

**leti**  
cea tech



# ***POWER DEVICES: A NEW ERA OF ENERGY CONVERSION WITH GAN***

Lea Di Cioccio

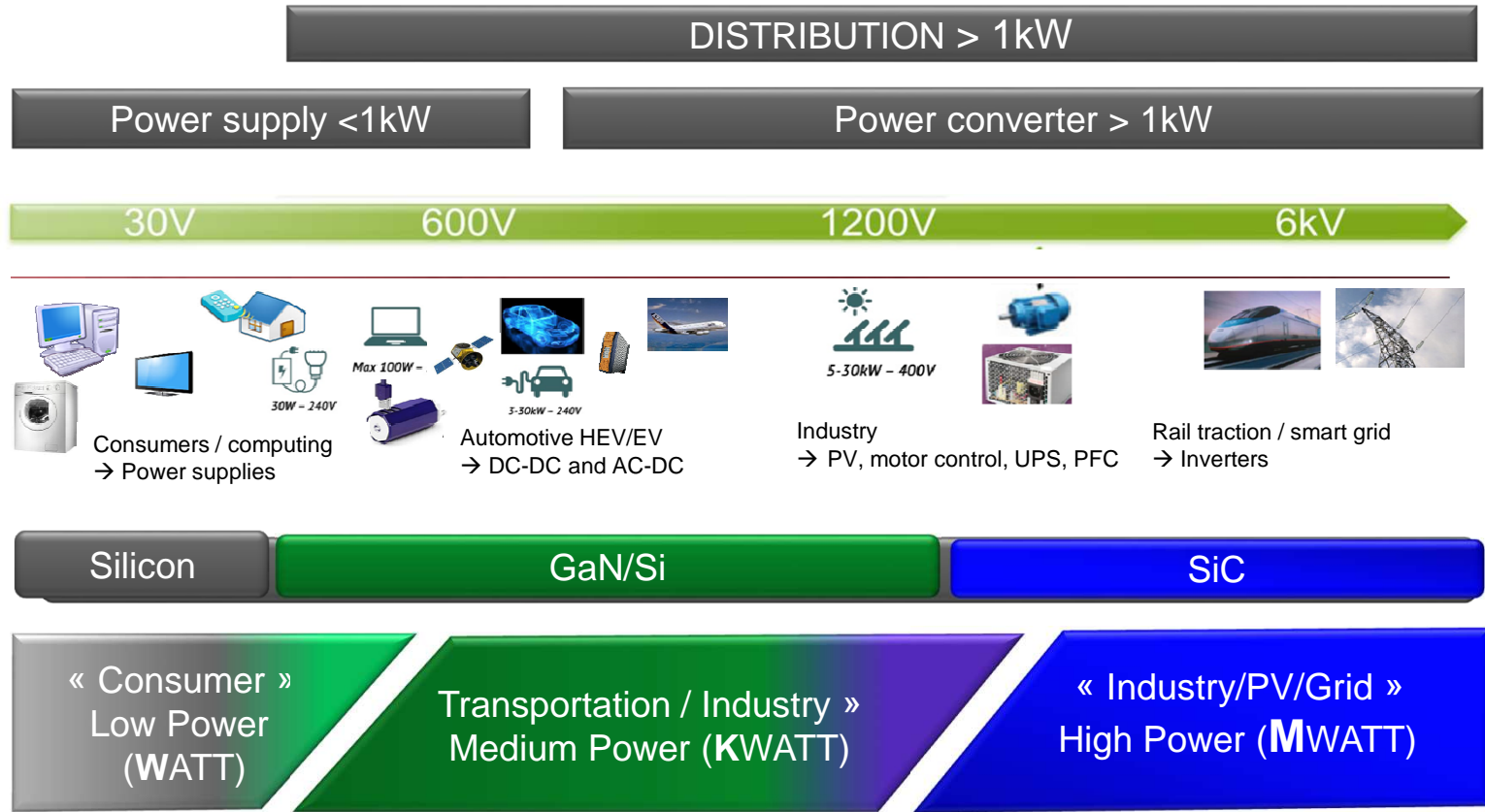
Leti Devices Workshop | December 3, 2017

## GAN FOR A NEW COMPACT POWER CONVERTER GENERATION

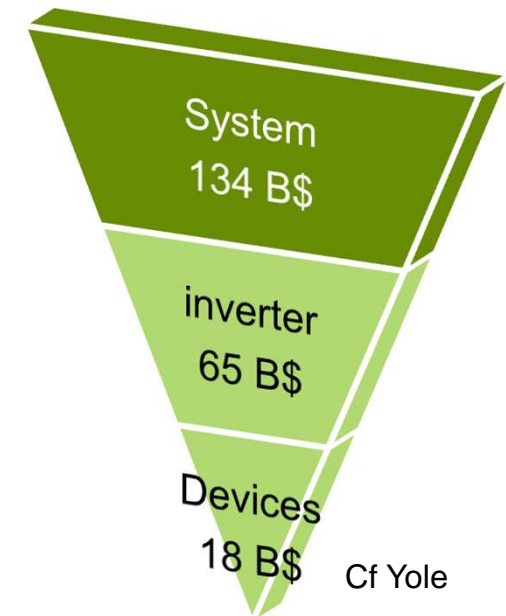
- 1** Power devices and systems market overview
- 2** Leti roadmap for GaN devices and systems
- 3** Leti GaN device figures
- 4** Leti GaN topology examples
- 5** Exagan (startup)



# WHICH TECHNOLOGY FOR WHICH APPLICATION



2020

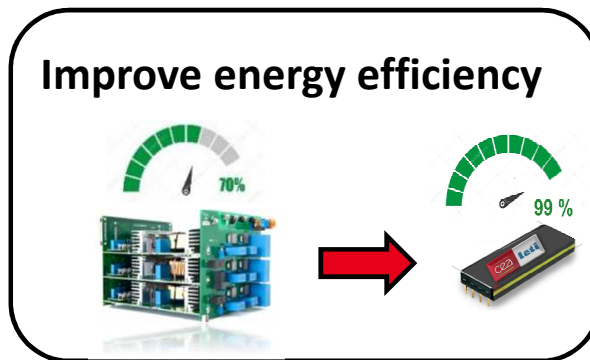
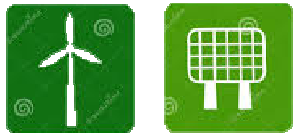


# SOLUTION: IMPROVE SYSTEM ENERGY EFFICIENCY

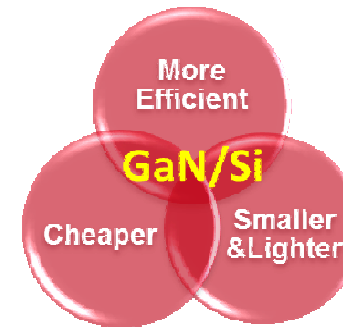
Building, automation, lighting



Renewable energy



Electrical transportation modes

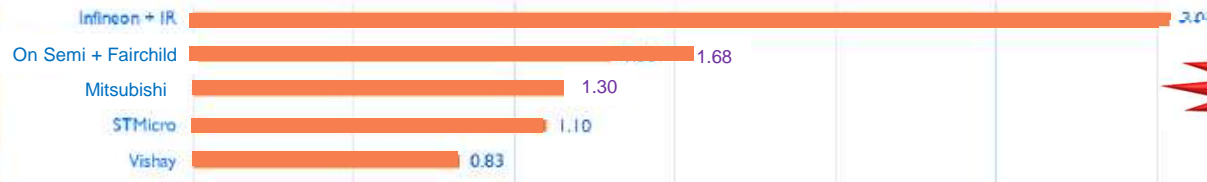
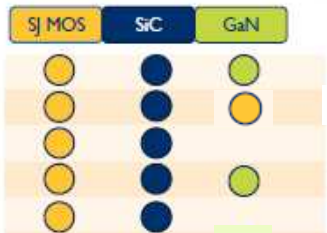


Frequency  
Power density  
Integrated functions



GaN/Si  
CMOS  
200mm

# GaN/Si POWER DEVICE MANUFACTURERS



**TOP 5**  
(cf Yole)

Fabless working with TSMC foundry

Acteur GaN	tension	maturité	catégorie	Substrat
transphorm	650 V	commercial	fabless	6"
ST	650 V 650V, 1200V	R&D R&D	IDM IDM	6" 8"
Visicore	650 V	commercial	fabless	6"
Panasonic	650 V	commercial	IDM	6"
GaN Systems	650 V	commercial	fabless	6"
Infineon	650 V	R&D	IDM	6"
EPC	400 V	R&D	fabless	6"
Dialog	650 V	R&D	fabless	6"
Texas Instruments	650 V	R&D	fabless	6"
EXAGAN	650 V	R&D	fabless	8"
TSMC	100 V 650 V	commercial	fondeur	6"



# GaN/Si A KEY TECHNOLOGY FOR NEXT ELECTRICAL CAR GENERATION

→ Power Electronic for Traction Drive System (55kW peak – 30kW continuous)

You want to

Power GaN/Si technology gives you

Increase Power Density (kW/l)

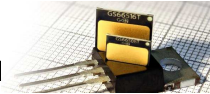


Ref Si 13 kW/l 20 kW/l  
2022



More power density (more than x10 Silicon)

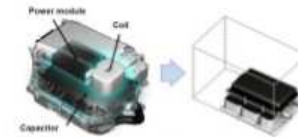
Google 2016: Little box challenge 8,7 kW/l



Decrease Size & Weight (kW/kg)



Ref Si 14kW/kg 20 kW/kg  
2022



Goal: 80% less volume

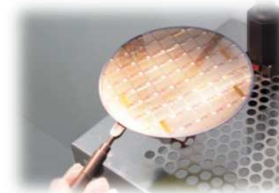
Higher frequency > 1MHz (more than x100 Silicon)  
Less passive  
Motor + inverter



Lower cost (\$/kW)



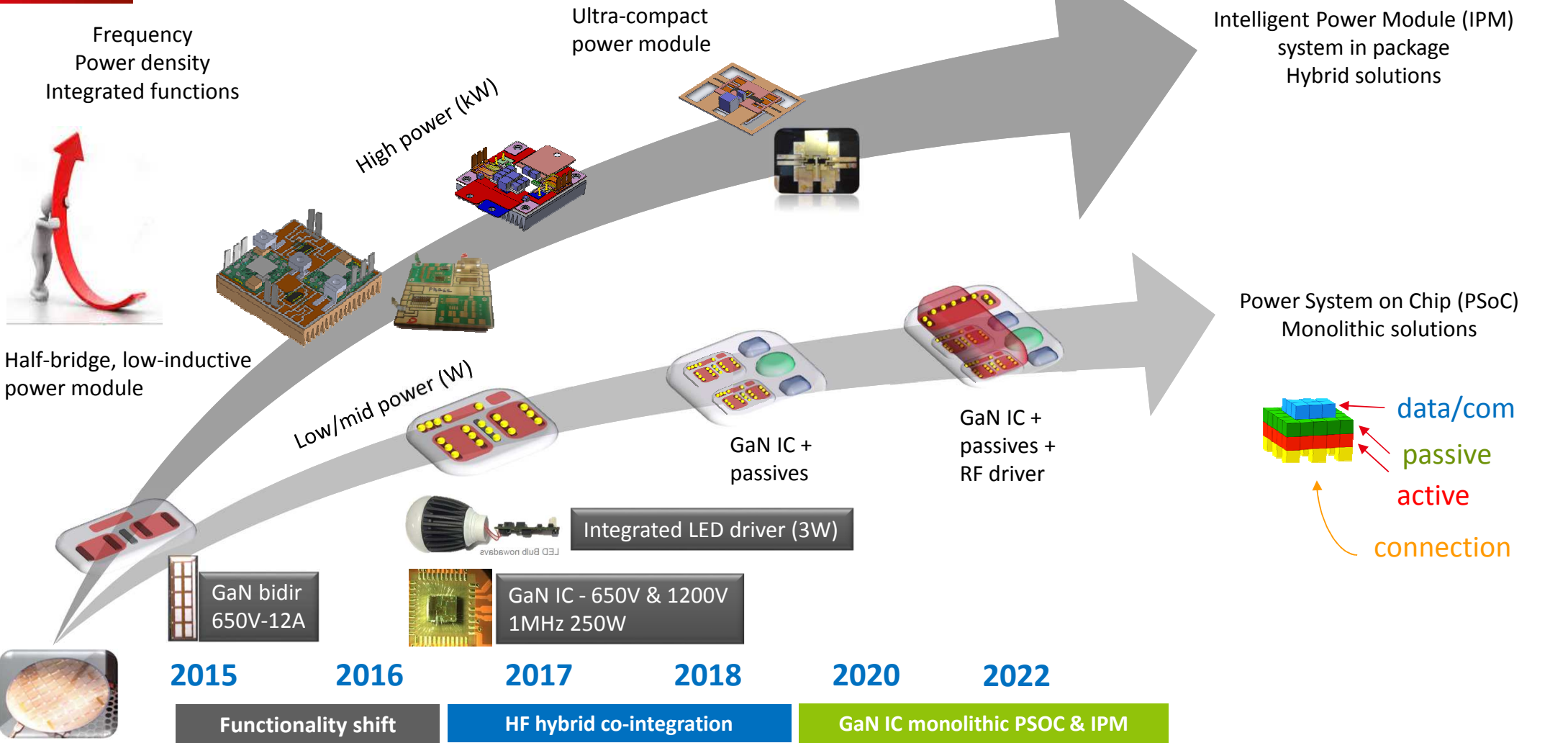
Ref Si 3,3\$/kW 2\$/kW  
2022



200mm GaN/Si CMOS  
Compatible technology  
2\$/kW



# LETI GaN POWER ROAD MAP AND DEMONSTRATORS





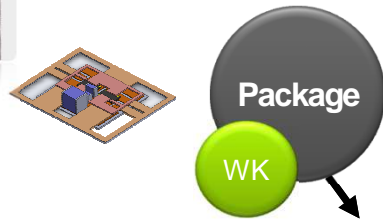
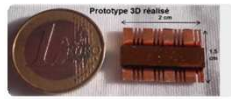
# CEA LETI FROM TECHNOLOGY TO SYSTEM

→ to respond to the main challenges

Co-integration

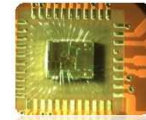
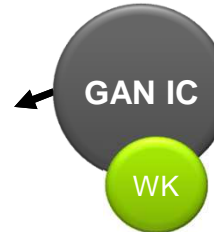
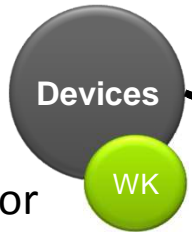
3D power module with integrated passives  
Driver for GaN/Si devices, PSiP

Functionality shift

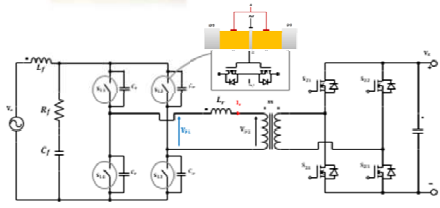
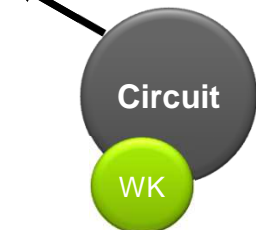
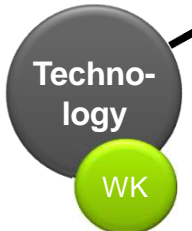


GaN IC, PSOC & IPM

GaN/Si bidirectional transistor



GaN IC



LED Bulb nowadays

Watt  
Kilowatt

High-frequency design:  
DAB, soft switching, resonant & matrix converters

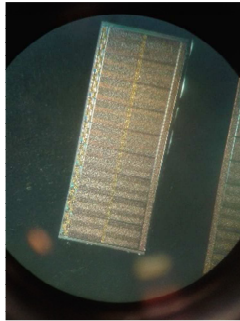
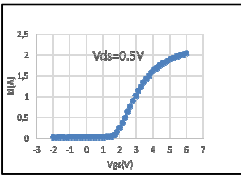
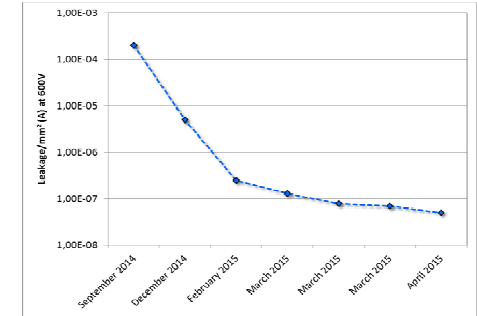


# MESSAGES TO TAKE HOME: LETI ACHIEVEMENTS



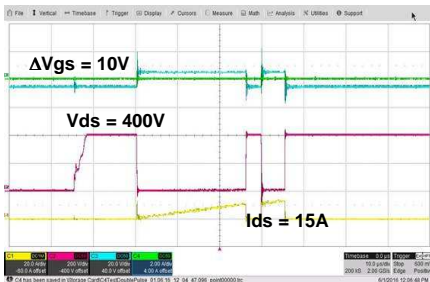
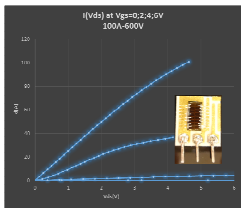
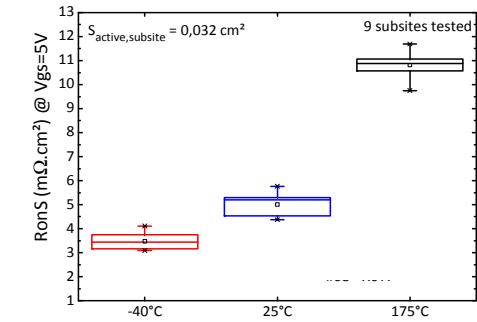
High GaN/Si production capacity with AIXTRON G5+ (200mm)

Low current leakage at 600V (<50nA/mm<sup>2</sup>) for GaN epitaxy coating



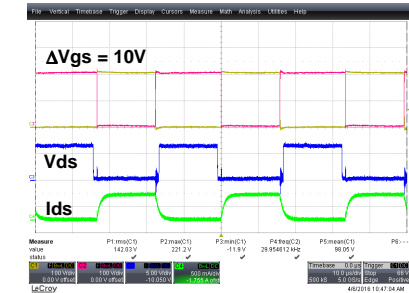
Monolithic n-off GaN/Si device manufacturing on Leti CMOS platform

Low leakage ( $I_{dss} < 0,01$  &  $I_{gss} < 2e-5 \mu A/mm$ ) & RonS (5 mOhm.cm<sup>2</sup>) for 600V @ 100A GaN/Si

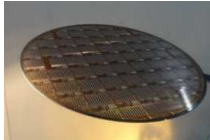


Double pulse characterization on inductive load (500 μH) Commutation 400V @ 15A without current collapsed

Demonstration for 200 V @ 30KHz on resistive load



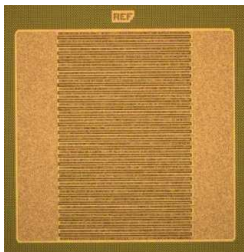
# GAN-ON-SI SCHOTTKY-BARRIER DIODE



Manufactured with a CMOS compatible 200mm process flow

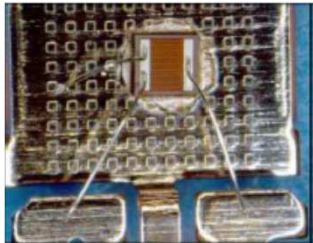


State of the art performances with  $V_{fwd}=2,6V$  @  $100mA/mm$  &  $150^{\circ}C$  (anode-cathode length =  $15\mu m$ )



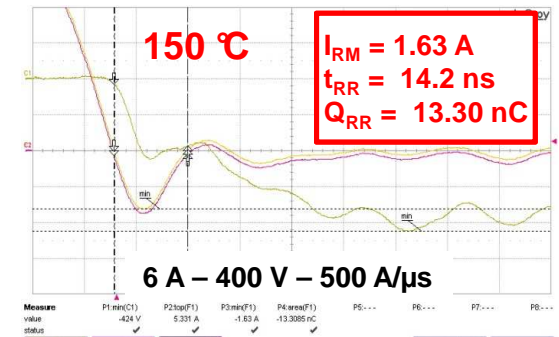
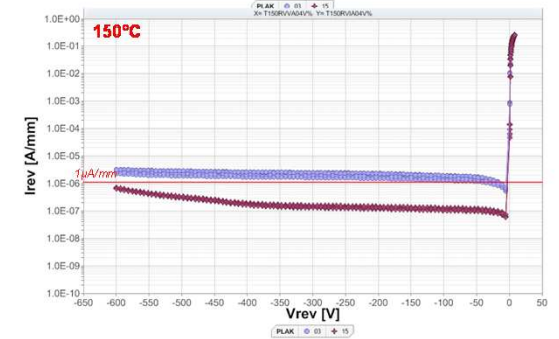
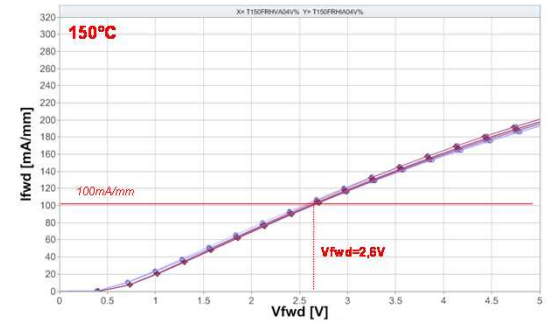
Interdigitated structure for high current density ( $R_{on,sp} < 3mW.cm^2$  at  $BV > 850V$ )

Low-leakage current ( $< 1\mu A/mm$  @  $650V, 150^{\circ}C$ )



Validation of assembly in standard package

Demonstration of high performances (High-speed switching, Low-recovery charge)

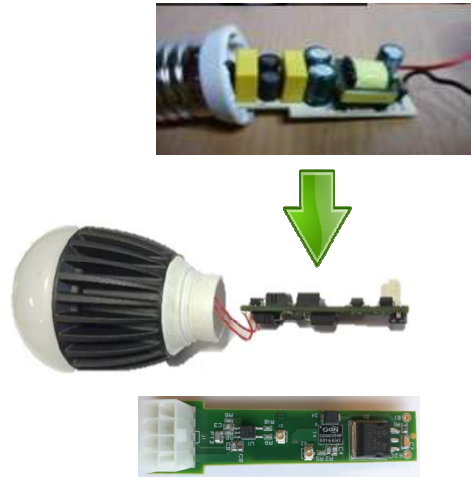
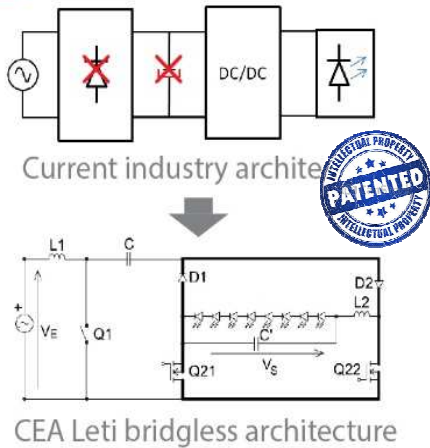


Work performed in the frame of TOURS 2015 project supported by the french  
« Programme de l'économie numérique des investissements d'Avenir »



# HF GaN DRIVER FOR LED: DAB

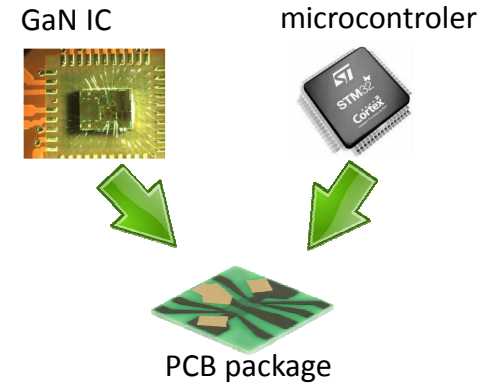
- High-performance and integrated 1MHz LED driver



- +** **Smaller:** more integrated (divided by 2)
- +** **Reliability:** No electrochemical capacity
- +** **Higher efficient:** >90% efficiency gain

## HF hybrid co-integration

### GaN IC monolithic PSOC & IPM



### APEC & PCIM 2017

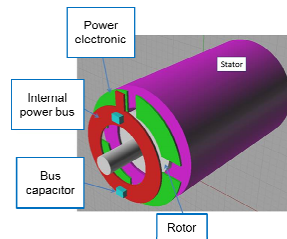
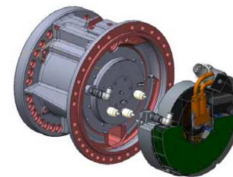
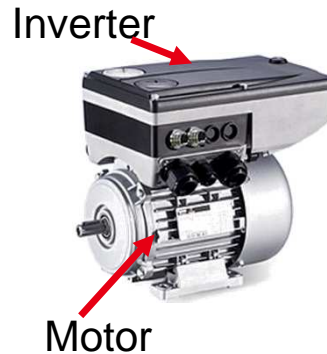


# GAN INVERTER INTEGRATED IN MOTOR

**GaN/Si mean :**

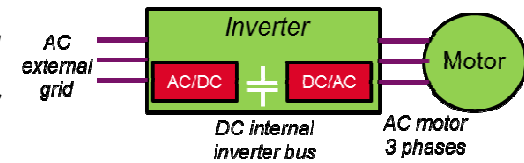
- Higher working temperature
- Higher speed

- + Proximity
- + Reduction losses
- + More flexibility
- + Less vibration
- + Higher reliability

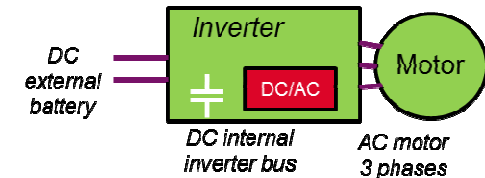


## HF hybrid co-integration GaN IC monolithic PSOC & IPM

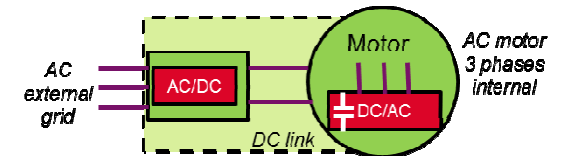
*Standard inverter-motor*



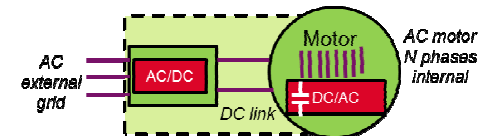
*State-of-the-art electric car*



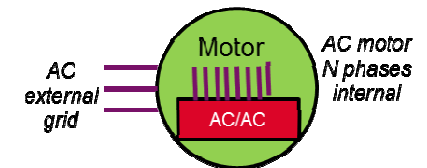
*Integration inverter/motor*



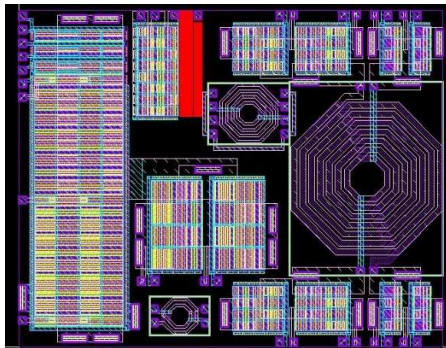
*Multi-phase motor*



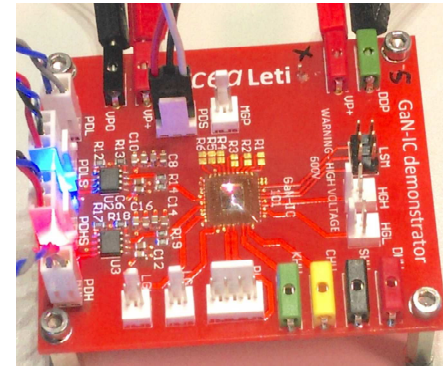
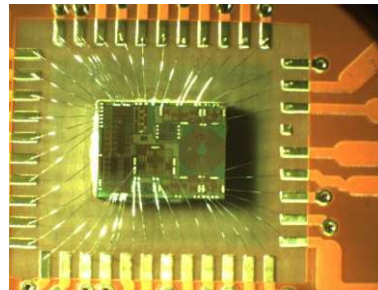
*Full integration – direct AC/AC*



- Product target: Micro voltage supply 230VAC/5V/1W on one die!
- high frequency > 1MHz
  - direct grid plug (AC 230V)



power transistor integration,  
pre-driver, inductances



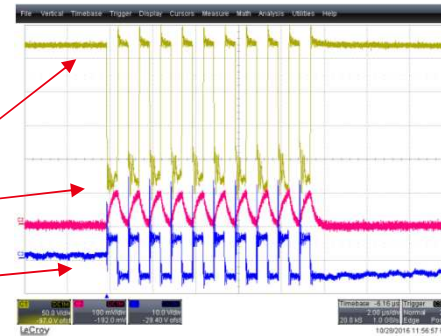
→ Results

- 250V
- 1MHz commutation
- 1A

250V commutation at 1MHz

Inductive load current

Tension pre-driver





## EXAGAN: A LETI STARTUP (SINCE 2014)



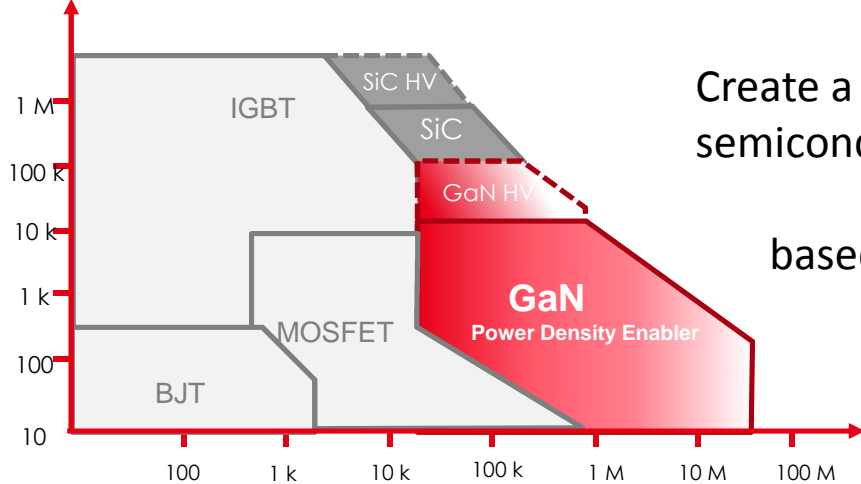
- Spinoff from Leti and Soitec
- Headquartered in Grenoble (Minatec)
- Power transistors 650/1200 V
- Proprietary G-FET™ 200 mm technology for full CMOS fab compatibility



Accelerate your systems roadmap toward 99% + energy efficiency,

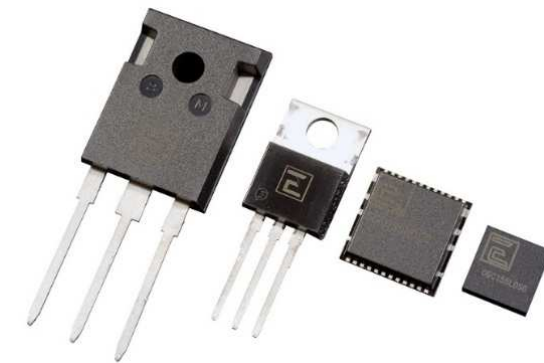
with faster, cheaper and cleaner GaN based power conversion solutions

Power By Application (W)



Create a new global leader in power semiconductor with a startup approach,

based upon a unique GaN/Si technology and robust fablight supply chain



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Marketing Strategic Manager @CEA-LETI



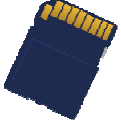
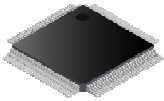













































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# PLANCHE DE PICTOS

										
	DISPOSITIFS MÉDICAUX	INTERNET DES OBJETS	CAPTEURS	IMAGING SENSOR	SERVEURS ET CALCUL INTENSIF	NANO ÉLECTRONIQUE	COMPOSANTS PHOTONIQUE	ÉNERGIE ÉLECTRONIQUE DE PUISSANCE	SÉCURITÉ	RF
										
										
										
										
<b>0</b>	<b>1</b>	<b>2</b>	<b>4</b>	<b>3</b>	<b>5</b>	<b>6</b>	<b>7</b>	<b>8</b>	<b>9</b>	