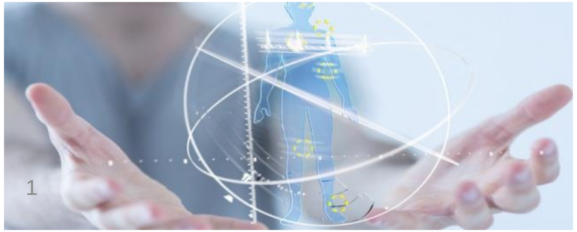






Nouvelles perspectives pour les technologies RF GaN

V. Di Giacomo-Brunel, JNM 2024, 06/06/2024



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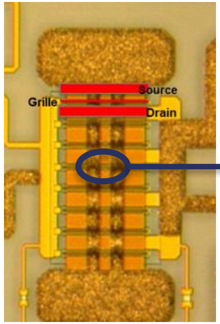
UMS
United Monolithic Semiconductors

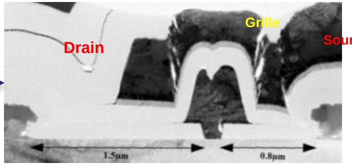
Outline

- Introduction: GaN HEMT
- Markets, Applications and players
- Panorama of available GaN Technologies
  - Examples from UMS portfolio
- Trends for GaN technology developments
  - Examples from UMS Roadmap
- Challenges
- Conclusions

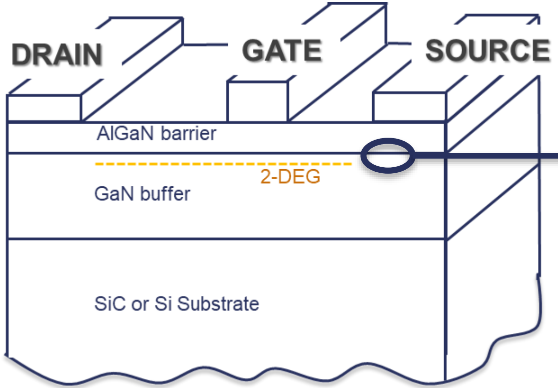
Introduction

GaN-based High Electron Mobility Transistor

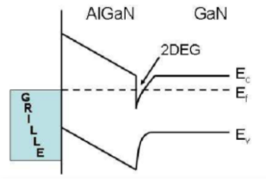




Zoom on gate area



Schematic representation



Working principle

- Physical properties of AlGaN/GaN HEMT:
  - Wide energy bandgap
  - High electron mobility
  - High saturation velocity

Si	GaAs	GaN
1.1 eV	1.42 eV	3.4 eV
1400 cm²/V·s	8500 cm²/V·s	1500 cm²/V·s
1 x 10^7 cm/s	1 x 10^7 cm/s	2.5 x 10^7 cm/s

Alternative barrier: InAlN/GaN, AlN/GaN, …

Why GaN?

- Wide energy bandgap ➔ High voltages and high temperatures handling
  - Higher junction temperature (200 to 250°C vs 175°C in GaAs)
  - Higher robustness
- High sheet carrier density ➔ High currents and power densities
- High thermal conductivity on SiC substrate ➔ High dissipated power handling
- Easier impedance matching ➔ Suitable for wideband applications

High-power and high frequency application, even in harsh environmental conditions

Drawback?
Mainly costs..

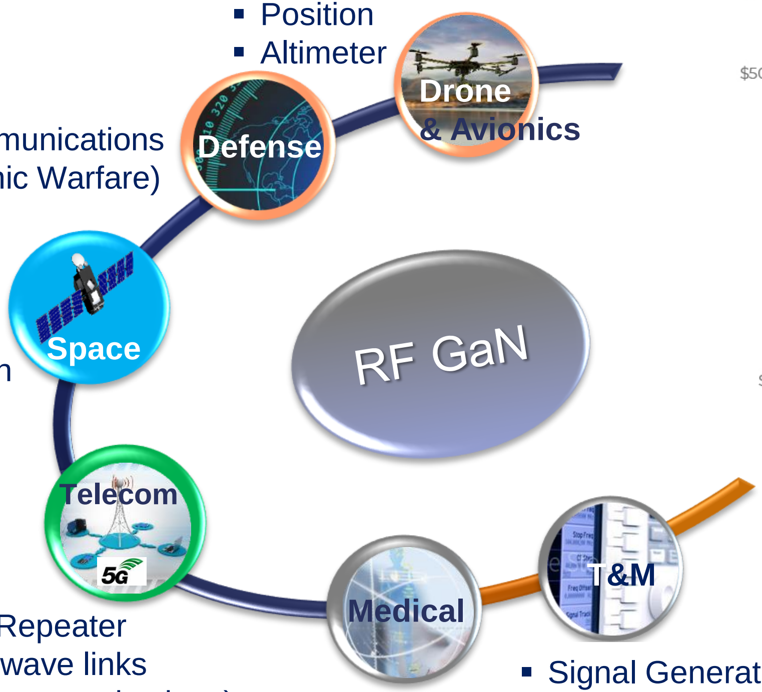
GaN-on-Si can be a good alternative for cost-driven applications, trading-off lower cost with thermal management

RF GaN Applications and Markets

- Collision avoidance
- Position
- Altimeter

- Radar
- Military Communications
- EW (Electronic Warfare)

- New space
- SatCom
- Earth Observation
- Localisation
- Science Missions



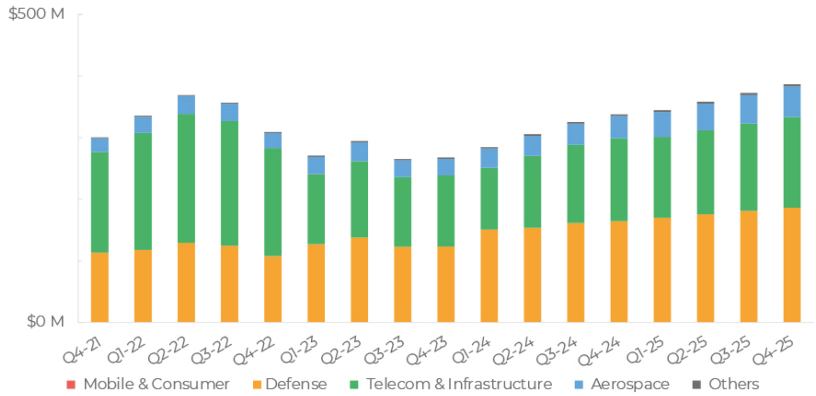
- 5G RAN, FWA, Repeater
- PtP, PtmP microwave links
- VSAT (Satellite communications)

- Imaging
- diagnostics

- Signal Generators and Analyzers

2021-2025 RF GaN device market revenues by market segments ($M)

(Source: RF GaN Compound Semiconductor Market Monitor Q1 2024, Yole Intelligence, March 2024)



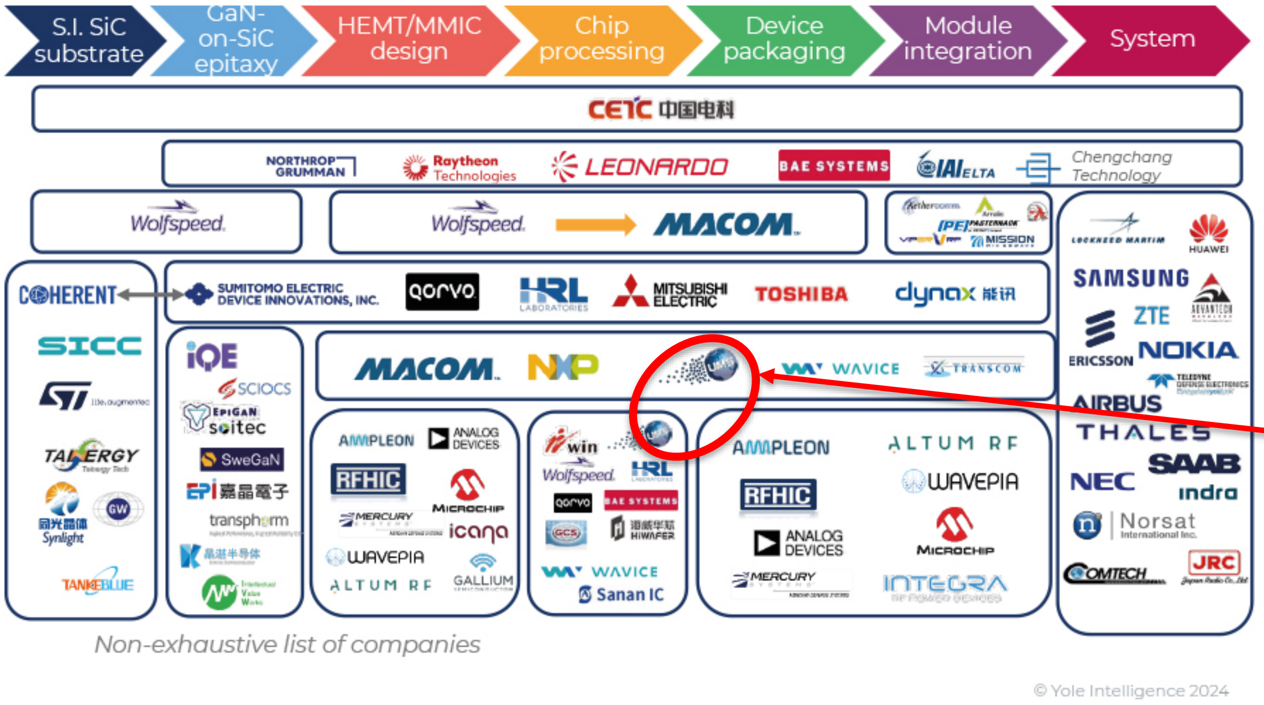
- ➢ High power
- ➢ High efficiency
- ➢ High frequency
- ➢ Robustness and Reliability under demanding conditions

- ➢ Too expensive for Mobile & Consumer

GaN-on-SiC Market Players

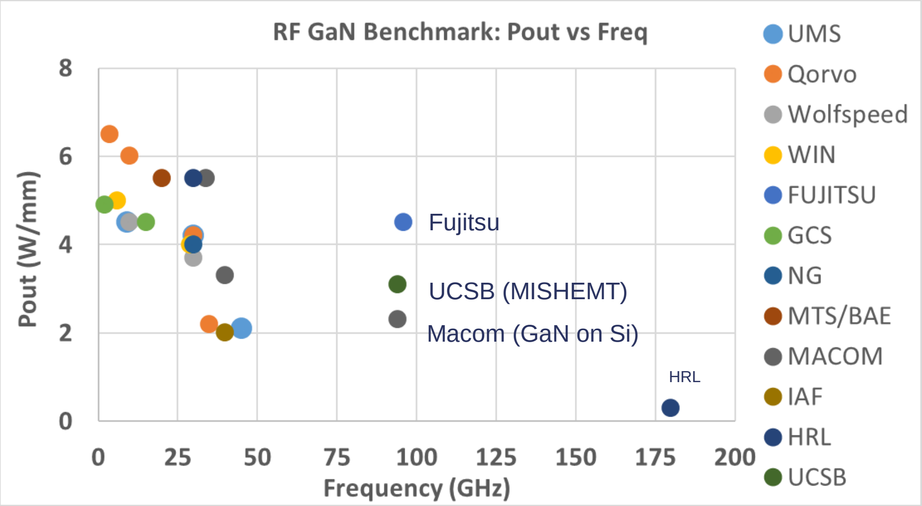
2023 global industrial supply chain – GaN-on-SiC capabilities

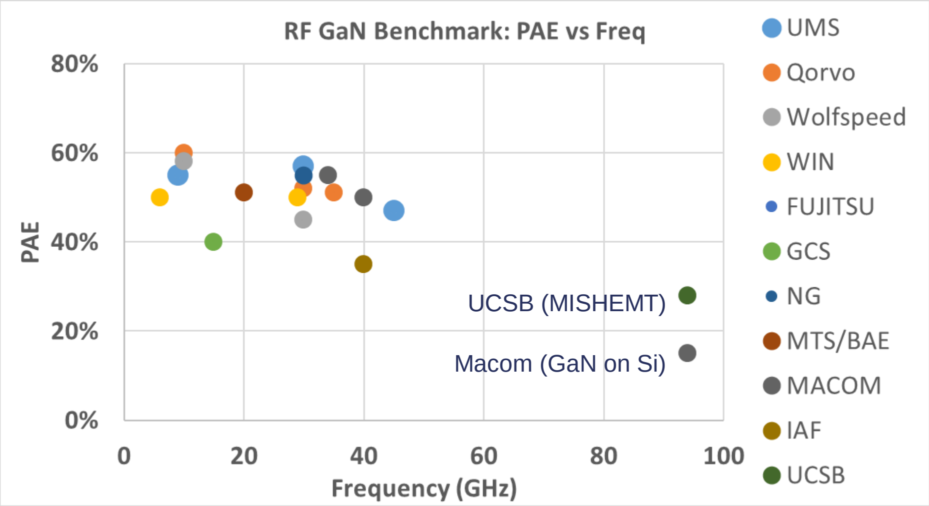
(Source: RF GaN Compound Semiconductor Market Monitor Q1 2024, Yole Intelligence, March 2024)



- Few players are able to largely cover the whole supply chain
- Lot of players located in Asia and USA
- Lack of European industrial actors for packaging and substrate
- UMS among few European foundries
  - can handle from technology design and fabrication up to module integration

RF GaN Performances Benchmark*

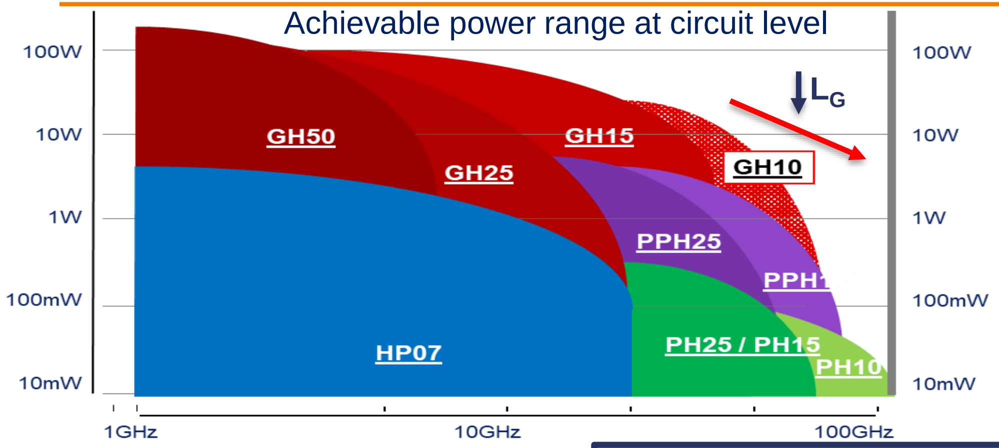




- Industrial technologies covering up to Q band
- Power and PAE decreasing with increasing frequency of use
- Similar performances provided by the foundries
- Few technologies available in E-band and more

*Non exhaustive list of technologies
*Performances from Labs missing

RF GaN Technologies: UMS portfolio



- **GH50**
  - 0.5-µm Gate length
  - 6 W/mm
  - 50 V
  - Power-bar only (Hybrid IC)

- **GH10**
  - 0.10-µm Gate length
  - 2.2 W/mm
  - 15 V
  - Full MMIC (resistors, capacitors, self-inductors)
  - *In Qualification phase*

- **GH25**
  - 0.25-µm Gate length
  - 4.5 W/mm
  - 30 V
  - Full MMIC (resistors, capacitors, self-inductors)

- **GH15**
  - 0.15-µm Gate length
  - 4.2 W/mm
  - 25 V
  - Full MMIC (resistors, capacitors, self-inductors)

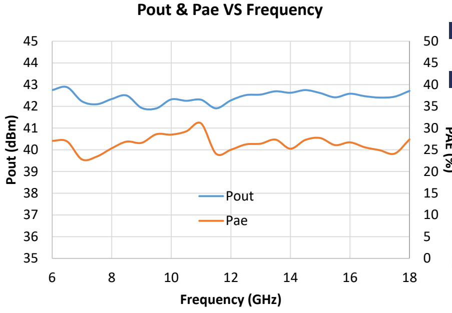
GH15-1x: One of UMS great successes

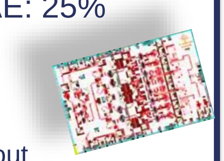
0.15-µm GaN HEMT on SiC

Multiple versions to fit several applications:
- GH15-10 → Space evaluated
- GH15-11 → with High Density Capacitors and Capacitors Over Via for compact design
- GH15-12 → with humidity protection for demanding applications
- GH15-13 → Optimized for Q-band

Wideband HPA

- Freq: 6-18 GHz
- Pout : 15 W
- PAE: 25%

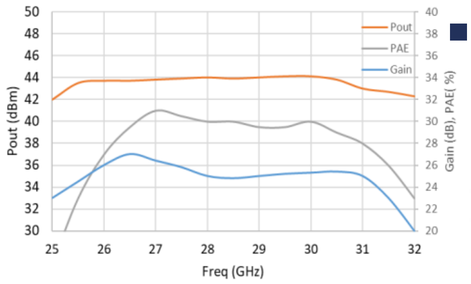


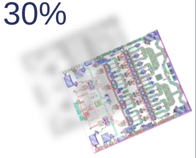


Pout
PAE

Ka-band HPA

- Freq : 27-31 GHz
- Pout : 25 W
- PAE : 30%

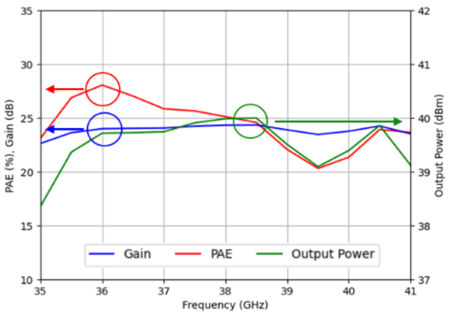


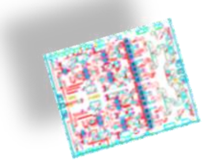


Pout
PAE
Gain

Q-band HPA

- Freq : 36-41 GHz
- Pout : 9 W
- PAE: 25%





Pout
PAE
Gain








What’s next?

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Drivers for GaN technology development

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Reduce environmental impact

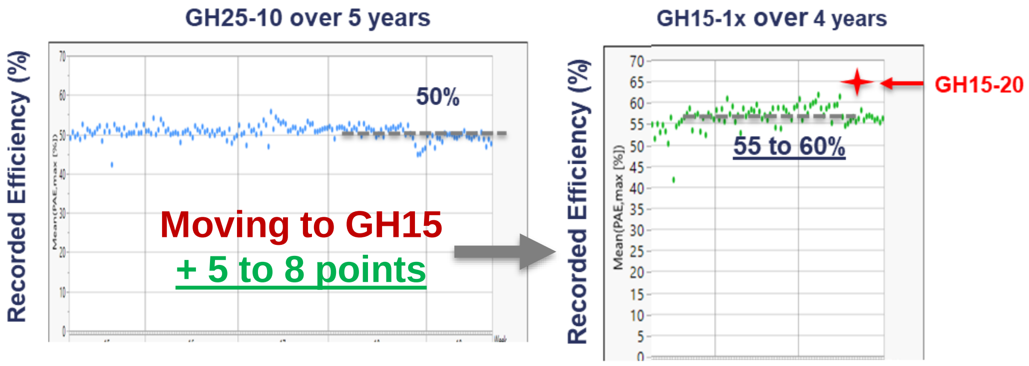
5G

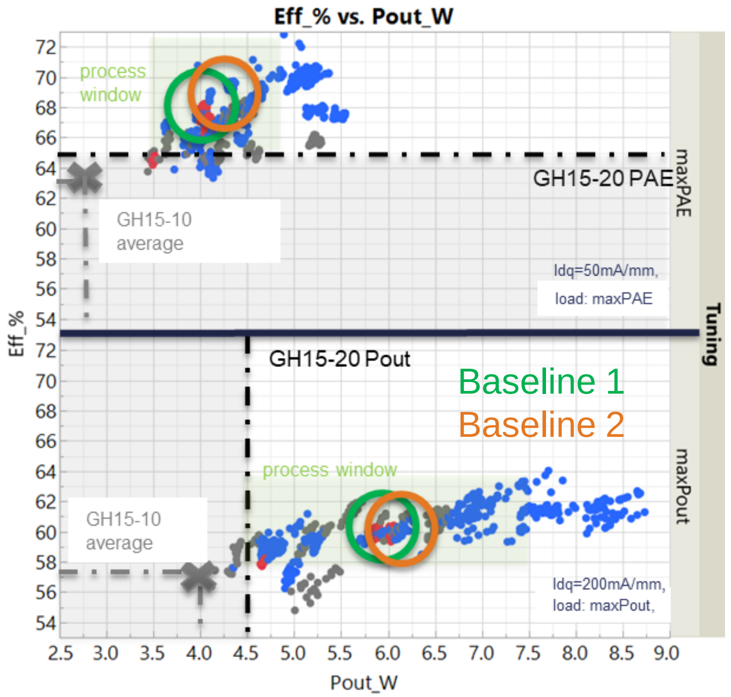
Improve Performances

Reduce costs

- **Higher efficiency and lower dissipation**
  - New generations of GaN technologies with higher power density and PAE
- **Higher frequencies**
  - Smaller gate-length to go up in frequency, thinner substrate to reduce inductances
- **Smaller sizes**
  - High density MIM capacitors and Capacitors over vias, compact transistor layout
- **Low-cost plastic packaging**
  - Mechanical and humidity protection
- **Compatibility with advanced packaging and heterogeneous integration**
  - Bumps, hot-vias

New technology generations: High Efficiency





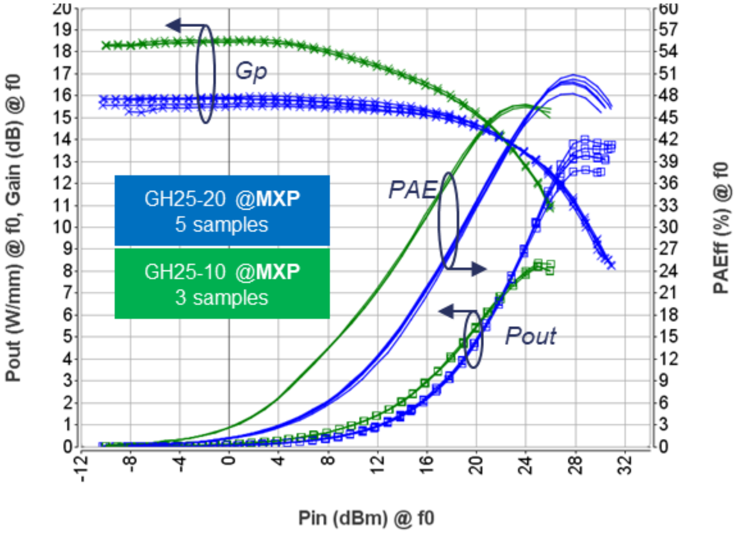
Higher Efficiency, lower power dissipation and consumption

- **GH15-20** Target: 5 points of PAE more than GH15-1x
- Today status: 2 baselines allowing the best performance/reliability trade-off

* All power measurements at 9 GHz

New technology generation: High power

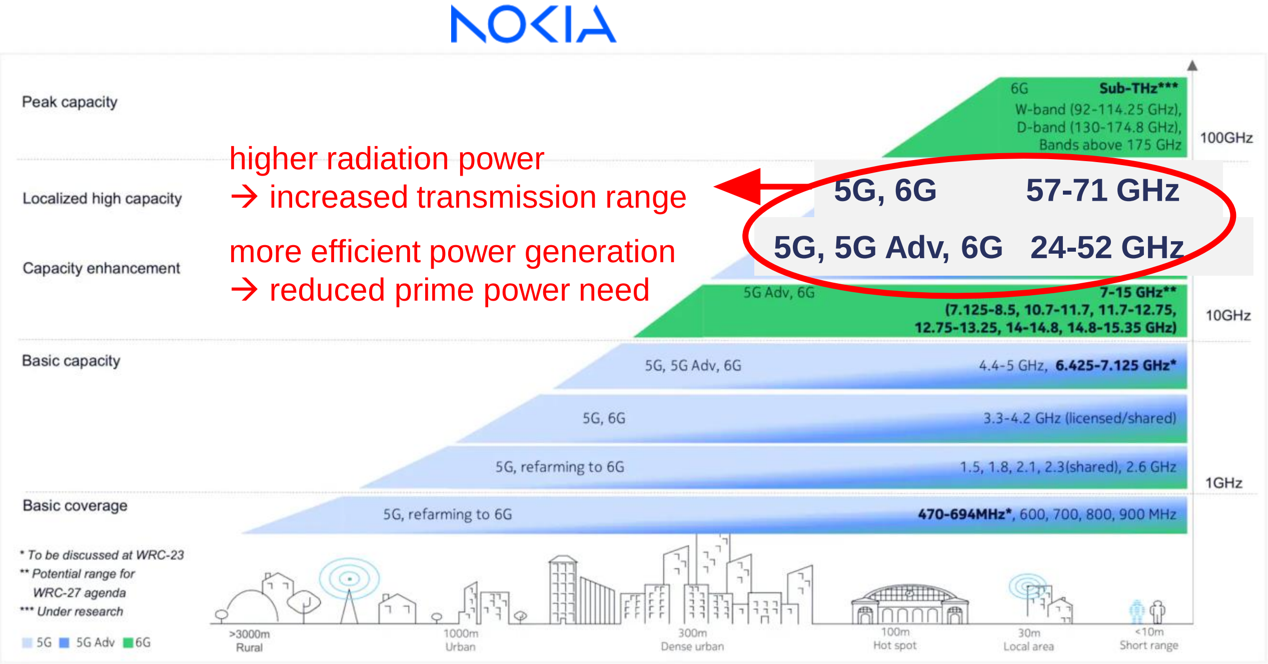
- **Higher Power density, smaller size and higher integration in the system**
- **Higher efficiency, lower power dissipation and easier thermal management**
- **GH25-20** target is Pout > 10 W/mm
- Today status: significant power increase compared to GH25-10, leading to a higher efficiency



Development phase,
Preliminary results

New technology generation: High frequency

- Main application: high data rate communication links
  - Telecom: 5G, 6G
  - Space: Inter-satellite links
  - Defence: EW, radar



New technology generation: High frequency

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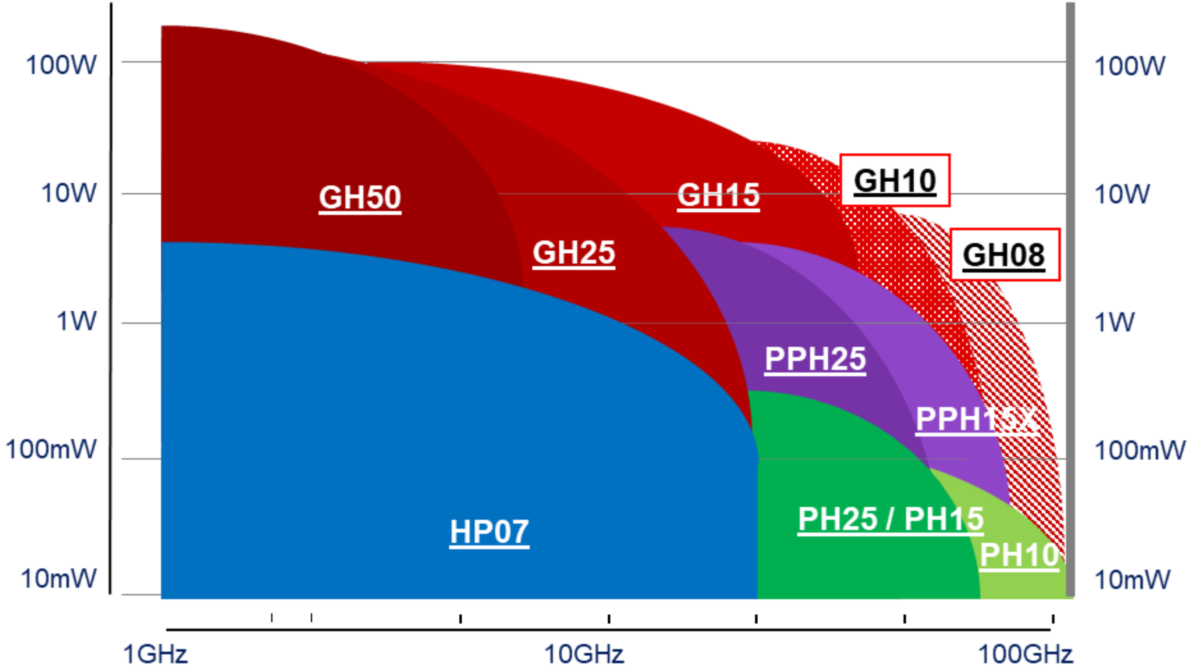
- Main application: high data rate communication links
  - Telecom: 5G, 6G
  - Space: Inter-satellite links
  - Defence: EW, radar
- UMS answer:
  - GH10, up to V band
  - GH08, up to E band



- What about the D-band for 6G? GaN on SiC is probably not the best answer..

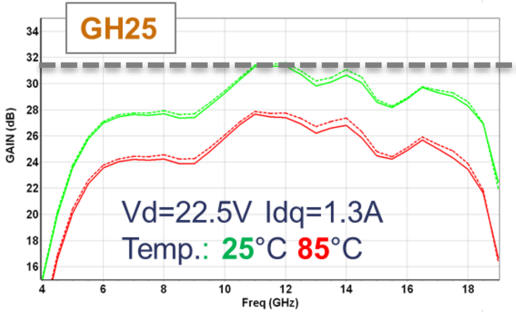
Not only for new needs…

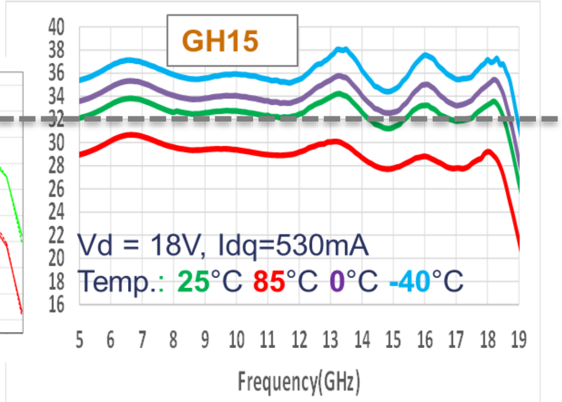
- New technology generations
  ➔ new product generations

E.g.: Wide-band HPA passing from GH25-10 to GH15-10

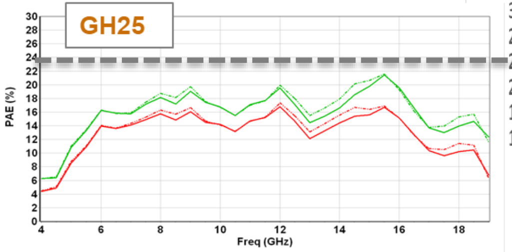
- ➢ More margin on the upper cut-off frequency
- ➢ Higher linear gain associated to reduced ripple
- ➢ Better PAE

Linear Gain

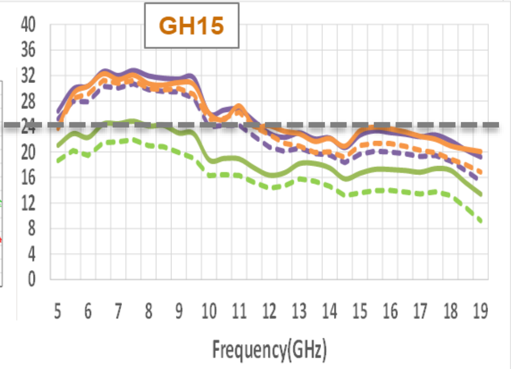




PAE



Vd=22.5V Idq=1.3A
Temp.: 25°C 85°C

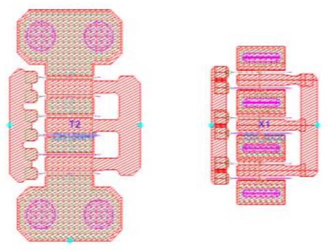


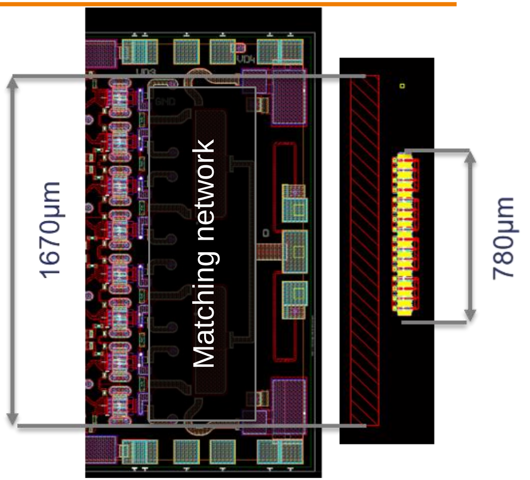
Vd = 18V, Idq=530mA
Temp.: 25°C (line) 85°C (dashed)
Pin: 8 , 16, 22 dBm

Size reduction

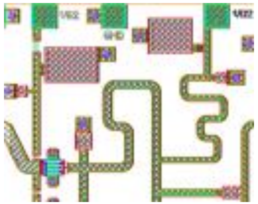
- Compact transistor layout
  - With Individual Source vias which also improve performances

GH15-11 → GH15-13

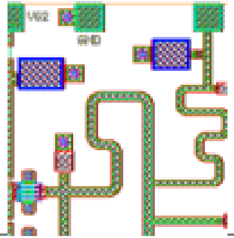


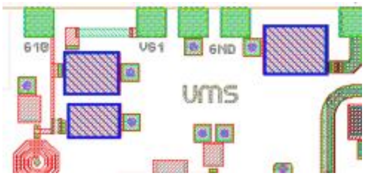


- High density capacitors (DHD) and Capacitors over-vias (COV)
  - Better decoupling in smaller room

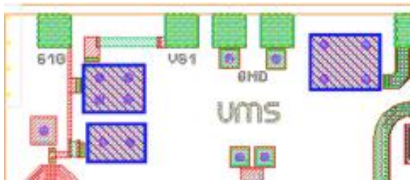


DLD → DHD



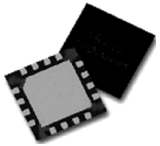


COV



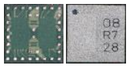
Compatibility with Packaging

- Low cost plastic packaging



- Advanced package for high integration
  - Heterogeneous integration: GaN, GaAs, SiGe
  - BGA platforms:
    - BGA platform for GaAs and Si

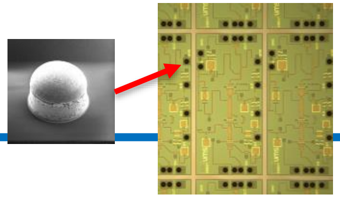
    - BGA top Cooling (GaAs & GaN)



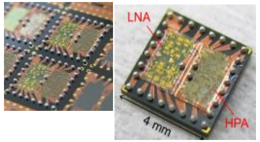
  - Heterogeneous FO-WLP (Fanout Wafer level Packaging) – 2D
  - Heterogeneous FO-WLP & PoP (Package on Package) – 3D

Needed Technology Options:

- Mechanical protection
- Humidity protection
- Hot-vias
- Bumps



RFFE26-28GHz FOWLP for



GaN & GaAs

Challenges

- **Technology**: Gate-length reduction for frequency increase makes more difficult the performance/reliability trade-off

- **Modelling**: high-frequency effects tricky to model, electro-thermal modelling mandatory for such high power densities

- **Packaging**:
  - Need for a package platform able to manage high dissipated power at high frequencies, with limited impact on performances
  - Industrialization of System in Package solutions for heterogeneous integration

- **Design**: being able to simulate in comprehensive way the 2.5 and 3D integration of SiP

- **Supply chain**: Sovereignty and geopolitical concerns push more and more towards a European supply chain

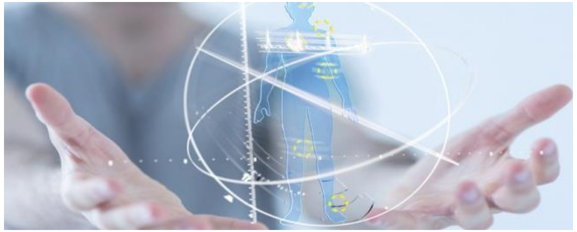
Conclusion

- RF GaN technologies emerged into the last decade, becoming unavoidable for performing and efficient Defence systems
- The role into Space application is expected to become more significant with SatCom and New Space
- Telecom infrastructures benefit from GaN superior performances to replace LDMOS and develop 5G and 6G
- Challenges remains to fully exploit GaN potentialities for high frequencies, high efficiency and high integration applications







Thank you for your attention!

Questions?

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