mm-Wave GaN-on-Si HEMTs with a P_{SAT} of 3.9W/mm at 28GHz

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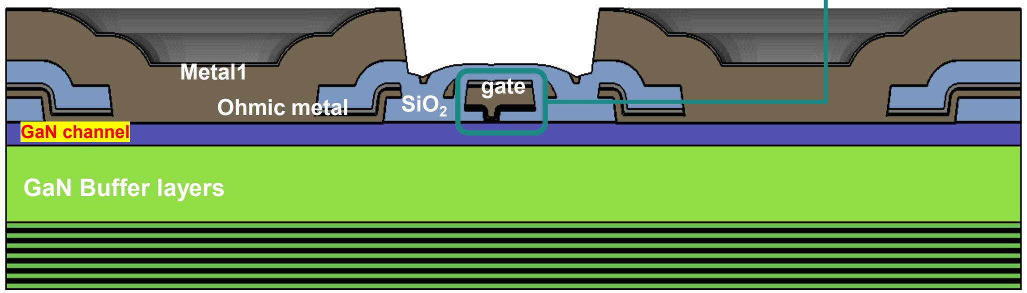
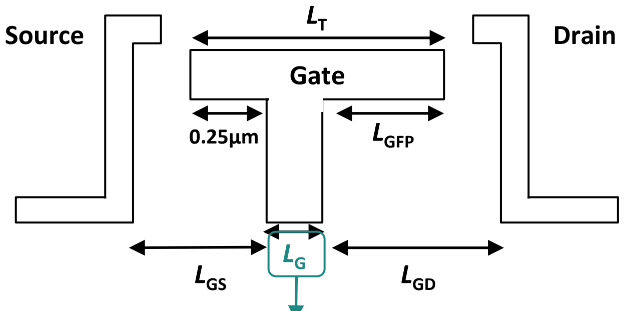
Motivation

Technology Downscaling for High Frequency Operation





L_G Downscaling to $\uparrow g_m \rightarrow \uparrow f_T, f_{max}$

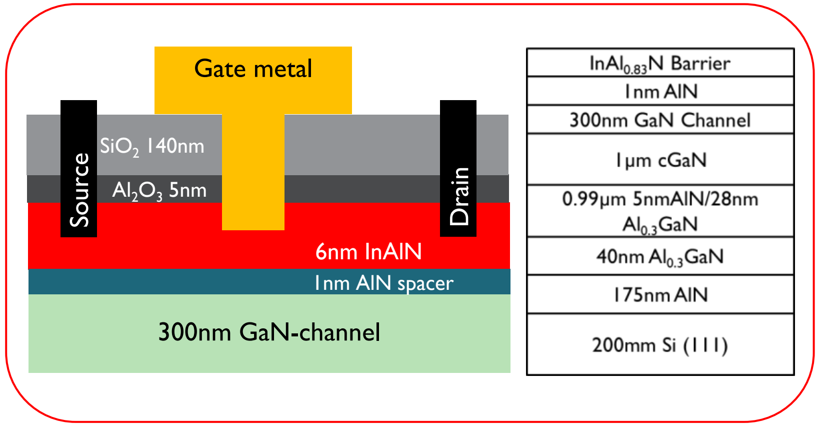
$\downarrow L_G$ causes $\uparrow$ Short Channel Effects

Vertical Scaling to mitigate SCEs

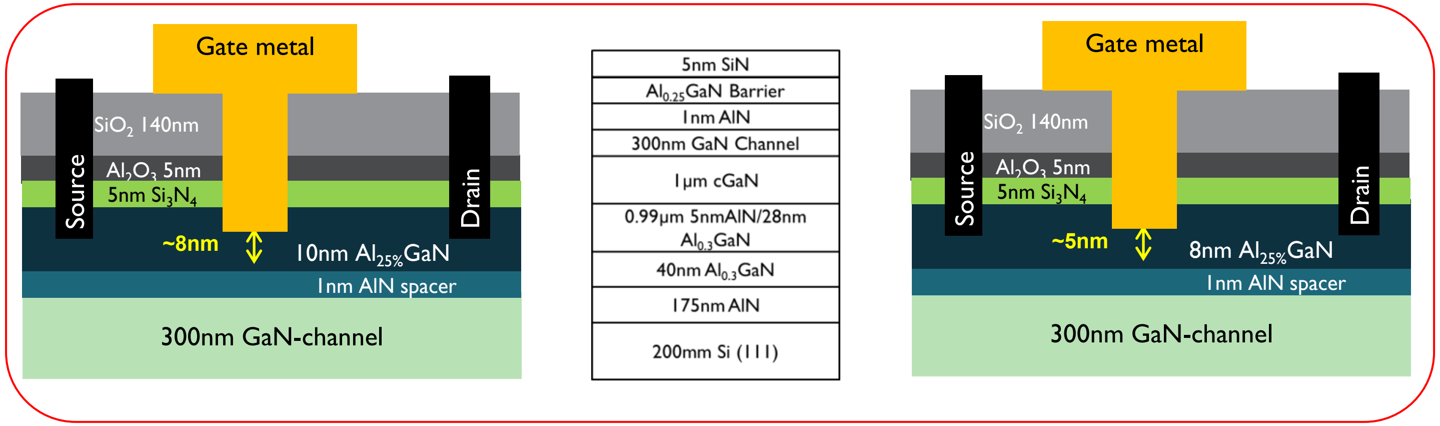
Motivation:
Quantifying the impact of barrier layer material and thickness choices on the large-signal performance of downscaled GaN-on-Si HEMTs

GaN-on-Si HEMTs with Varying Top Barriers

InAlN



AlGaN



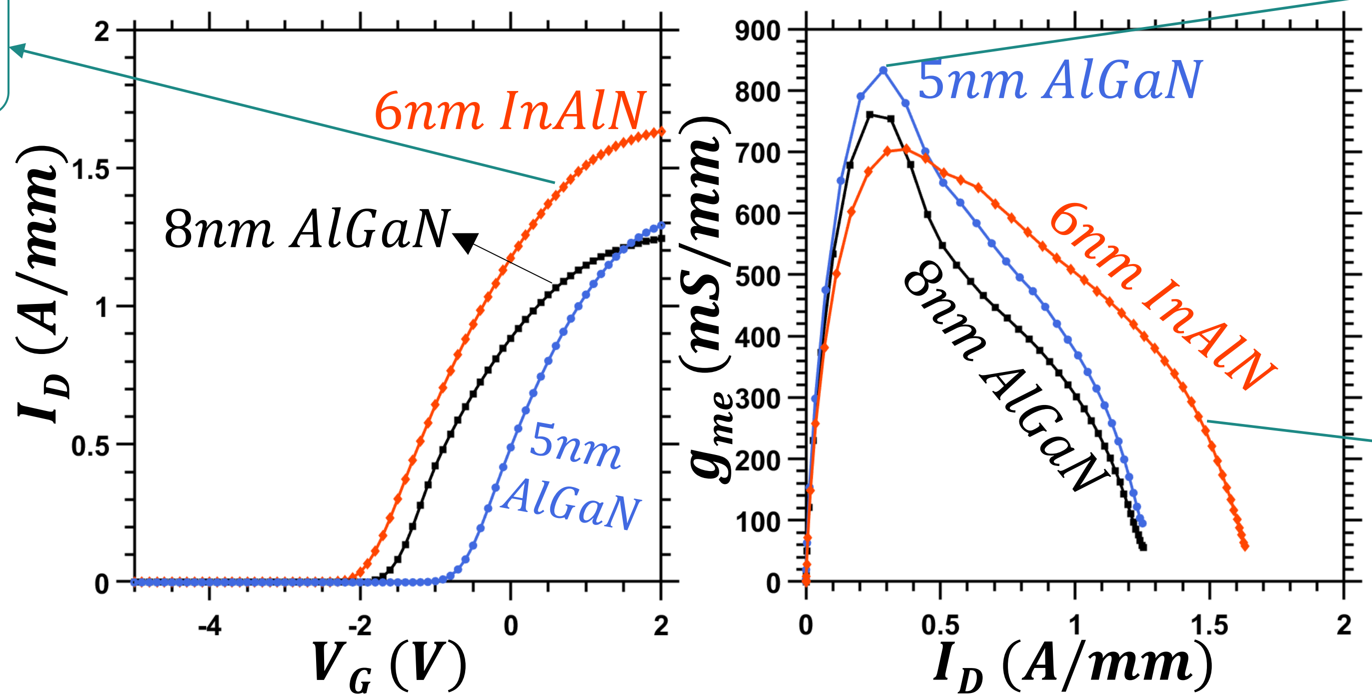
These GaN-on-Si devices have varying thinned down top barriers:
6nm InAlN
5nm AlGaN
8nm AlGaN

f_T/f_{MAX}: (3.3V)
100/120GHz
(L_g~100nm)

GaN-on-Si HEMTs with Varying Top Barriers

DC Characterisation

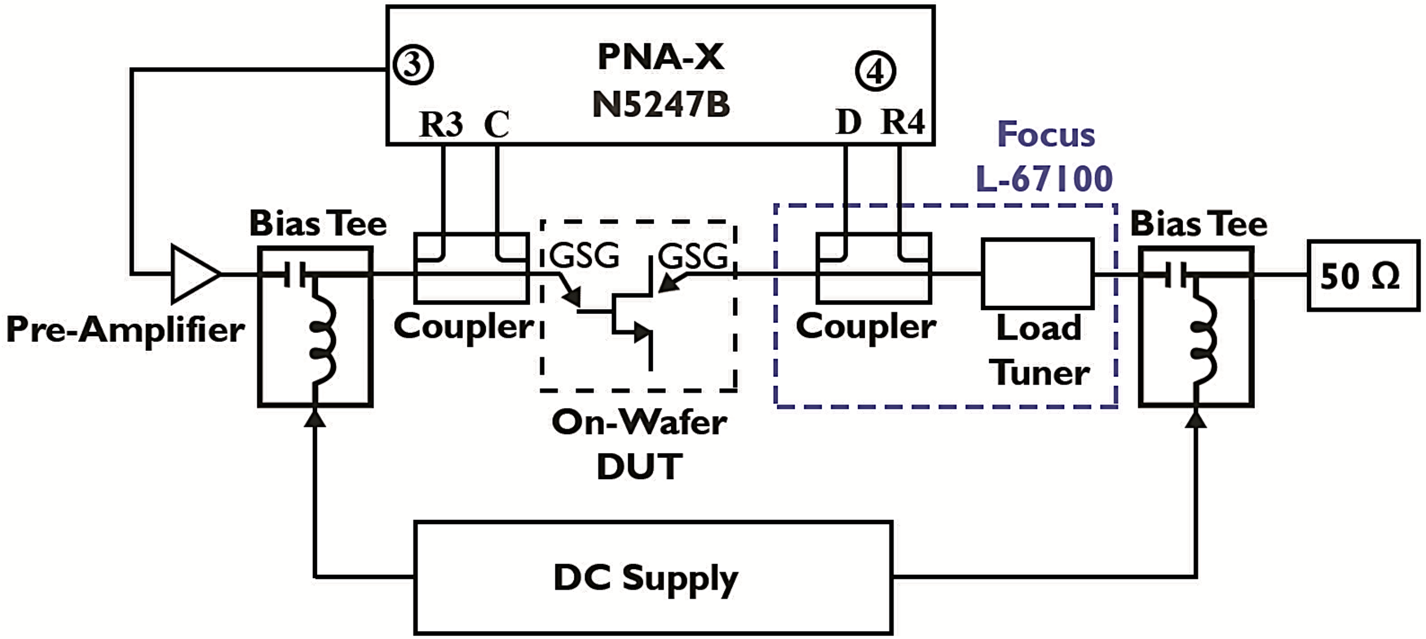
InAlN has a higher I_{max} owing to its larger n_s



Thinnest AlGaN barrier has the largest peak g_{me} due to its small CET.

InAlN shows a larger g_{me} at higher current densities.

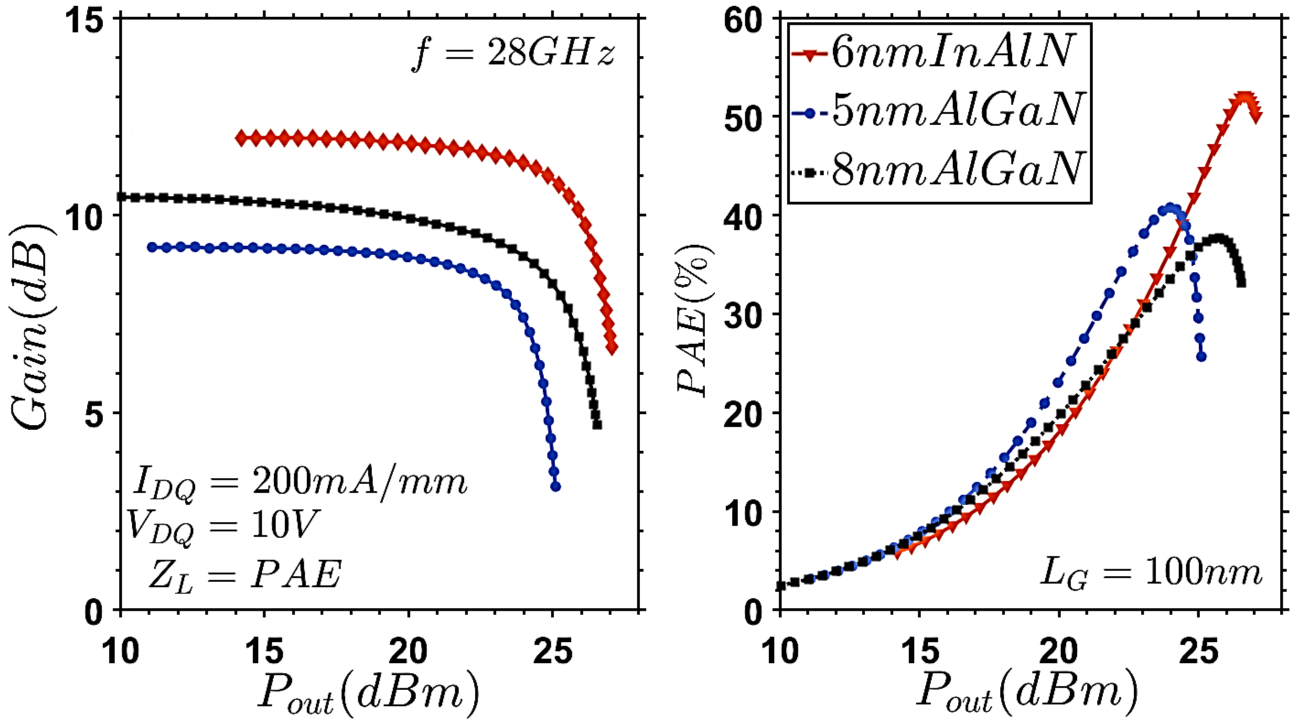
Large-Signal Characterisation Setup



Setup Specs	
f_0	28GHz
Tuning	Load Pull
Mode	CW
VSWR	11.5 (Passive LP)

L_G	N_F	W_F	L_{GFP}	L_{GD}	L_{GS}	T_{BAR}
100nm	8	25µm	0.25µm	0.67µm	0.54µm	Variable

Large-Signal Characterisation Results



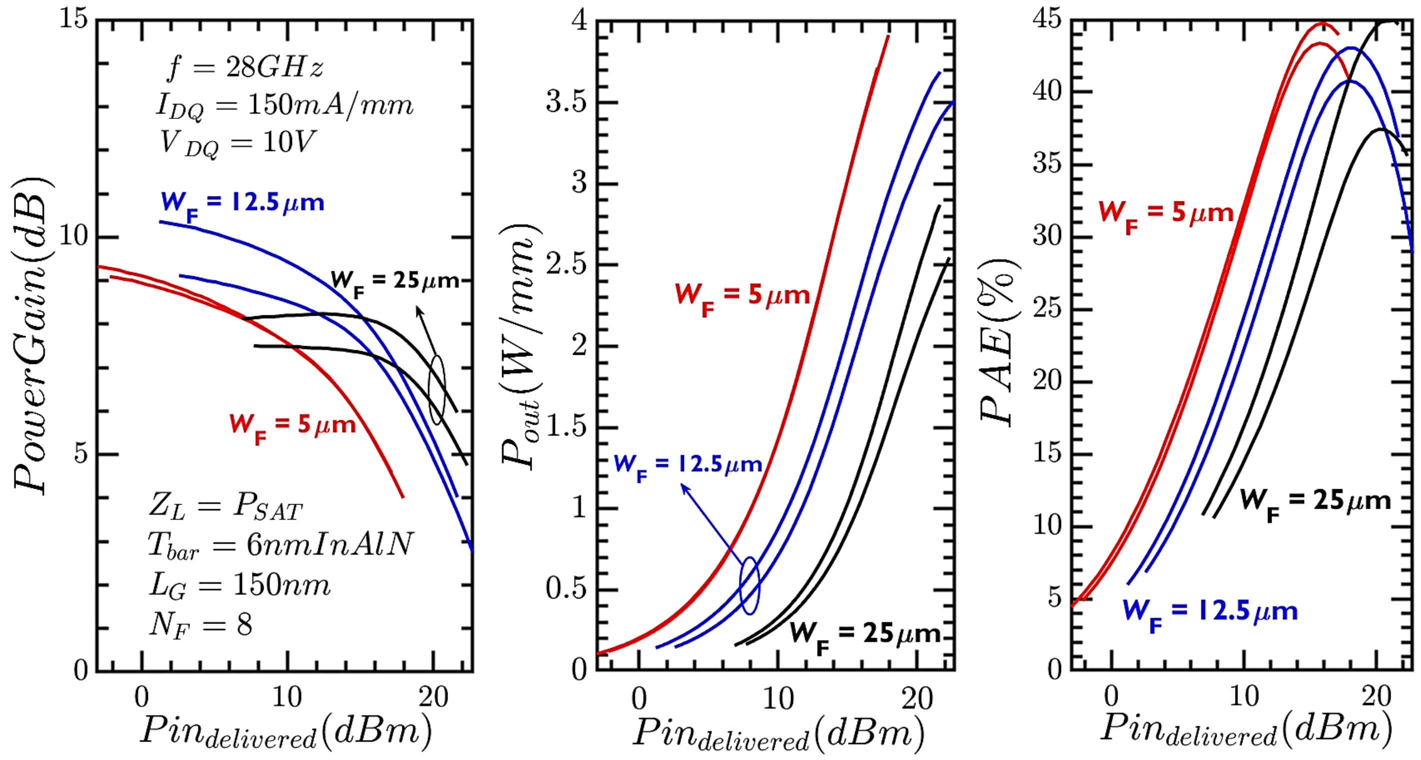
$$P_{out} = \frac{1}{8} I_{max}(V_{max} - V_k)$$

The higher I_{max} for the 6nm InAlN barrier boosts its large-signal performance compared to the AlGaN barrier devices. P_{sat}~2.8W/mm, PAE~50%.

L_G	N_F	W_F	L_{GFP}	L_{GD}	L_{GS}	T_{BAR}
150nm	8	Variable	0.25µm	0.67µm	0.54µm	6nm InAlN

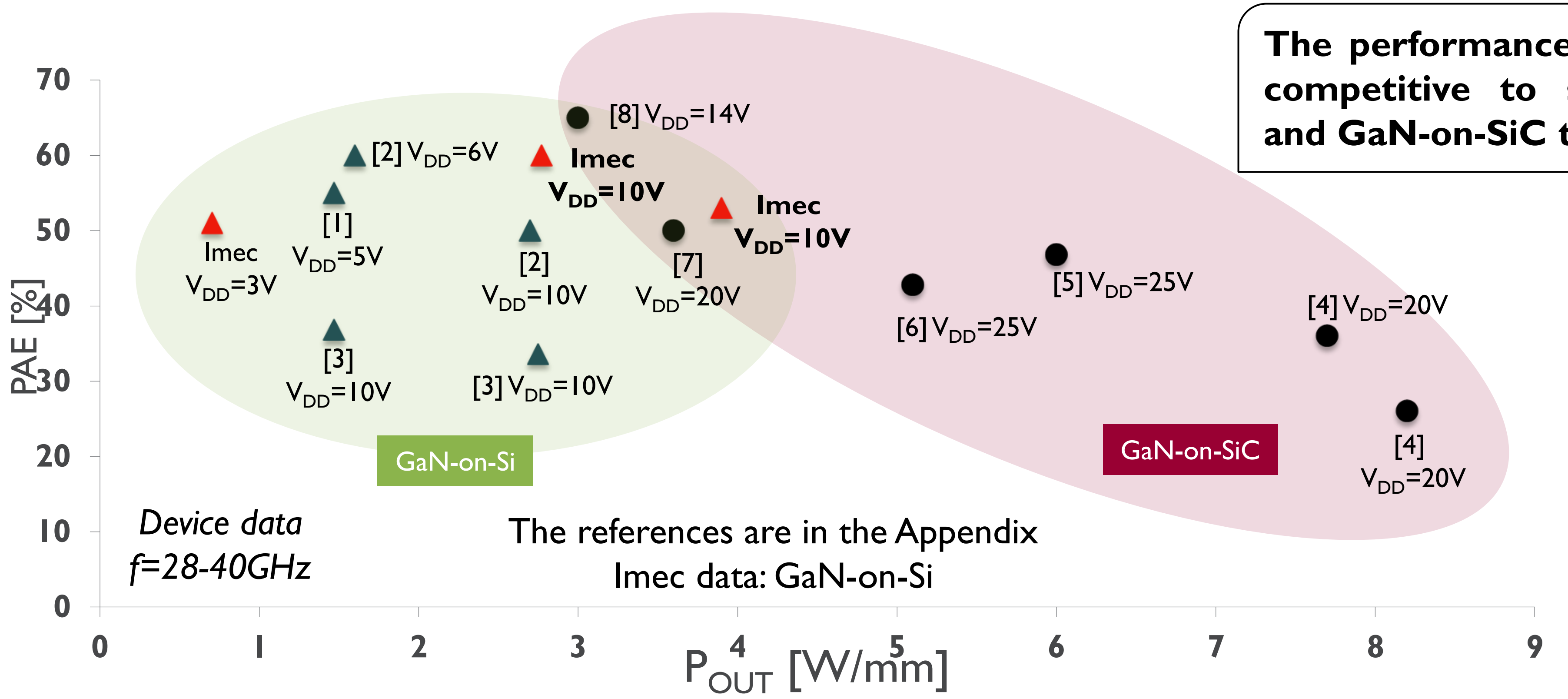
Large-Signal Characterisation Results

6nm InAlN: Device Finger-Width Variation



For a 6nm InAlN barrier, reducing the device width from 25µm to 5µm boosts P_{sat} to ~ 3.9W/mm with no distinct impact on the PAE (L_G~150nm).

Comparison with State-of-the-Art



The performance of these InAlN HEMTs is competitive to state-of-the-art GaN-on-Si and GaN-on-SiC technologies.

Summary

- InAlN/GaN-based HEMTs outperform AlGaN/GaN-based HEMTs owing to InAlN's higher I_{max} and better linearity:
  - At 100nm L_G (8x25μm): 2.8W/mm @ 50% PAE.
  - At 150nm L_G (8x5μm): 3.9W/mm @ 45% PAE.

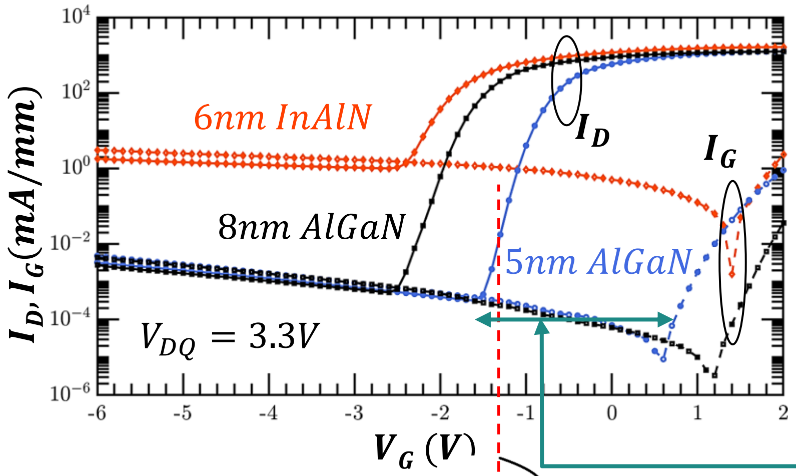
  → Suitable for power amplifiers in battery-powered user equipment at mm-wave.
- Accounting for several limitations can further boost the large-signal metrics:
  - Gate-leakage mitigation to improve the linearity for thin barrier devices
    - Adopting a MISHEMT topology can be useful.
  - Reducing R_S for thinner AlGaN barriers to improve the linearity
    - Replacing the 2DEG-based access regions with heavily N-doped GaN.
  - Layout optimisations

Thank you for your attention!

L_G	N_F	W_F	L_{GFP}	L_{GD}	L_{GS}	T_{BAR}
100nm	8	25µm	0.25µm	0.67µm	0.54µm	Variable

Appendix

More positive Vth and Gate Leakage: The impact on device linearity at large-signal



Typical *P*in sweep range

Unit	$P_{in,\,min}$	$P_{in,\,max}$
dBm	-5	20
V_{pp} (50Ω)	~0.36V	~6.3V