LDMOS to GaN

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Why migrate from LDMOS to GaN?

- Before we try to answer that, lets look at why we are where we are.
  - LDMOS is the dominant technology for high power SSPAs (outside A & D)
    - Up to a certain power after which you need TWTs!
      - Or combine many transistors & accept the losses
    - Up to a certain frequency ~3GHz
  - For a decade or more GaN has been adopted in Aerospace & Defence applications
    - …in RADARs, Jammers & increasingly in Milcomms
    - So, GaN is well established in some markets

Why is LDMOS dominant today?

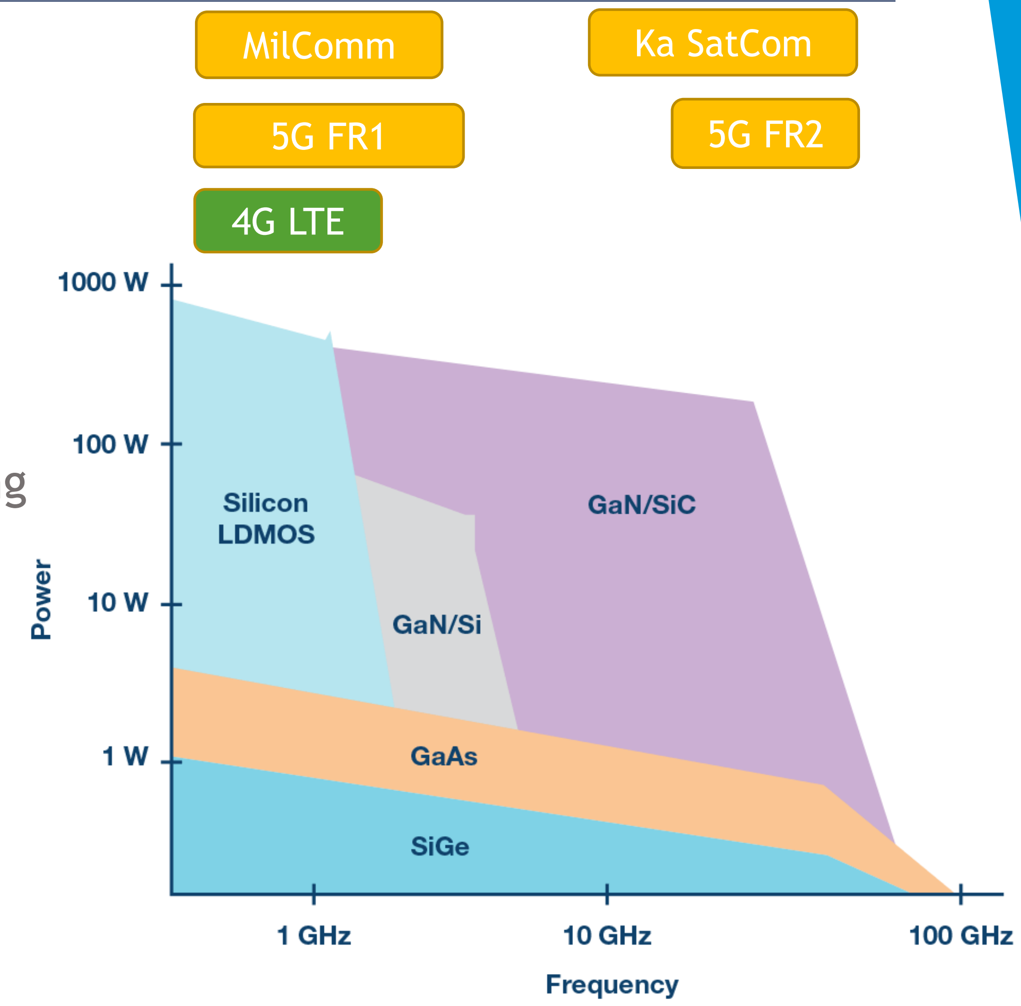
- RF Silicon LDMOS (Lateral DMOS)
  - rose to prominence during the early 1990s, due to its greater capability over Silicon Bipolar transistors
    - by delivering better linearity, gain & efficiency at a lower cost.
  - It became the dominant technology for RF applications.
  - earned its dominant position in the late 1990s **due to its satisfying the evolving RF demands.**
- it had become default technology for Cellular PAs up to ~2700MHz.
- Became the default for RF amps, in industrial & medical applications.

Why change?

- LDMOS sustained its dominant position, **till now!**
- In our changing world there are **again** evolving demands for higher frequency, higher efficiency, greater instantaneous bandwidth & power.
- There are **new markets**; 5G, SatCom, wide-bandwidth Jammers
  - Upper sub-6GHz 5G bands cannot be implemented with LDMOS
  - 5G mmWave & Ku / Ka-band Satcom cannot be supported by LDMOS
- The reason for change is the same as that which made LDMOS king.
  - **The Market! – a need for satisfactory technology**

Change to what?

- There are other technologies can address higher frequency:
  - Gallium Arsenide (**GaAs**),
    - GaAs is long established for high frequency devices all the way to 100GHz, but it is low voltage, limiting the power it can deliver.
  - Silicon Germanium (**SiGe**),
    - Achieves high frequency but not too much power
  - Gallium Nitride (**GaN**)
    - High power density with better gain & instantaneous bandwidth at higher frequency



[Source Analog Devices]

Why now?

- Decades of development & **investment**
  - Resolving/minimising issues like the memory effect
  - Resulting in high frequency processes and high power processes.
- A number of applications in evolving markets NEED the combined benefits GaN brings
- Adoption by BTS, Macro & massive MIMO… a high volume market enabling cost-down.
- Adoption in ORAN – where there are many more players
- Outside of RF… this is the time for high volume EV production.
  - This is GaN or SiC devices

Time for change

- Leaders in LDMOS, like NXP have invested in a new high capacity GaN Fab
  - after using commercial GaN foundries as they recognize that the future of RF transistors will be GaN.
- LDMOS has not gone away & still has its applications.
  - Silicon Bipolar transistors are still in use today, but the volumes are very small.
  - The processes are old & arguably at risk.
- Emerging applications are demanding greater performance.
  - They simultaneously need greater instantaneous bandwidth, higher frequencies & higher power
- GaN is not ‘better’ than LDMOS per se, but in some applications it is the only technology that fits!
- It has been adopted in Aerospace & Defense applications for some time, but the wider adoption of GaN increases volumes & enables lower cost, through economies of scale.
- GaN is now mainstream & that is because of the reduction in cost & the wide array of devices; discrete transistors & MMICs that are currently available.
- It is possible to easily find a GaN part that meets your application needs.

Strengths of LDMOS

- Familiarity!
  - it is well understood
- Design techniques yield good results
- Maturity!
  - Processes are well established
  - Production yields are high!
- Cost
  - The gap is closing & this becomes less of an advantage

Strengths of GaN

GaN’s High Band Gap permits …

High Temperature operation

High Power density

Higher Ft

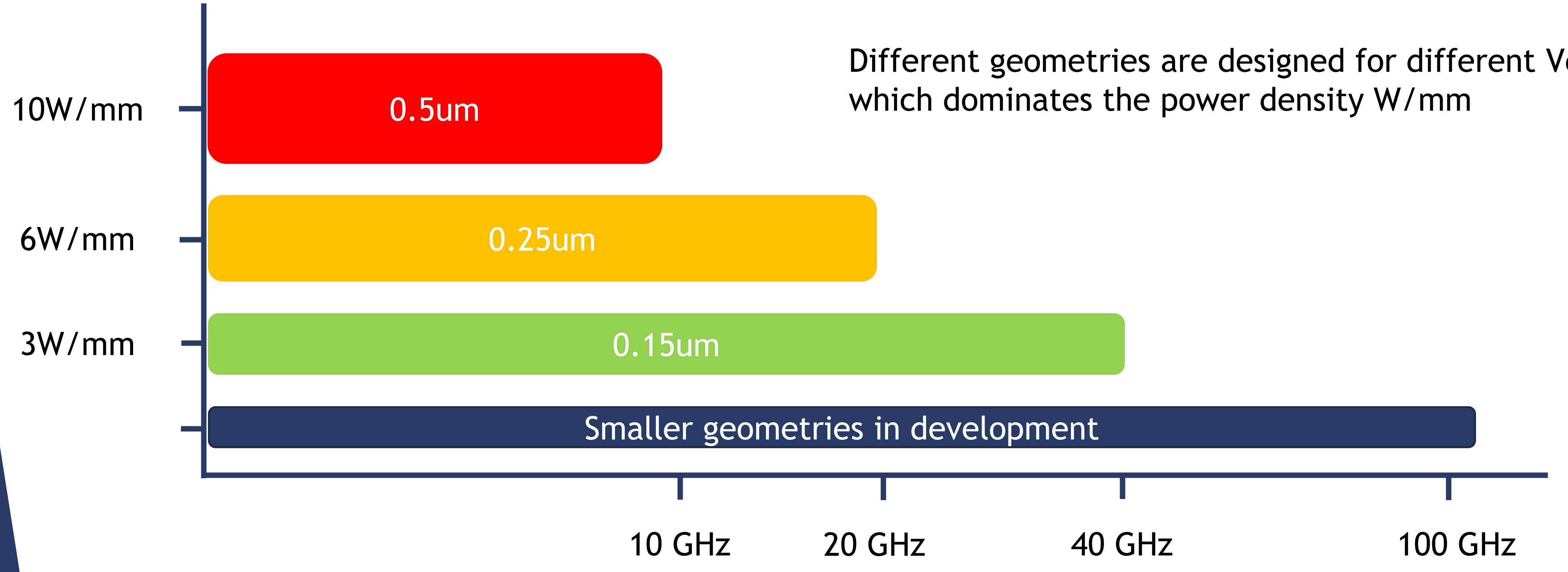
Large Instantaneous bandwidth

High gain at high frequency

= Better efficiency

- SiC wafers offer
  - very low Thermal Resistance
  - Robust devices

Not one GaN, but many flavours…



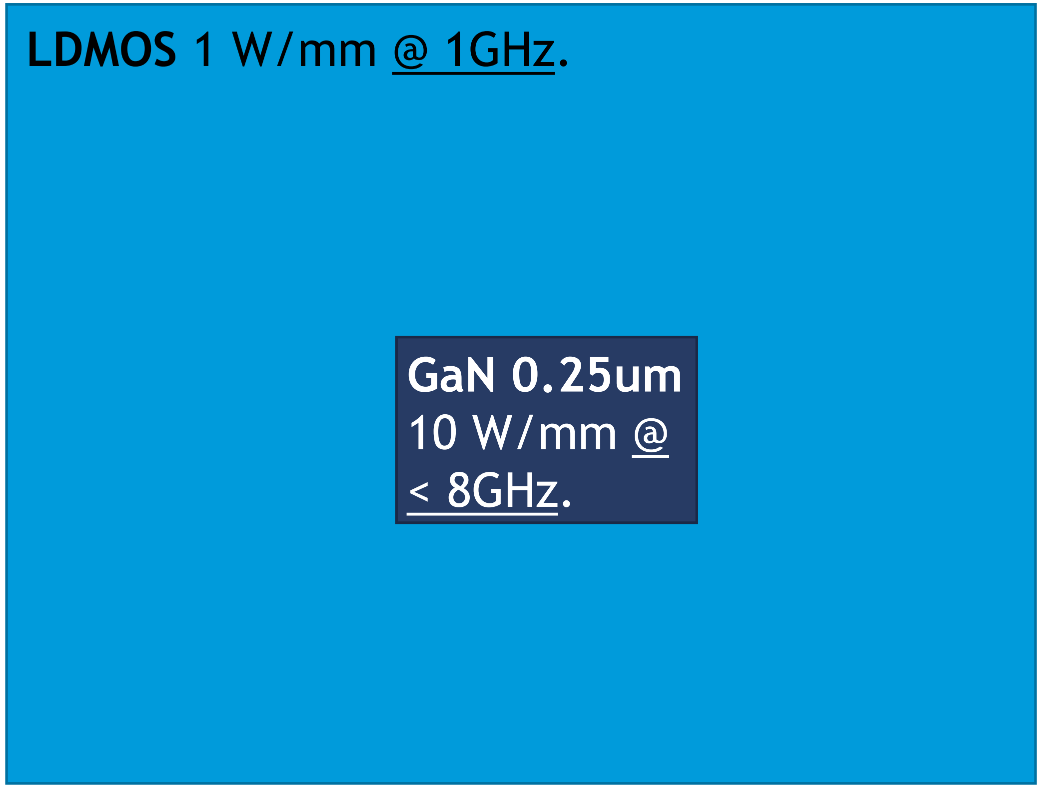
Different geometries are designed for different Vdd which dominates the power density W/mm

Power Density

Higher power density = higher thermal density

- More W/mm on die
- Hotspot is smaller,
- At higher temperature (225 DegC)
- Need SiC to achieve low Rth
- Drives need for better packaging to get 10E7 hours MTBF
- Drives need for better device attach. No voids!

For the same transistor PSat, GaN is much smaller than LDMOS



SWaP

Size, Weight and Power

- GaN’s attributes allow
  - Shorter line-up thanks to the gain
  - Smaller PAs:
    - since more power is delivered in a single device (less combining)
    - A single wideband PA can be developed
  - Lighter units:
    - less heatsinking, do to better efficiency
    - Smaller batteries
  - Higher power:
    - Greater power density

Barriers of conversion from LDMOS

- Was cost
- Was lack of experience of GaN
- Target markets were A&D, hence less need for linearity measurements
- Historic memory issues, making DPD tricky
- Depletion-mode transistors that require a negative Gate bias.
- Power sequencing is necessary.

What has changed?

- GaN die cost!
- Attitudes of Telecom's customers. Thanks to 5G – it is show-time for BTS
- Adoption in Satcom - an enabler for higher power Ku & Ka band SSPAs
- mMIMO needs power density/compact solutions
  - (more gain = shorter line-ups)
- Innovative packaging

Examples of where GaN used

- Cellular
  - BTS, mMIMO, O-RAN
- Milcomm,
- SatCom - Gnd Station & LEO
  - ‘New Space’ (LEO) can exploit GaN’s inherent tolerance to radiation
  - Intra-satellite communications
- Jammers
- RADAR (L, S, C, X, Ku)

Examples of integration/architecture to overcome issues

- Integration:
  - MMICs,
  - Tagore GaN switches with integrated CMOS driver,
  - GaN bias sequencing integrated into devices
  - Application Specific RF FEs
- Choice of architecture defined by application need
  - DPD/CFR,
  - ET (Envelope Tracking) PA
  - Balanced design
  - Doherty

The flood gates are open…

- GaN is mainstream!
- There are many GaN transistors & MMICs.
- Some vendors* are offering Commercial GaN **foundry** services
    - Where **you** get the design kit
    - **You** develop the component you want
    - **You** Simulate… Simulate… Simulate…
    - The **foundry** reviews your design
    - **You** sign-off
    - The **foundry** delivers your design as bare die or packaged parts.

* UMS, Wolfspeed

It’s not all about technology

- Vendors’ Application Competence
- Evaluation boards, example designs
- models
- IP ownership
- Geo-politics; manufacture in USA, European or in the South-China sea?
- Packaging
- Reliability
- Capacity… Ability to supply / Availability

END

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