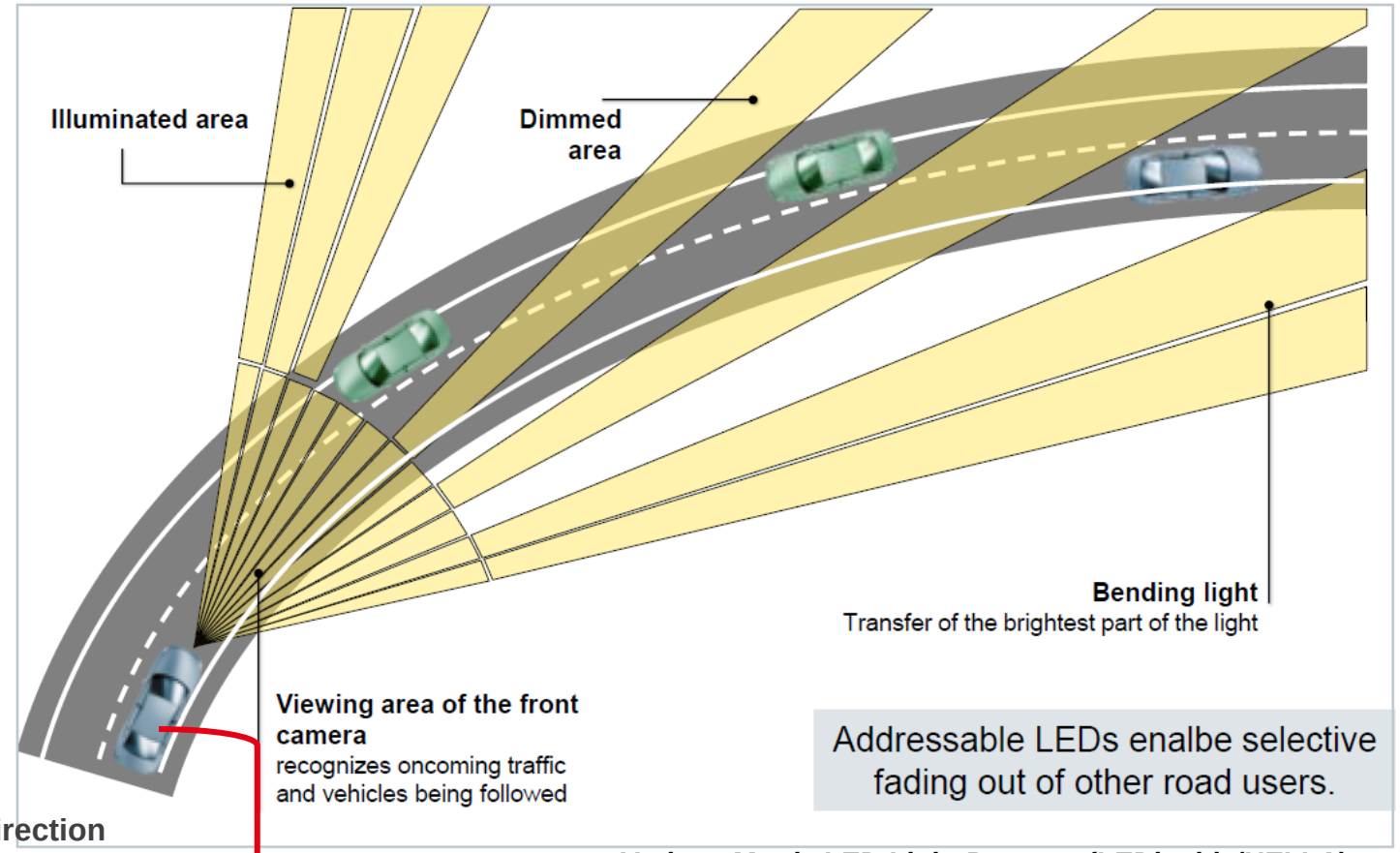
Mercedes-Benz



µAFS demonstrator (OSRAM)

Tomorrow's LED technology

WHY HIGHT DEFINITION LED GAN ARRAY HEADLAMPS?



Various Matrix LED Light Patterns (LEDinside/HELLA)

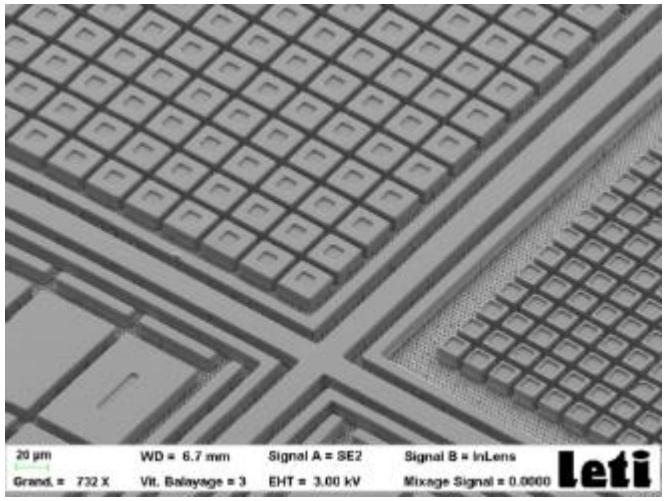
System requirement:

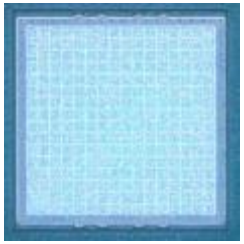
- **Compactness**
- **Field of view :**
  - **-30° to +30° in H direction**
  - **-10° to 4° in V direction**
  - **Color temperature 5000-6000K**
  - **Resolution of 0,1° in Both direction**
  - **60-70 µm Pixel size**
  - **Pixel dimming**
  - **ASIC for pixel driving**

New high brightness LED GAN MATRIX

HOW TO MAKE A GAN LED ARRAY?

1-GaN on Sapphire Substrate etching For electrically independent pixels



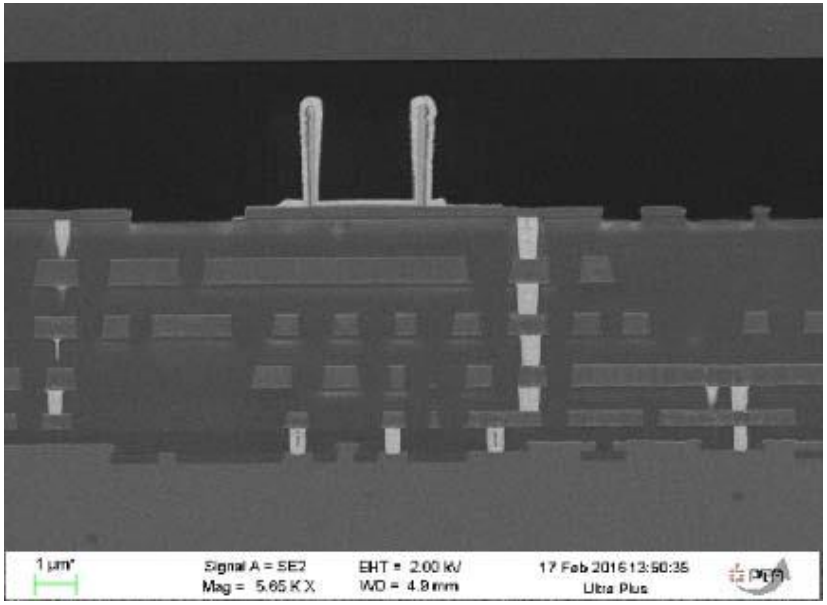


Narrow GaN etching

High active area ratio

Compatible high pixel numbers

2-High voltage Silicon Interposer driver circuit AC-LED



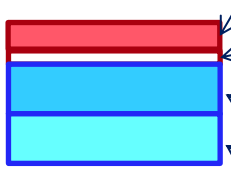
3-Hybridization for electrical connection

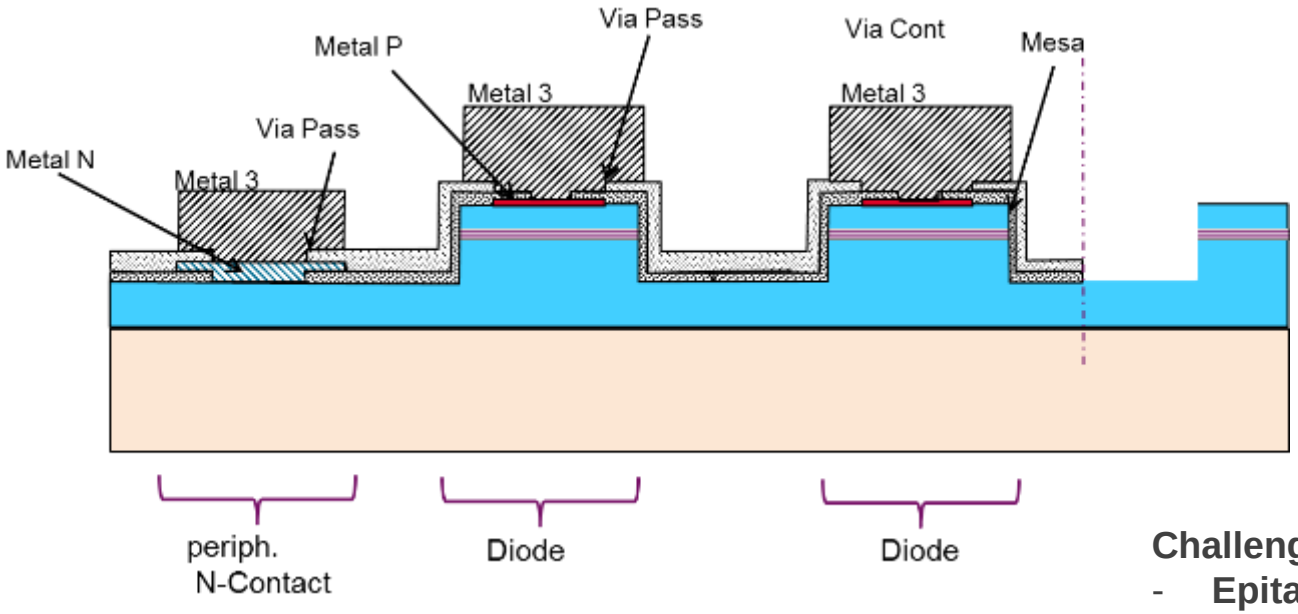
DEVELOPMENT OF 10 µM PITCH GAN LED ARRAY

GaN Diode process on saphire

→ Towards small-pitch LED arrays
→ Development of dedicated process

Epi LED structure: (MOCVD)



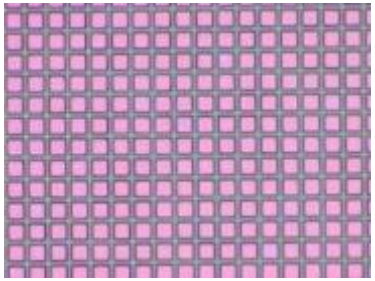


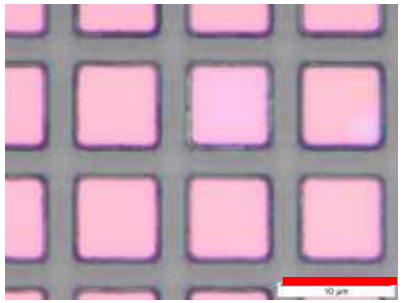
Mesa
Metals P/N
Insulations

Challenges:
- **Epitaxy quality**
- **Contacts**
- **…Small-pitch**

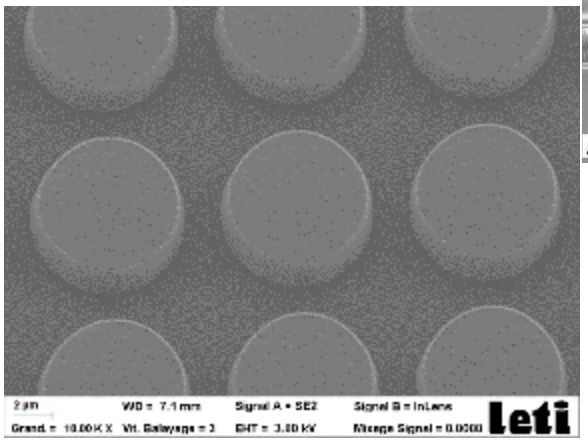
DEVELOPMENT OF 10 µM PITCH GAN LED ARRAY

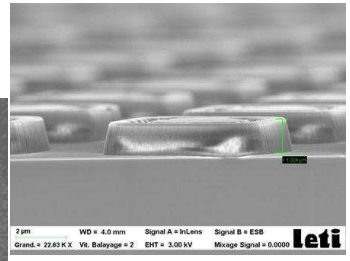
GaN LED array were fabricated on 2-in. and 4-in. sapphire substrates.

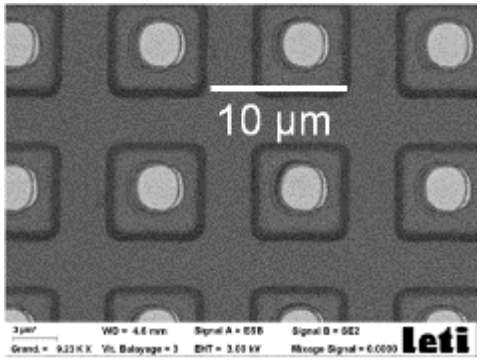


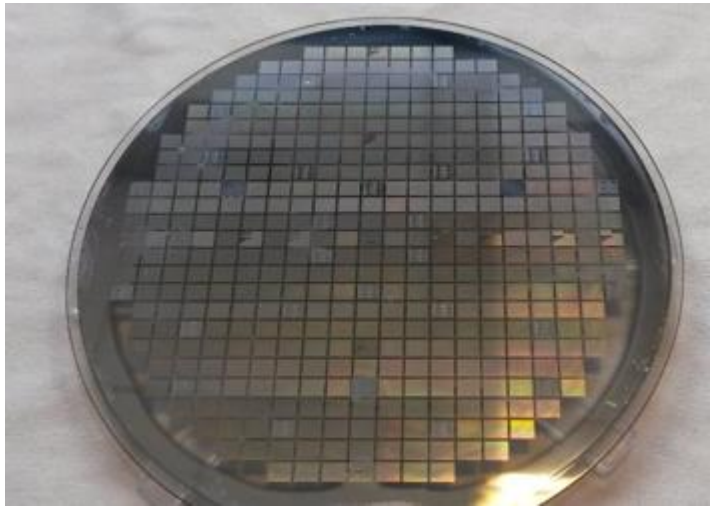


10 µm





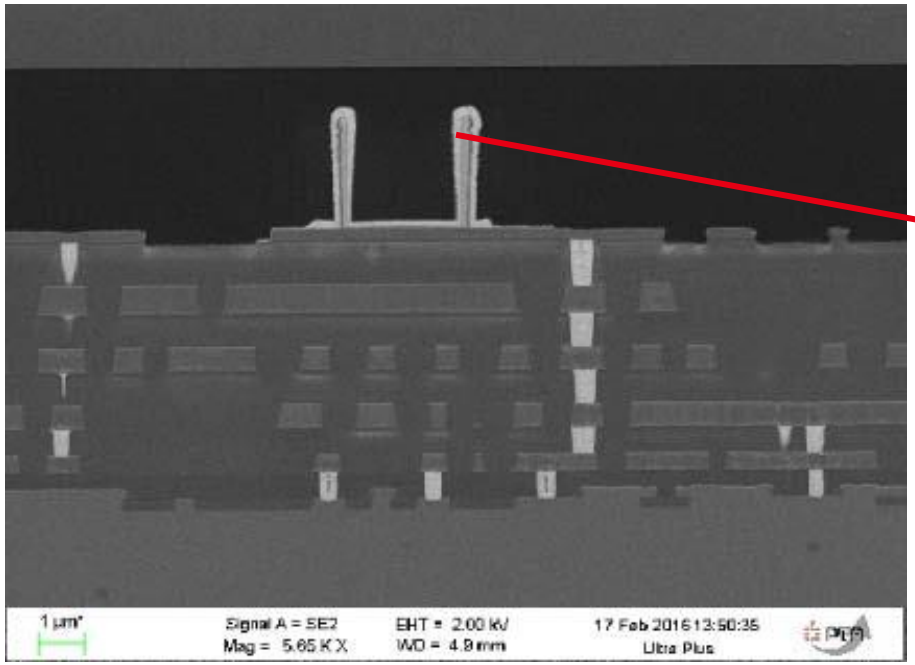


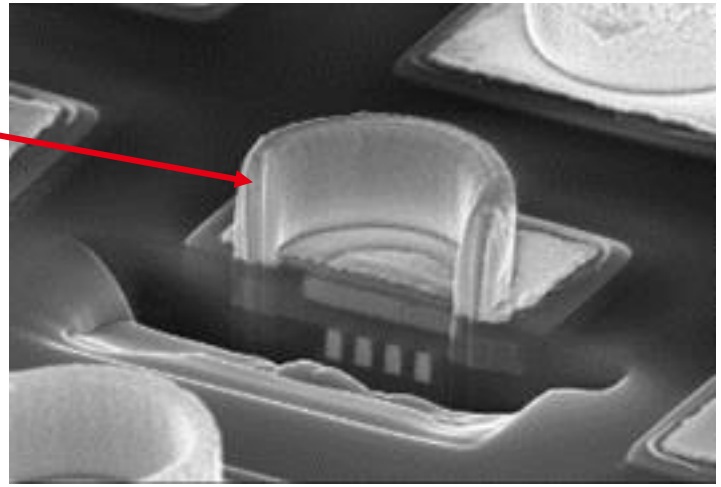


Each die: GaN array :
300 x 252 = 75 600 pixels
at 10 µm pitch

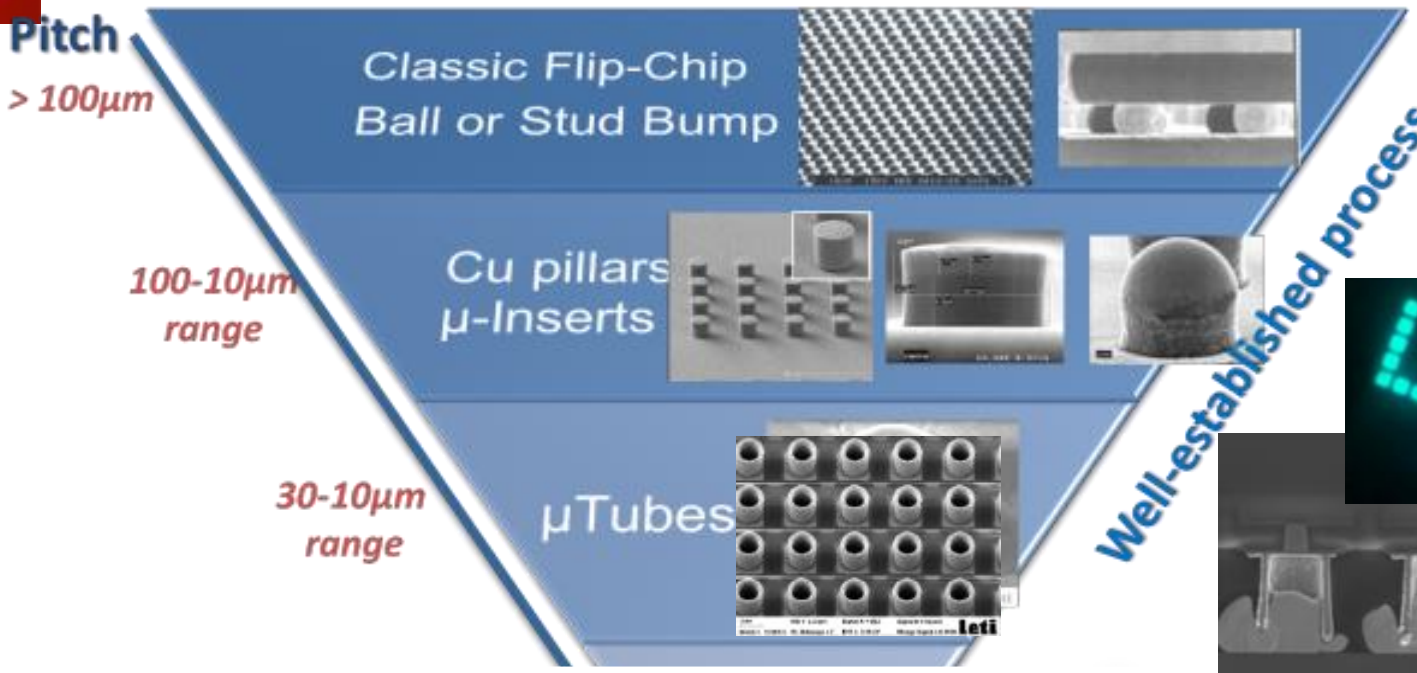
DEVELOPMENT OF 10 µM PITCH SILICON INTERPOSER DRIVER CIRCUIT

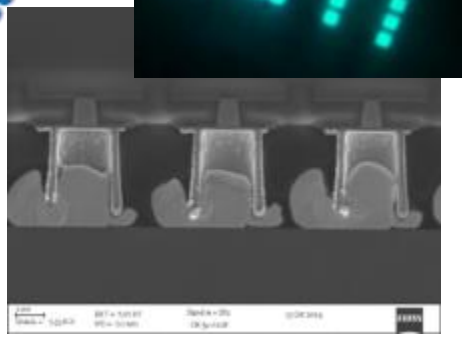
The CMOS circuit is built on a silicon substrate





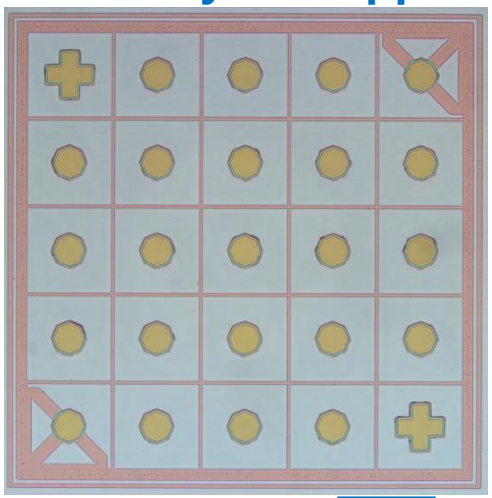
LED MATRIX HYBRIDIZATION ON CMOS TECHNOLOGIES





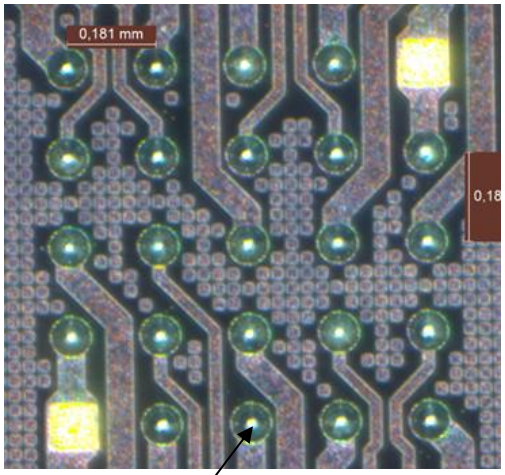
DEMONSTRATORS OF 178 µm PITCH BLUE GAN LED ARRAY FOR PROJECTION APPLICATION

LED array on sapphire

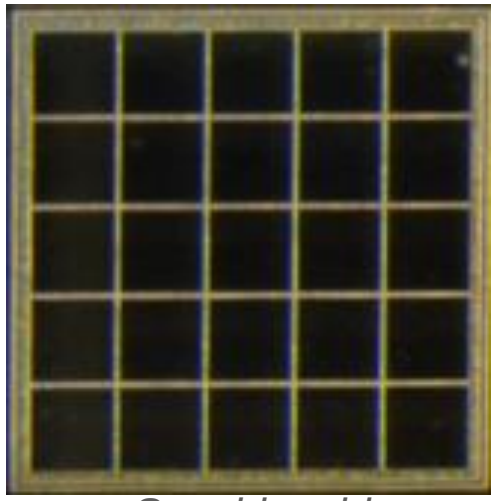


GaN side

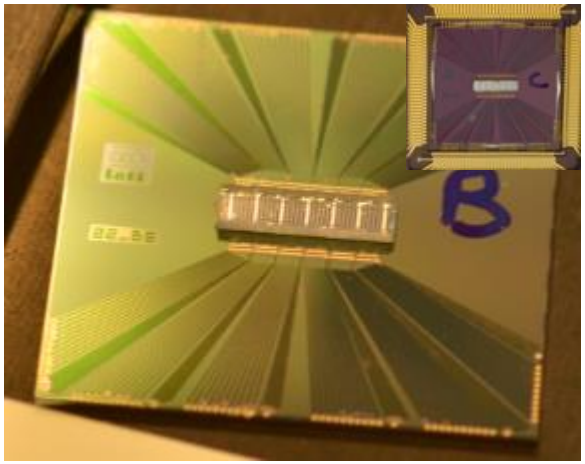
Passive array on Si

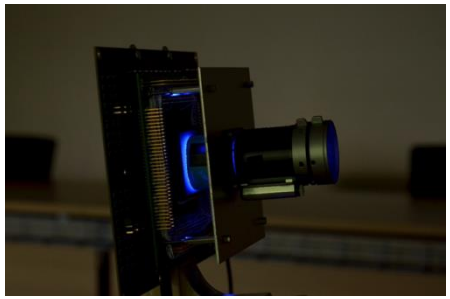


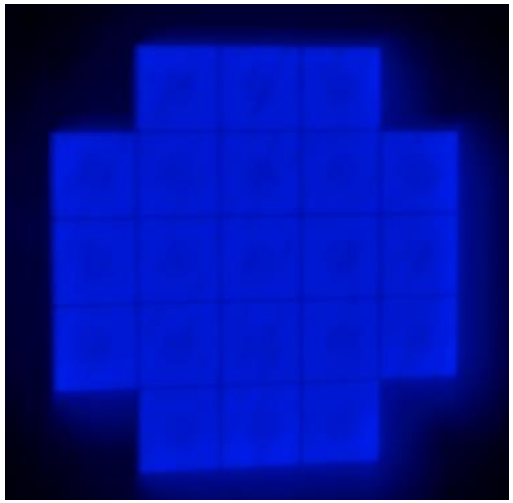
Hybridized LED array



Sapphire side



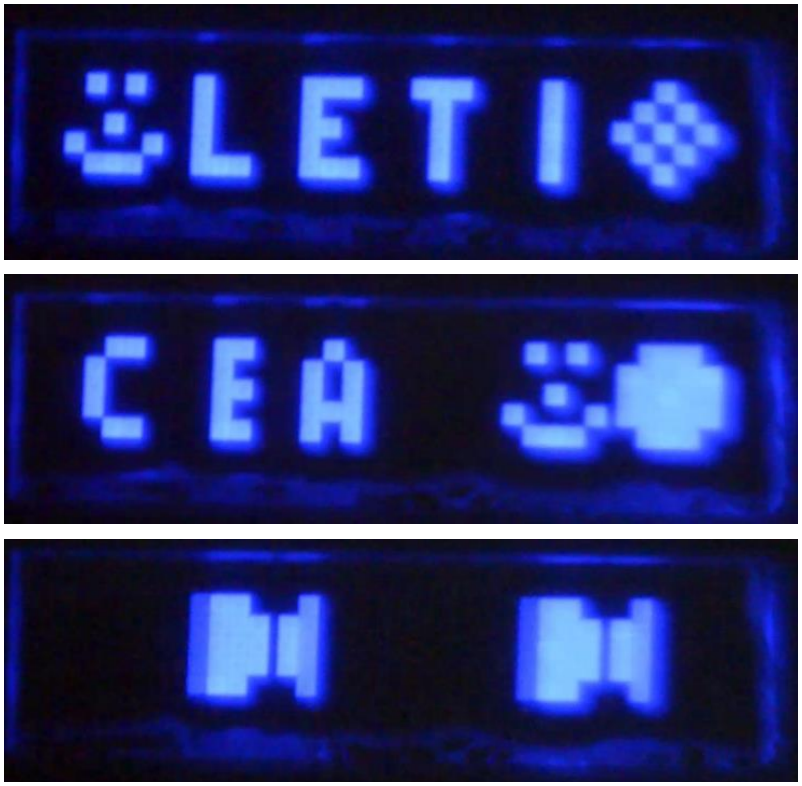




Sapphire side

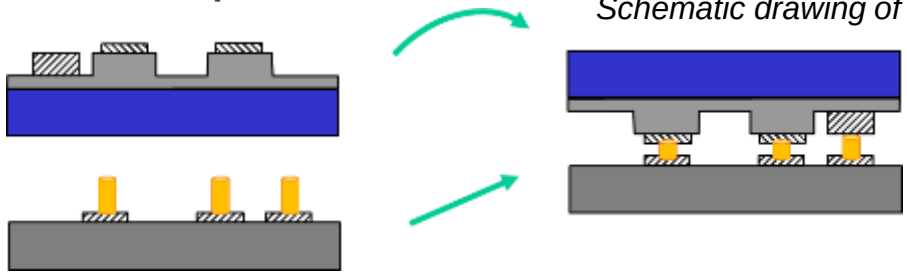
DEMONSTRATORS OF 178 µm PITCH BLUE GAN LED ARRAY FOR AUTOMOTIVE HEADLAMPS

Blue LED matrix projection
CEA / LETI 2016



HYBRIDIZATION WITH MICRO-TUBE TECHNOLOGY

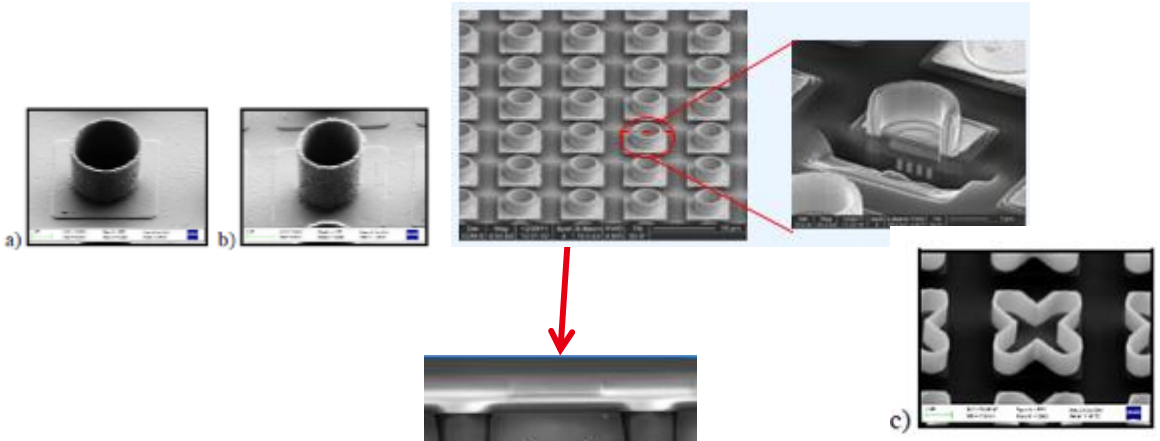
Principle: µTube inserted in pad



Schematic drawing of the insertion flip-chip technique

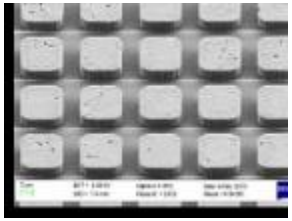
Microtubes on silicon side:

silicon side: ROC, active-matrix,…



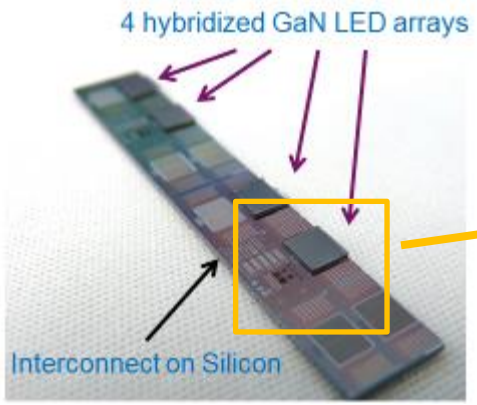
Pads on opposite side:

top side: sensor, …GaN array



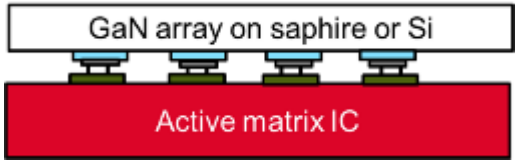
- Room temperature assembly using thermo-compression
- Few mN per connection
- Multi materials approach possible for insertion
- Standard IC technology

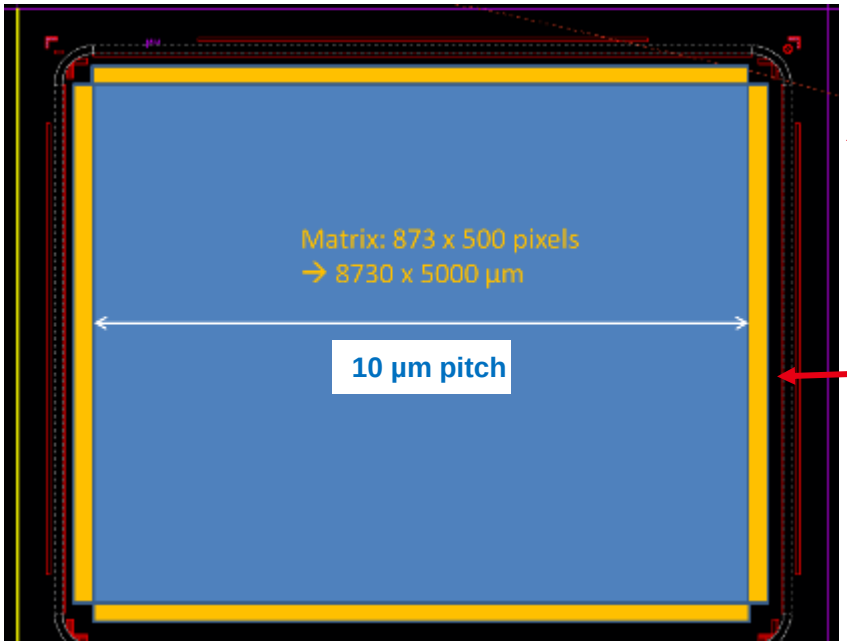
DEMOSTRATOR OF 10 µm PITCH GAN LED ARRAY MADE AT LETI



WVGA ACTIVE-MATRIX GAN LED MICRODISPLAY

- **Active-matrix WVGA (873 x 500) LED demonstrator**



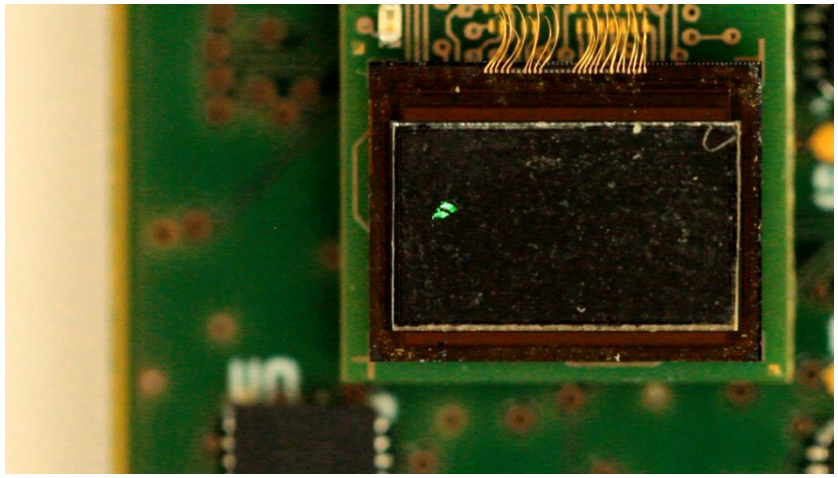


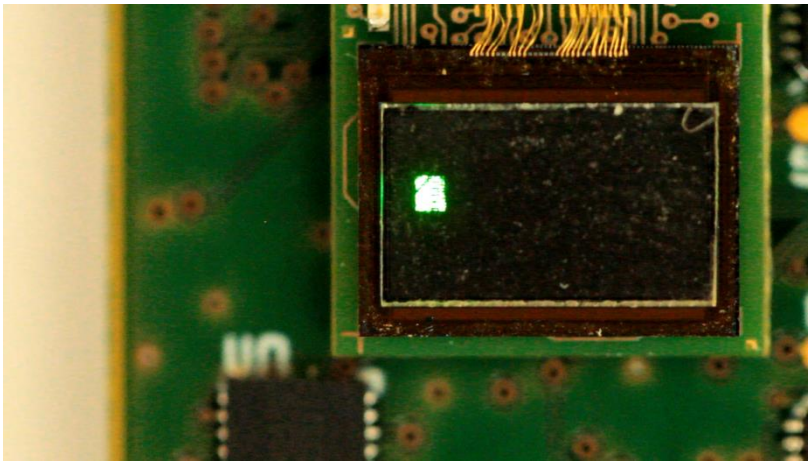
CMOS Active matrix

GaN LED array

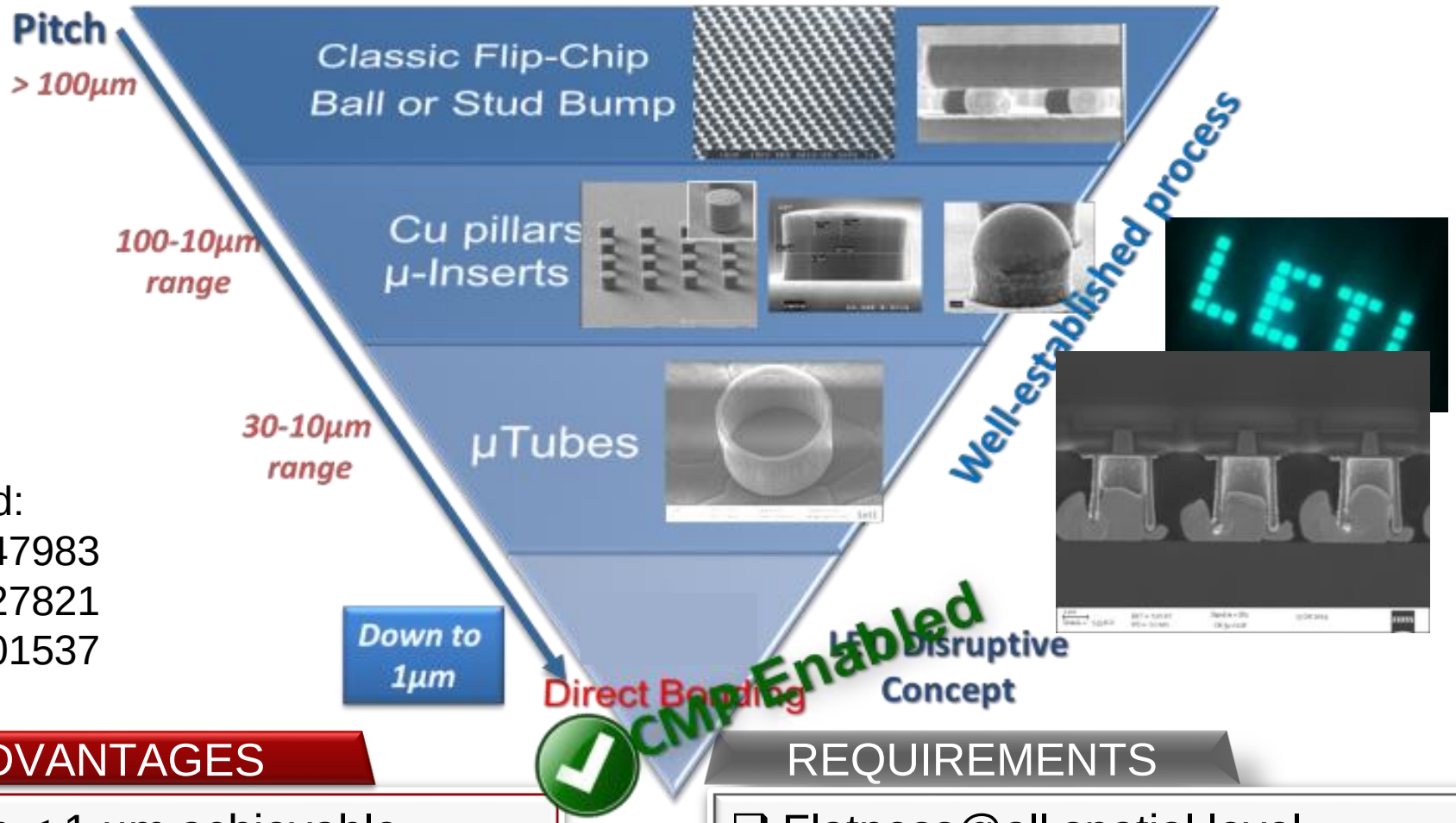
ACTIVE-MATRIX WVGA GAN LED MICRODISPLAY

AMLED demo





LED MATRIX HYBRIDIZATION ON CMOS PORTFOLIO



Patend:
US8647983
US9027821
US8501537

ADVANTAGES

- ✓ Pitch < 1 µm achievable
- ✓ Done at RT, ambiant pressure
- ✓ No glue needed

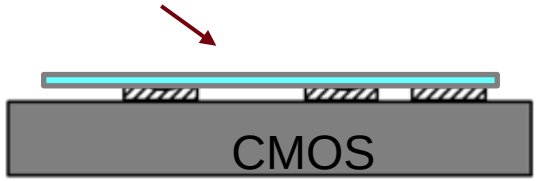
REQUIREMENTS

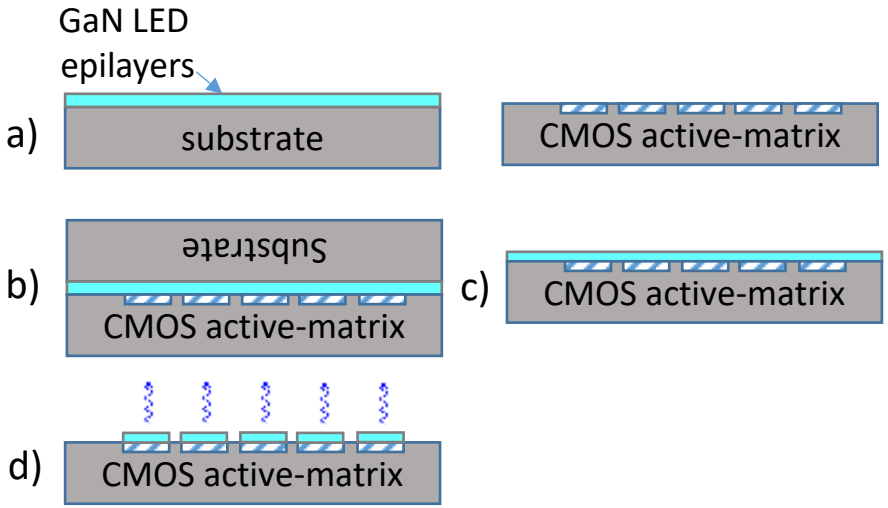
- ❑ Flatness@all spatial level
- ❑ Surface Roughness of ~0.5 nm RMS

NOVEL APPROACH FOR GAN MICRODISPLAYS

Novel approach: transfer of GaN on CMOS

Monolithic, GaN transfer:

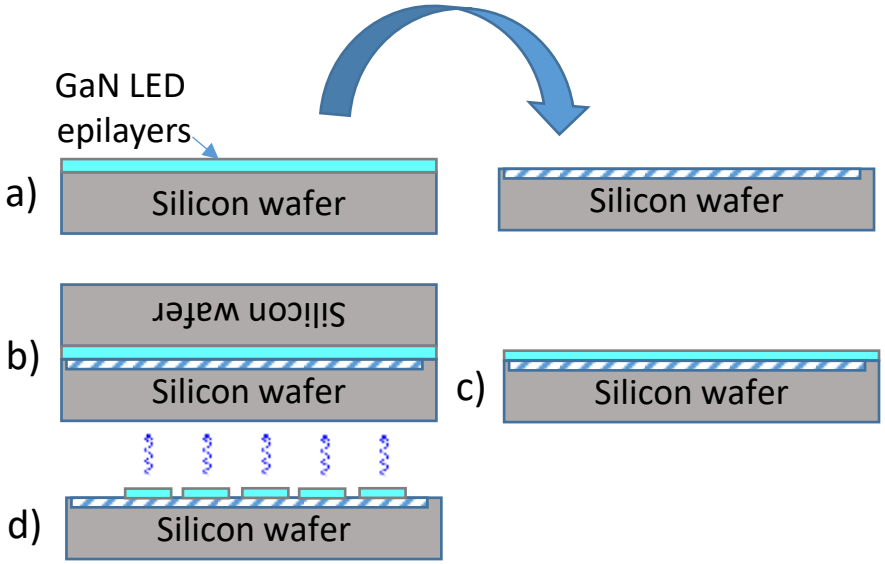


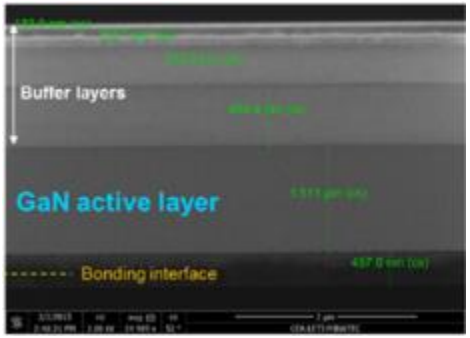


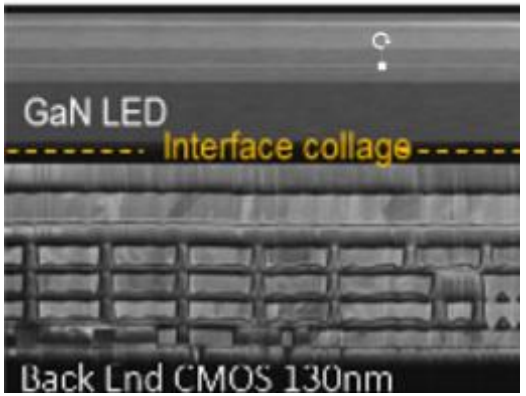
NOVEL APPROACH FOR GAN MICRODISPLAYS

Novel approach : transfer of GaN on CMOS

Proof-of-concept

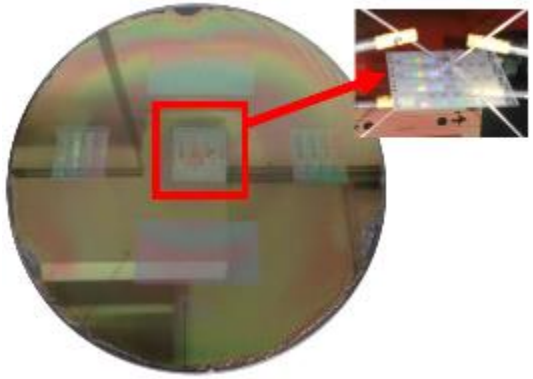


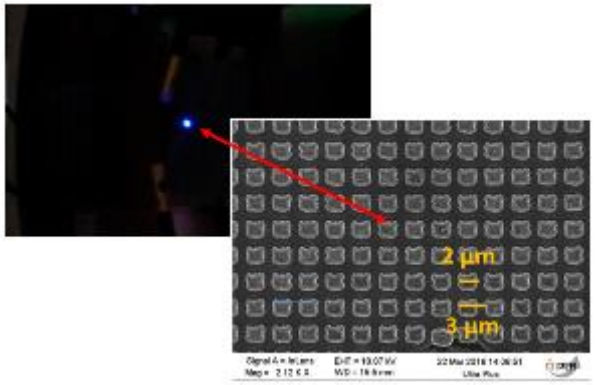


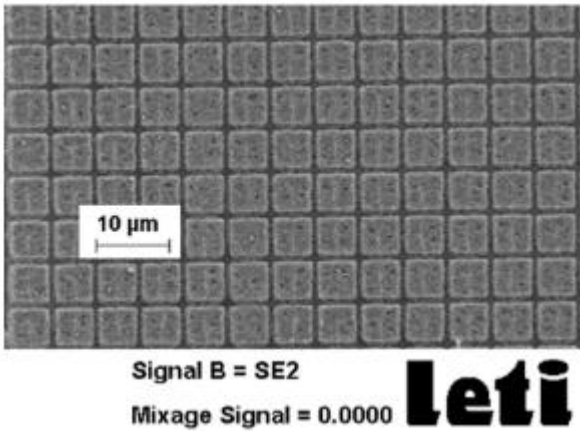


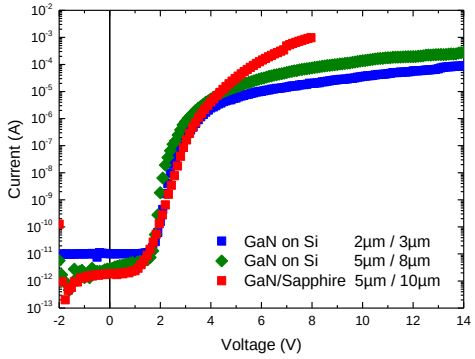
NOVEL APPROACH FOR GAN MICRODISPLAYS

Proof-of-concept









Next steps:

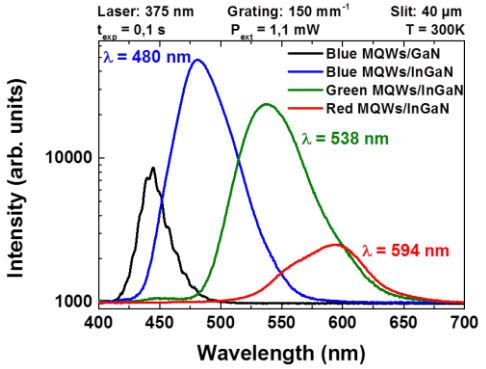
- Epi LED Si; saphire…
- LED processing
- Active matrix

Summary:

- Versatile: epi, metals, ..
- Small pixel pitch
- Full CMOS
- …color

THE COLOR CHALLENGE

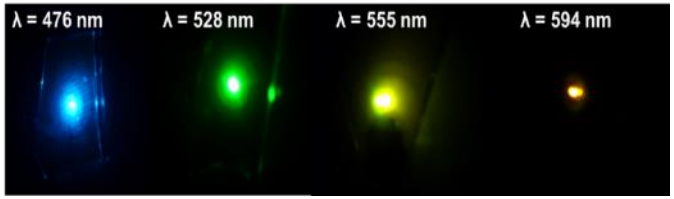
- 3 colors on same wafer
- small pitch (10 / 5 / 3 µm)
- crosstalk



Direct generation:

- Selective Area Growth (SAG)
- Epi stack (IOP, Ostendo)
- ….

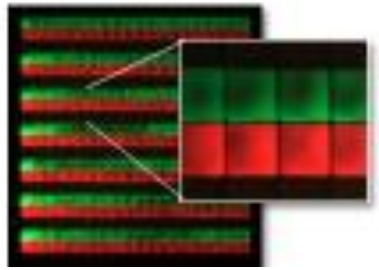
→ Longterm



Color conversion:

Phosphors, QDs

Pb.:
Thickness
Lifetime
Patterning



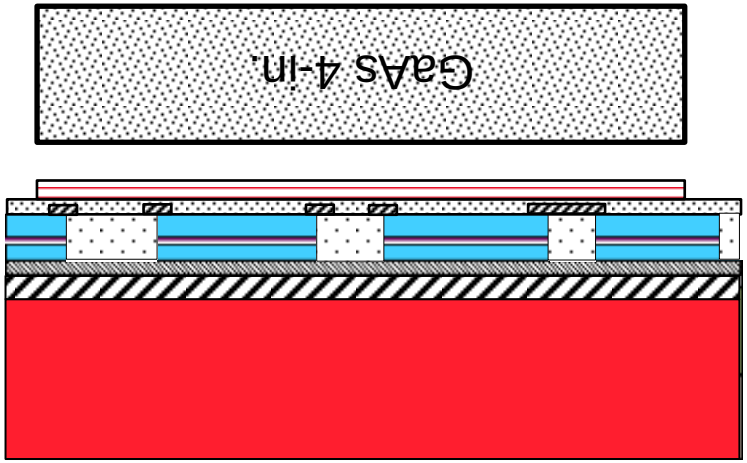
2D layers

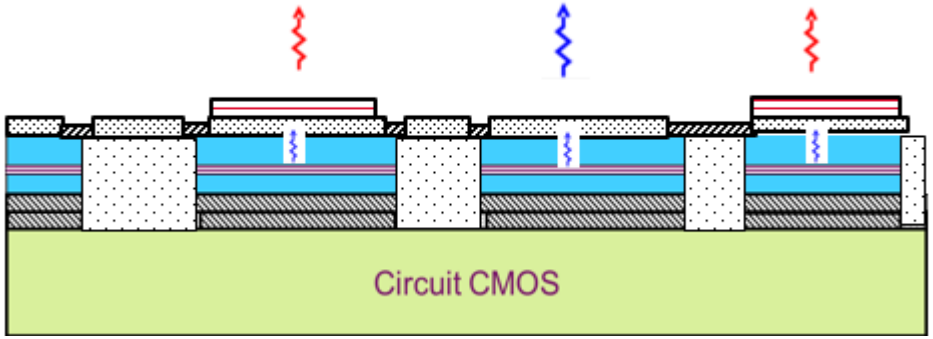
→ **MQWs Green : InGaN/GaN/saphire**

→ **MQWs Red : InGaAlP/InGaP/GaAs**

SOLUTION FOR HIGH RESOLUTION FULL COLOR LED MICRODISPLAYS

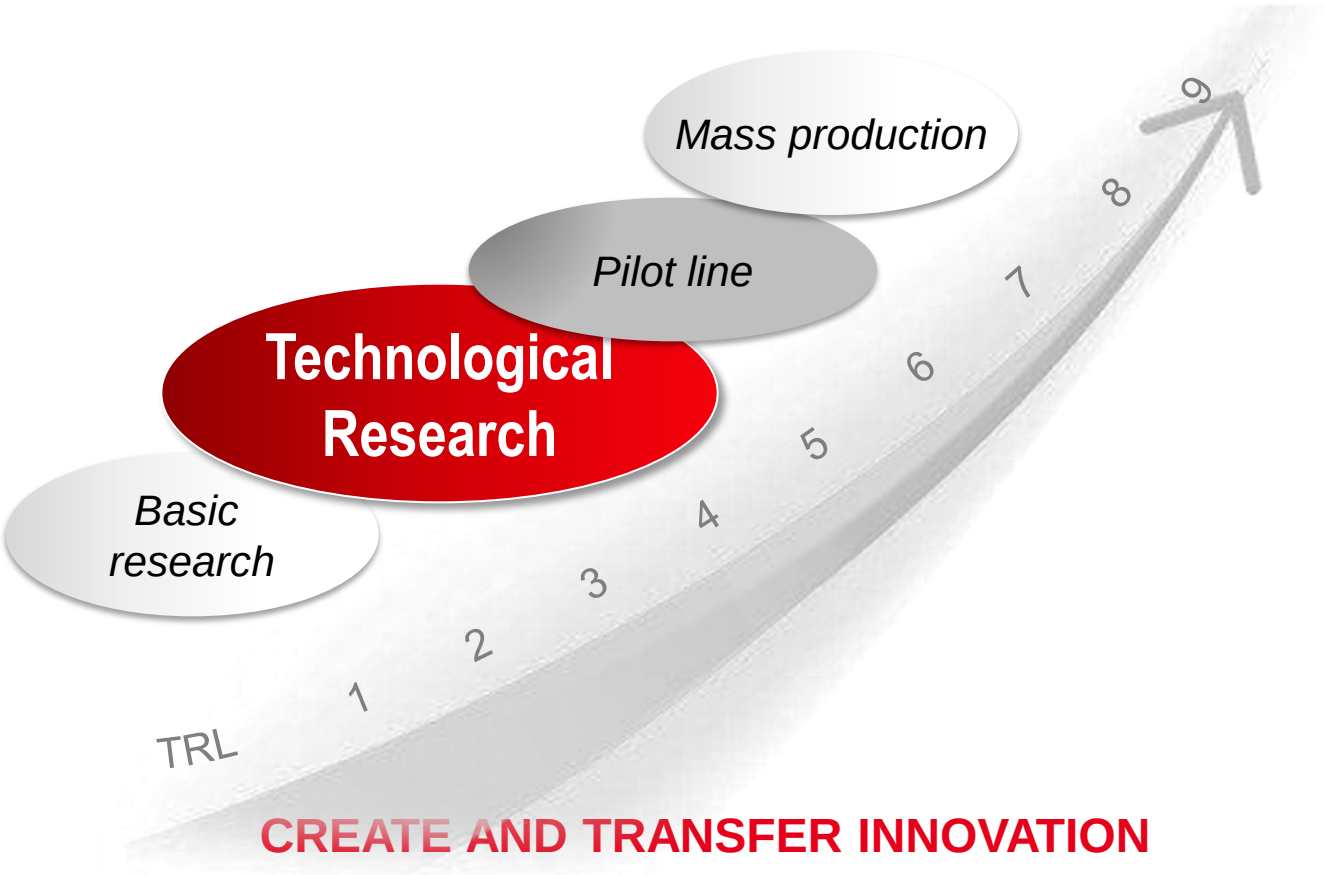
→ Using color conversion with 2D materials, transfered on LED arrays





↳ **Solutions for full-color**
Small pixel-pitch
Active matrix displays

THANK YOU



CREATE AND TRANSFER INNOVATION TO INDUSTRY