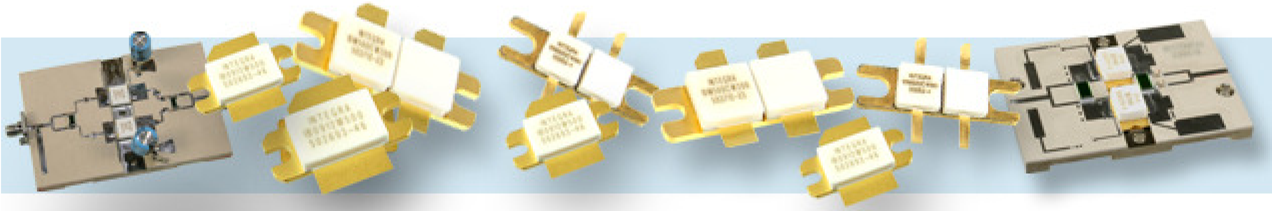
Integra TECHNOLOGIES, INC.

High Power GaN Transistors

John Walker
Integra Technologies, Inc.

Integra Technologies, Inc. • 321 Coral Circle • El Segundo, CA 90245-4620 •
Telephone: (310) 606-0855 • Fax: (310) 606-0865 •
 www.integratech.com

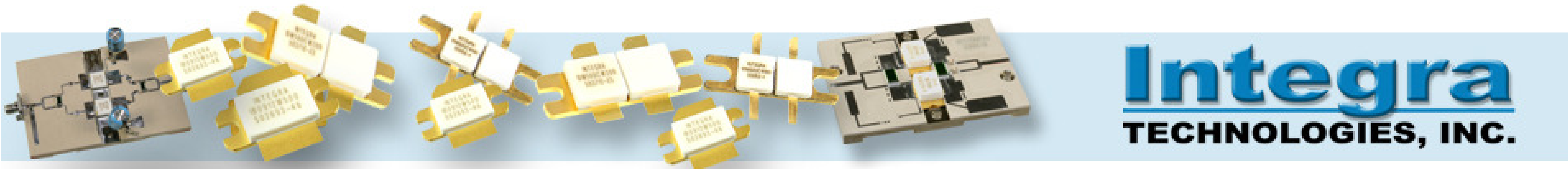


SCOPE

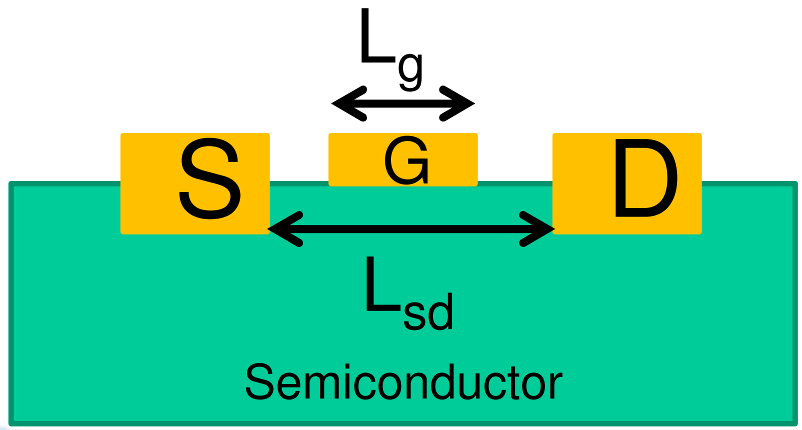
- >100W
- >1GHz
- Pulsed

AGENDA

- Technical Background
- Integra Die Manufacturing Process
- State-of-the-art GaN Products
- Conclusions



THE TECHNICAL PROBLEM



As frequency $\uparrow$

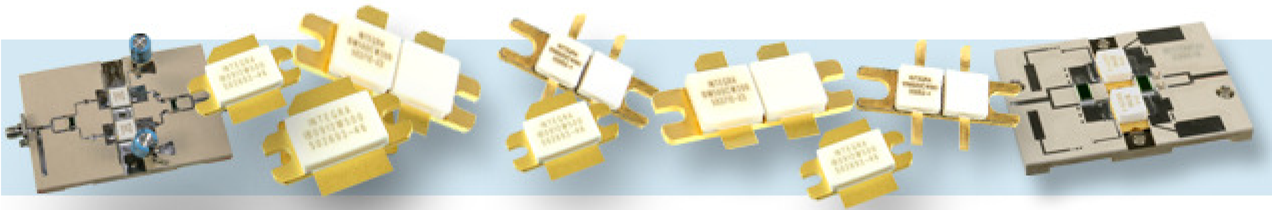
$L_g \downarrow$ (to reduce capacitance)

$L_{ds} \downarrow$(to reduce parasitic series resistance)

$V_{dsBK} \downarrow$ (Critical field remains constant)

RF output power /mm of gate width$\downarrow$

The solution: Use a semiconductor with as high a critical field as possible



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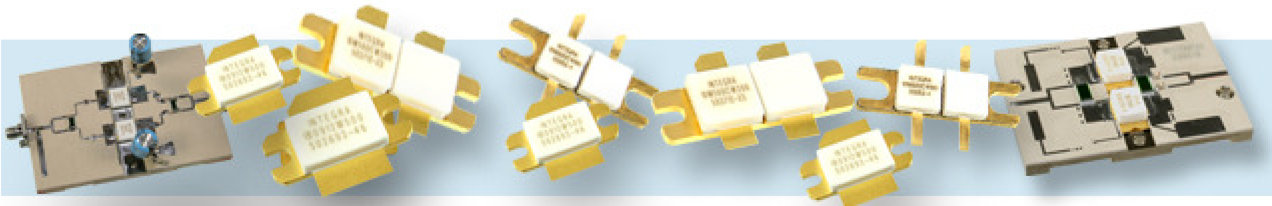
THE TECHNICAL PROBLEM (Cont.)

	Critical Field	Thermal Conductivity
Si	x	y
GaN	10x	y
SiC	10x	3y

- Cannot utilise factor of 10 power advantage of GaN c.f. Si using only GaN because of thermal limitation
- Even GaN on SiC will allow only a factor of 2-3 power advantage in CW
- GaN on SiC can offer >3x Si power in pulsed applications
- NB Higher power/mm^2 means lower Capacitance/Watt i.e. GaN can operate to higher frequency than Si.



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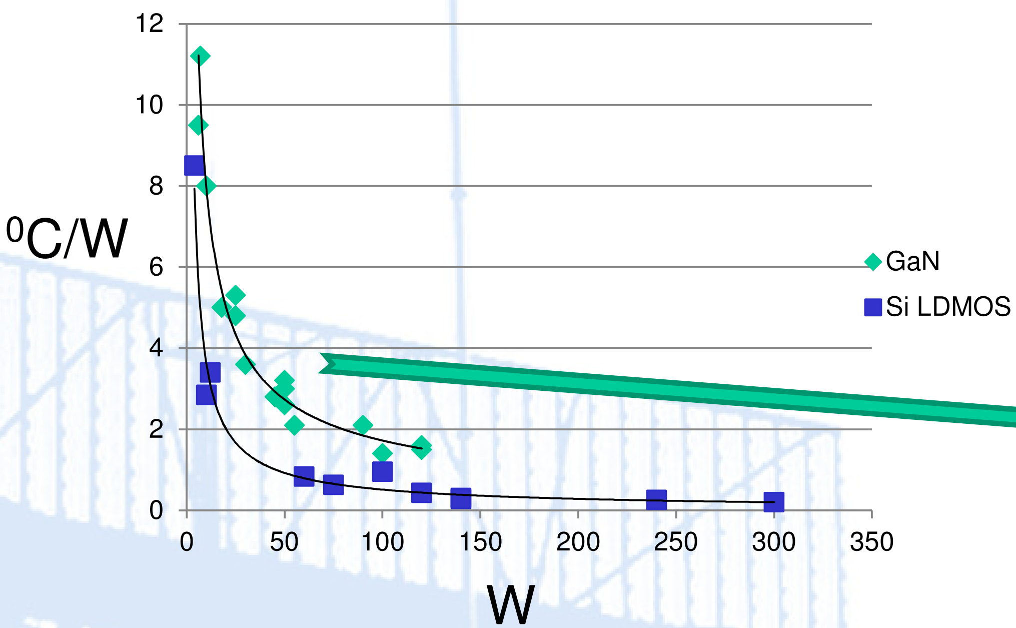
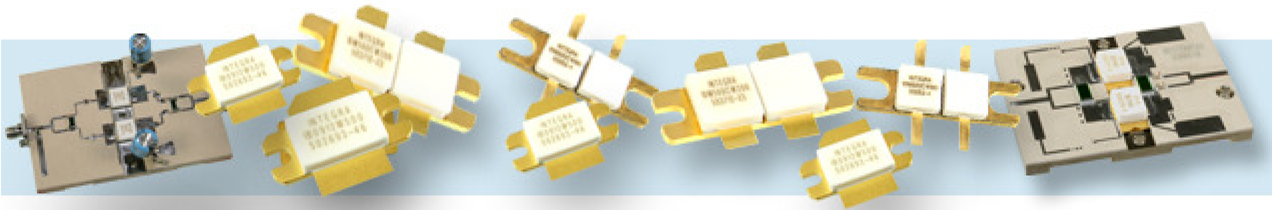
CW Thermal resistance of discrete single-ended transistors



$R_{\theta GaN} \approx 2.5 \text{ x } R_{\theta Si\ LDMOS}$

GaN is an ideal technology for pulsed applications!

16 manufacturers worldwide of pulsed GaN transistors!



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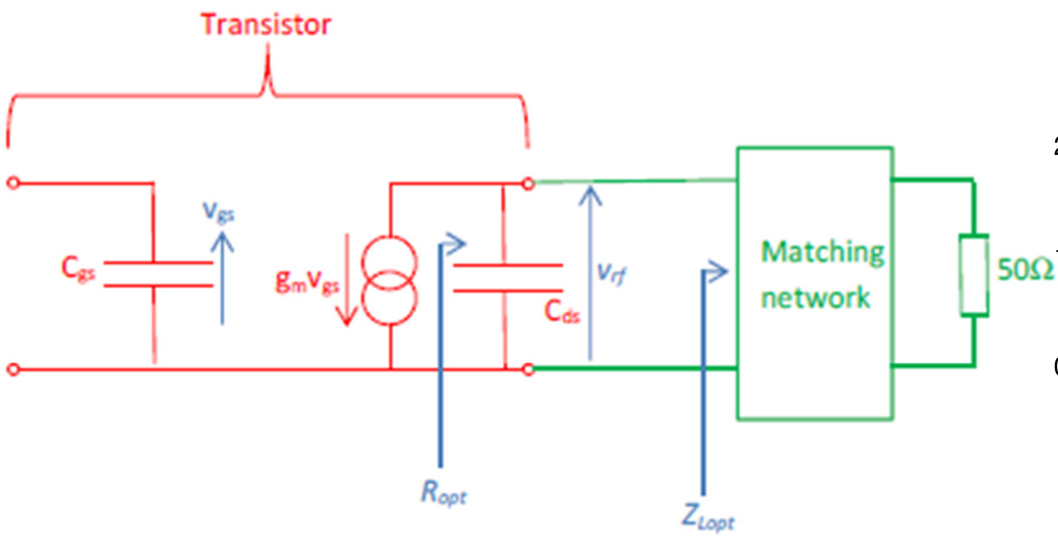
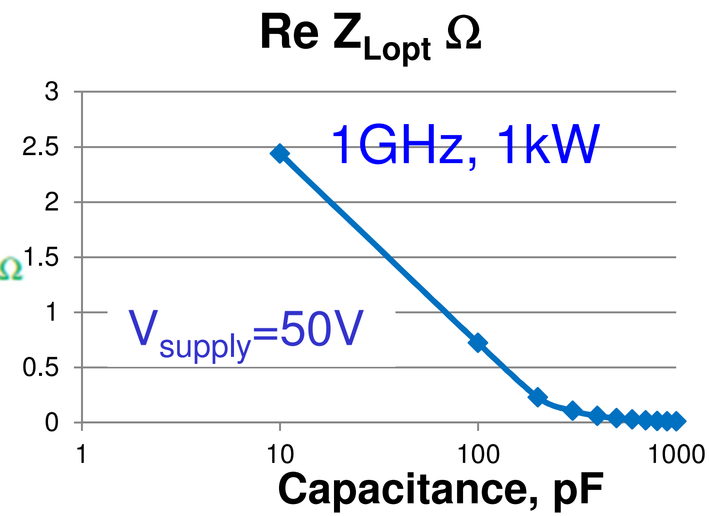
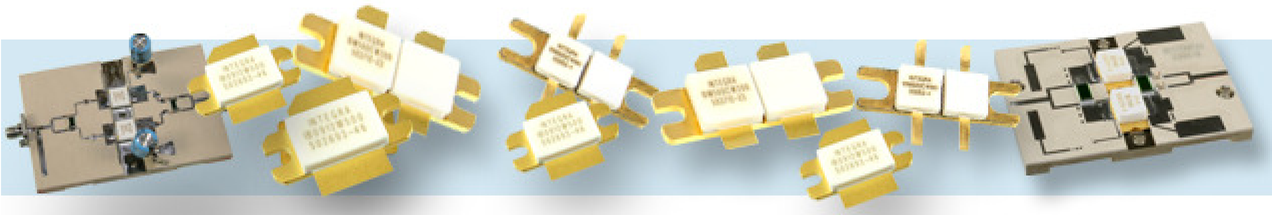
IMPORTANCE OF LOW CAPACITANCE





- $Z_{Lopt} = \frac{R_{opt}}{1-j\omega C_{ds} R_{opt}}$



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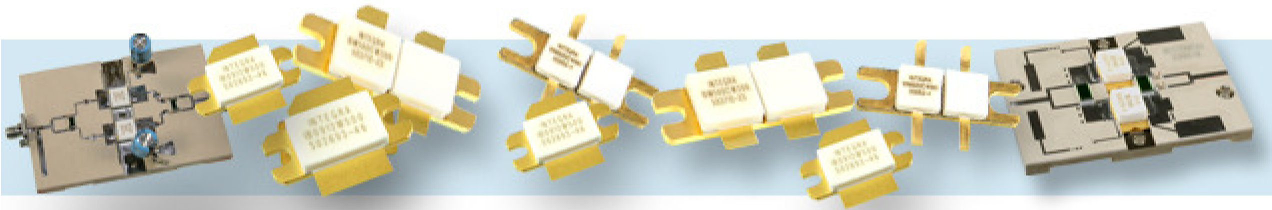
TECHNOLOGY COMPARISON

Si Bipolar

- Very mature
- Very reliable
- Higher efficiency than LDMOS (class C vs class A/B) – almost as good as GaN
- ➢ Simplest & cheapest circuits of any technology
- Frequency extension via common-base mode
- Lowest gain
- Very non-linear
- BeO package



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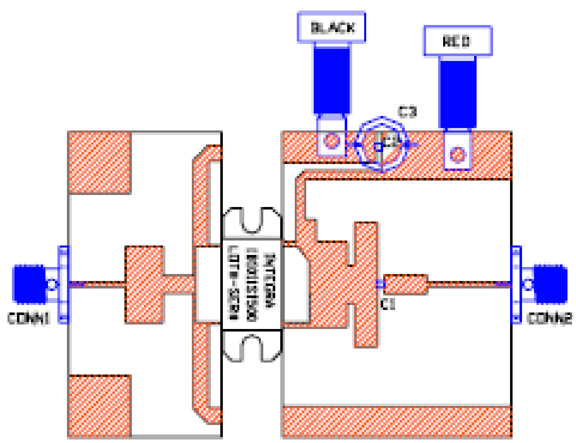
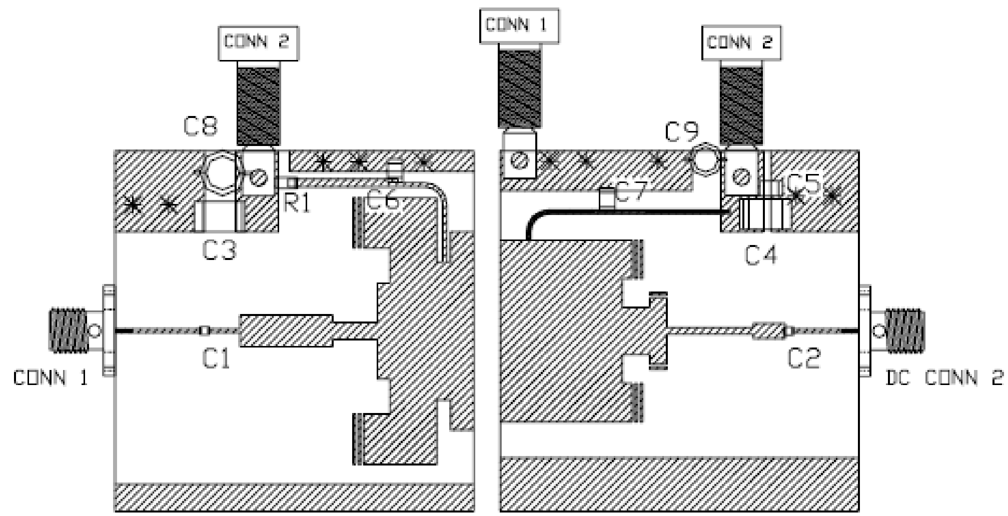
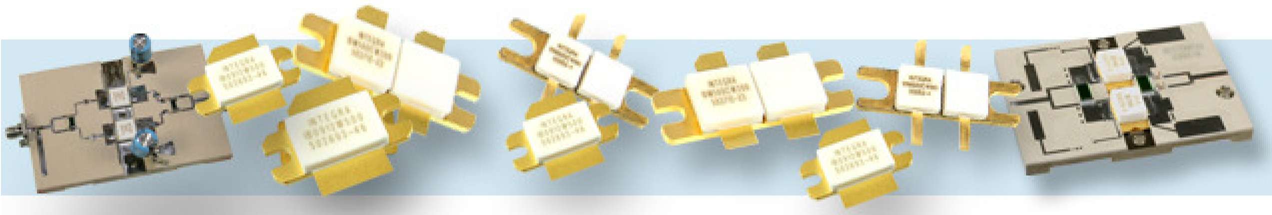


1.5kW bipolar L band
Just 2 chip capacitors
1 supply voltage



1kW LDMOS L band
10 capacitors, 1 resistor
2 supply voltages



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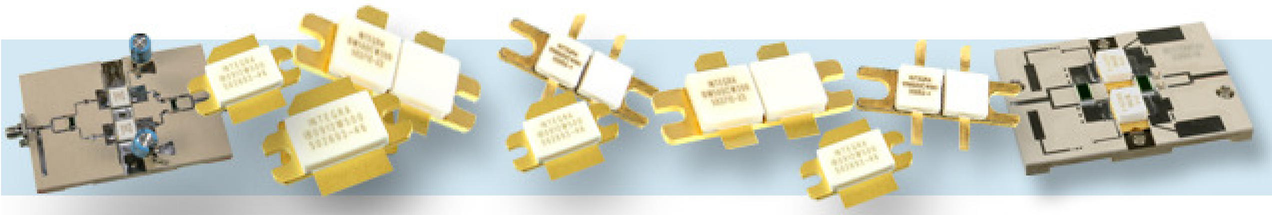
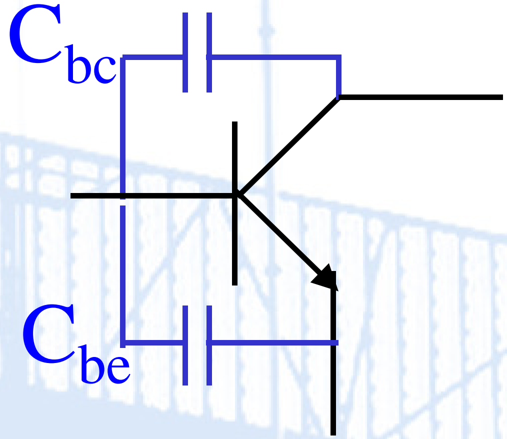
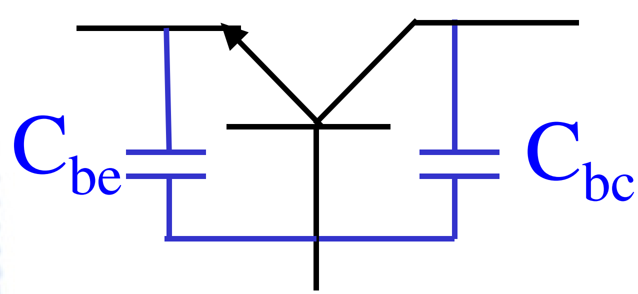


TECHNOLOGY COMPARISON

Si Bipolar

- Frequency extension via common-base mode





$$f_t \propto \frac{1}{C_{in}} = \frac{1}{C_{be}+C_{bc}}$$

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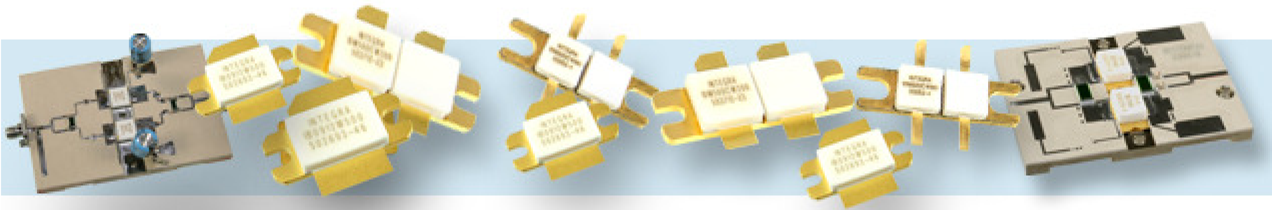
FETs have C_{ds} which is comparable in value to C_{gs} so no frequency extension by using common gate mode



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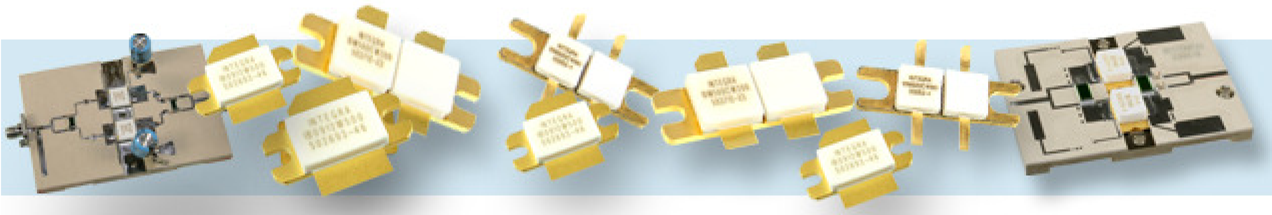
- Simplest & cheapest circuits of any technology
- Frequency extension via common-base mode

➢ Lowest gain
➢ Very non-linear
➢ BeO package



TECHNOLOGY COMPARISON

Si LDMOS

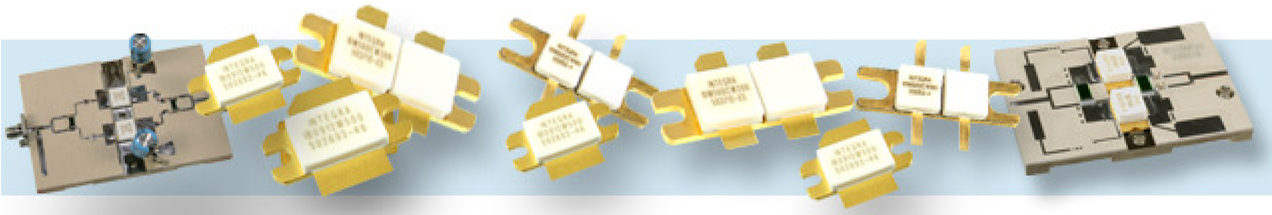
- Very linear
- BeO-free and cheaper package
- About 2dB more gain than bipolar but less than GaN
- Lowest efficiency
- No increase in power output compared with bipolar

TECHNOLOGY COMPARISON

GaN

- Lowest capacitance per Watt of any technology
  - Wider bandwidth and higher frequency, less ripple
- ➢ Higher optimum load impedance

- Highest power density
  - Thermal issues
- Worse linearity than LDMOS



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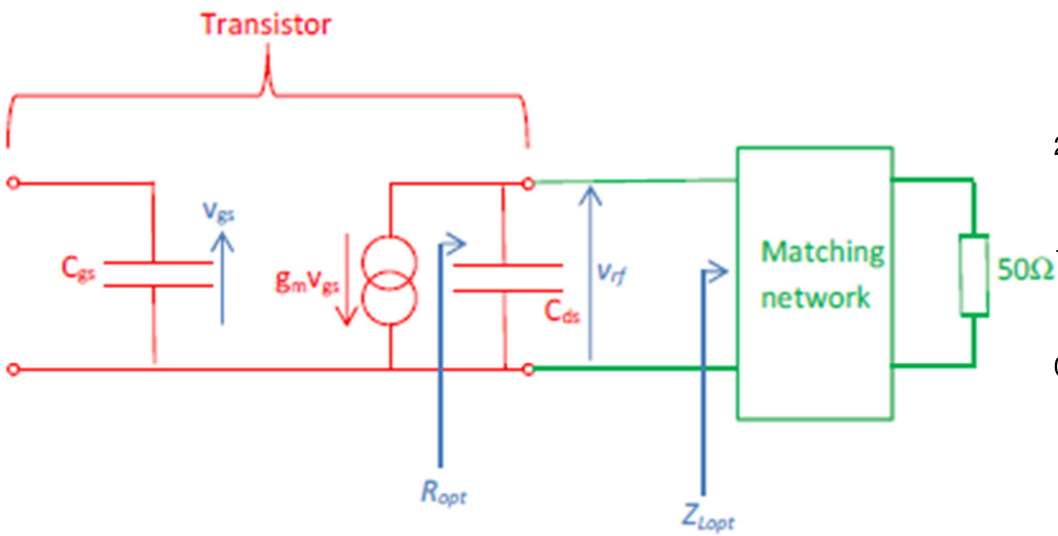

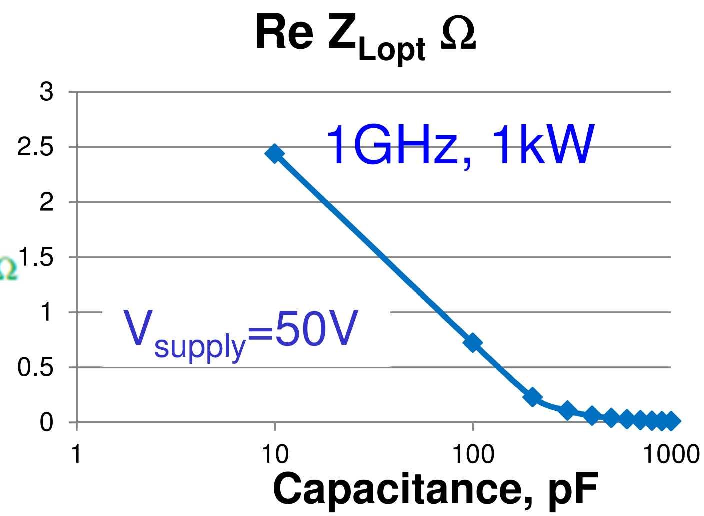

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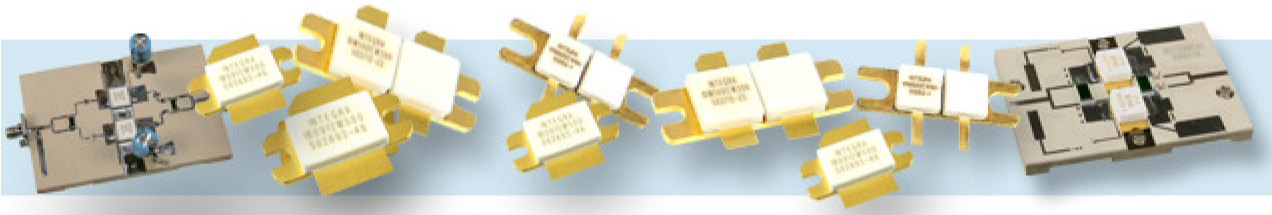

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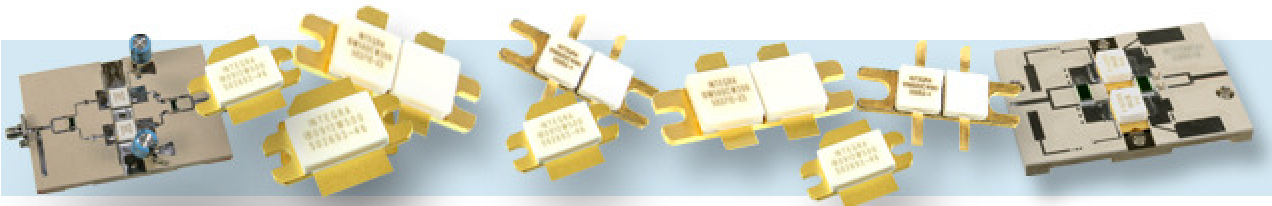
TECHNOLOGY COMPARISON

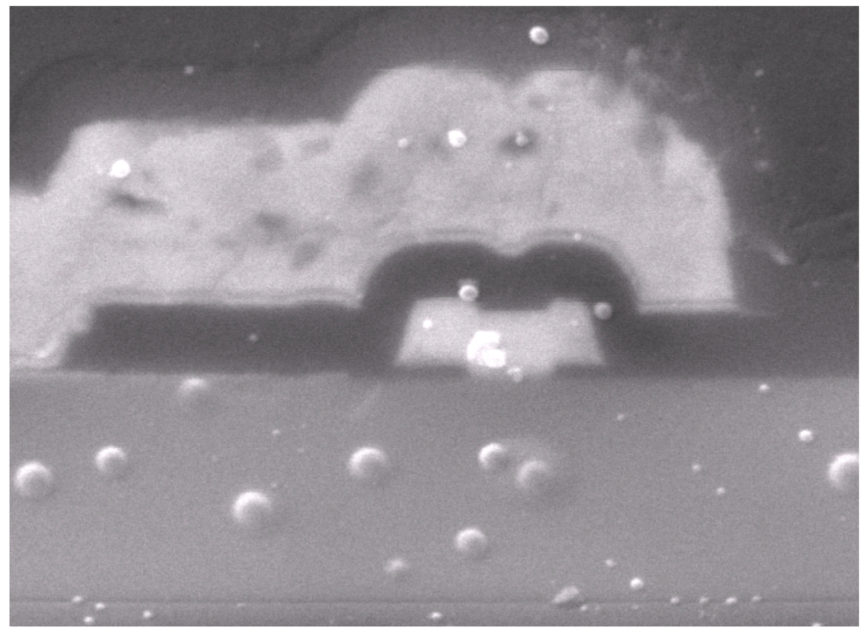
2.7-2.9GHz, 300μs, 10% duty cycle

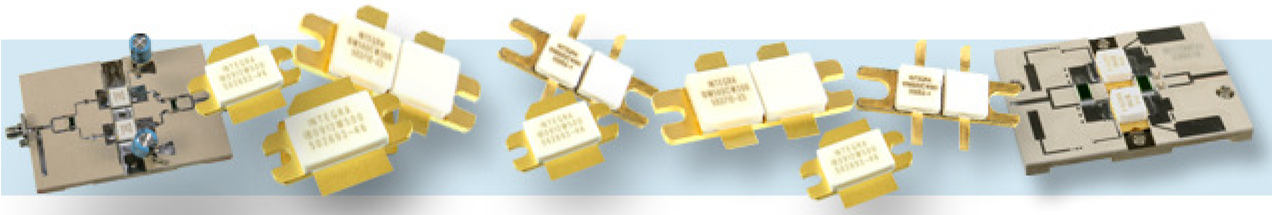
Device	Technology	Power (W)	Power-Added Efficiency %	Gain (dB)	Voltage (V)
IB2729M170	Si Bipolar	190	45	9.5	36
ILD2731M140	LDMOS	180	40.5	10.5	32
IGN2729M250	GaN	260	51	9.5	36
IGN2729M800	GaN	1000	55	11	50



Integra Die Manufacturing Process

- Integra designs and manufactures its own GaN die
- Die specifically designed for **pulsed operation**
- 4” GaN on SiC (6” ready)
- 0.5µm process
- Ti/Al/Ni/Au Ohmic contacts
- Ni/Au Gate contact
- 3 mil die thickness
- Double field plate design
- No via holes
- All gold process for high reliability
- High breakdown voltage for reliable 50V operation





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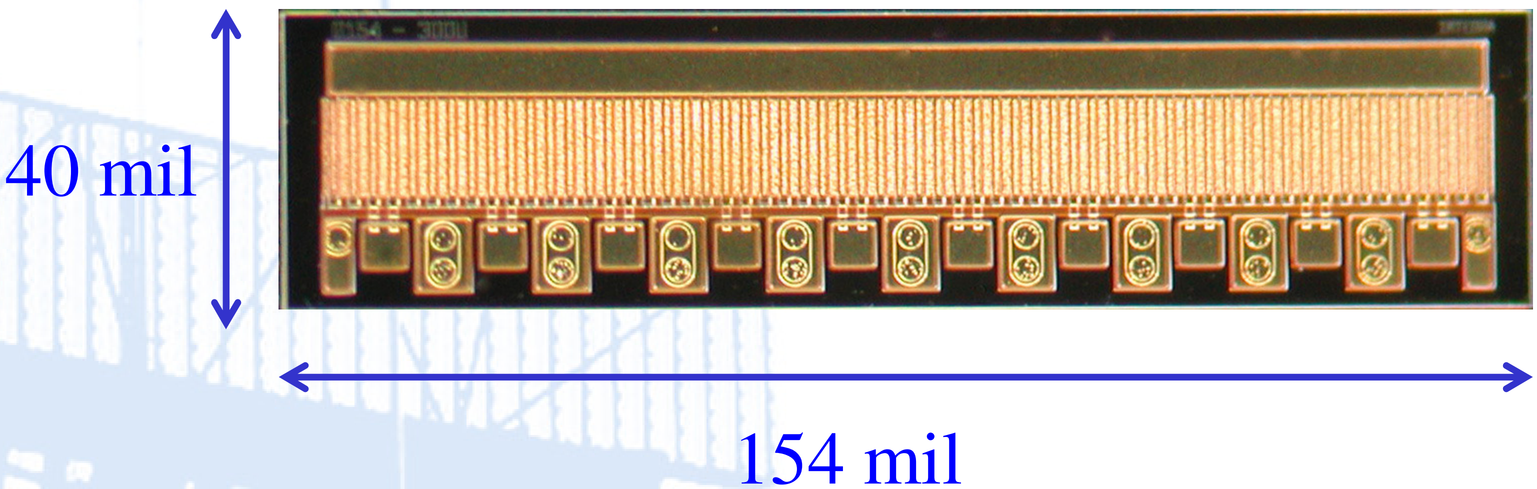
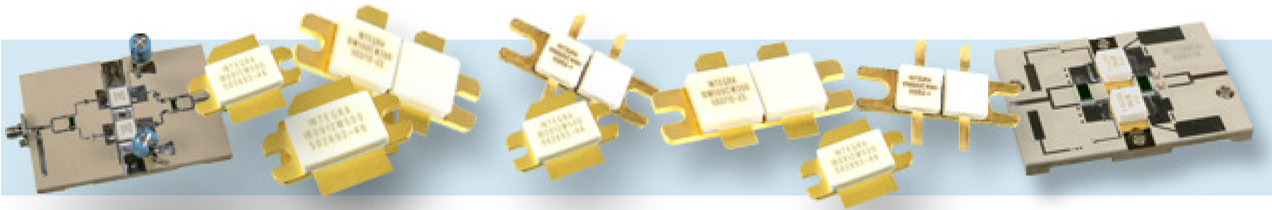
Die Details

- 36mm total gate periphery
- 300µm finger width
- >150W 2.7-2.9GHz





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AGENDA

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- ➢ State-of-the-art GaN Products
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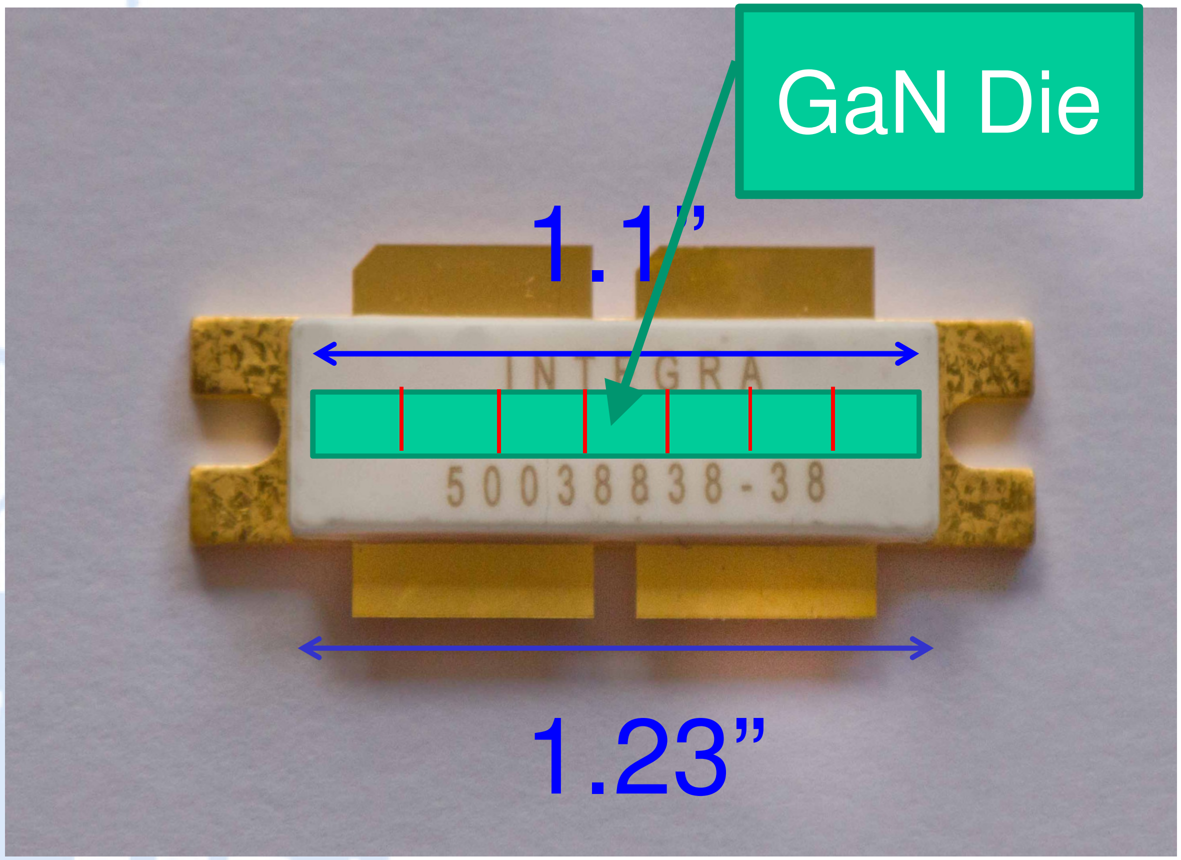
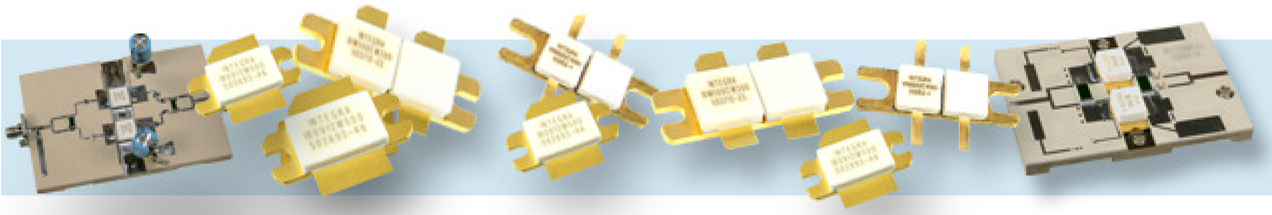
Integra 800W S band Package Details





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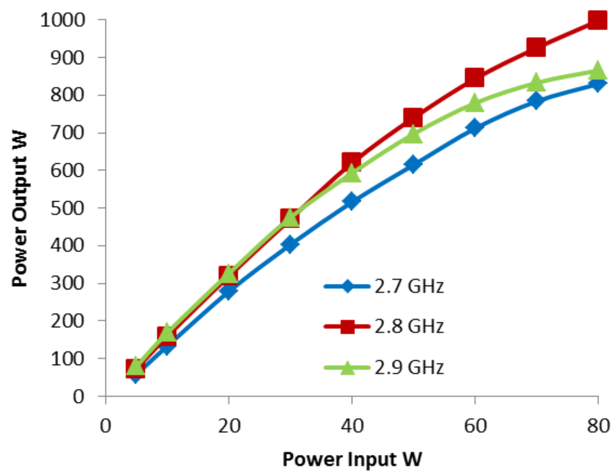
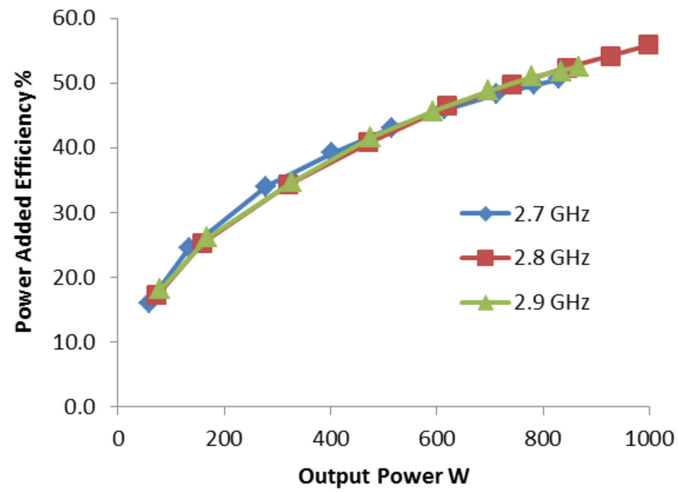
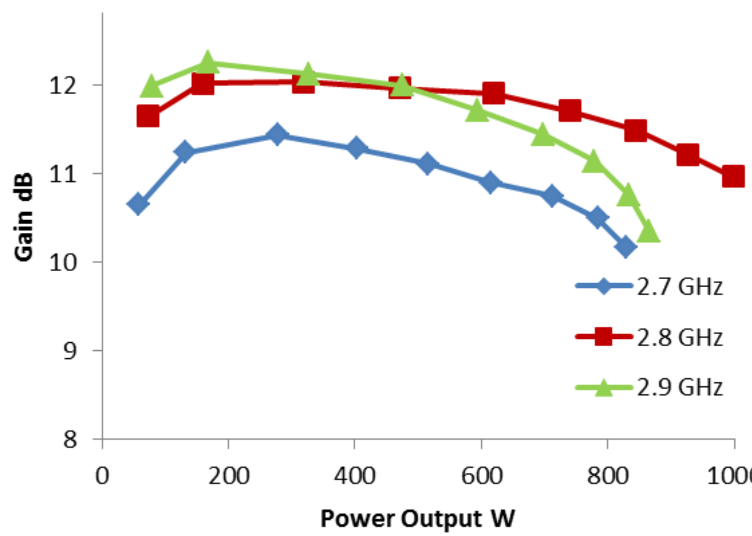
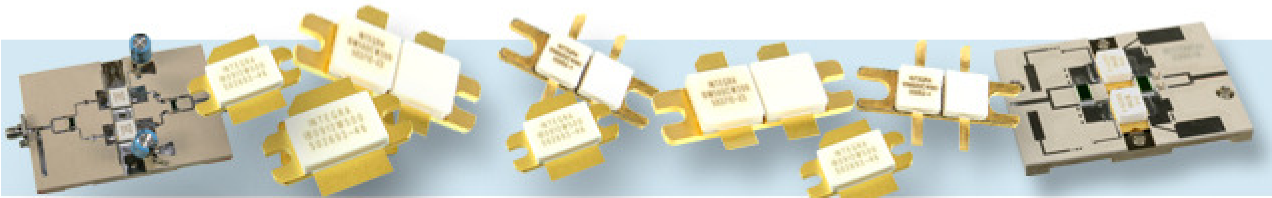
Integra 800W S band Results







Test Conditions:
300µs, 10%
50V, I_{DQ}= 100mA



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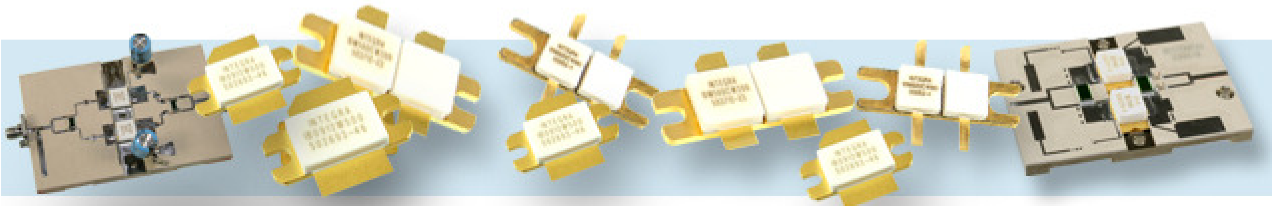
Integra 135W 3.1-3.5GHz 50Ω matched transistor

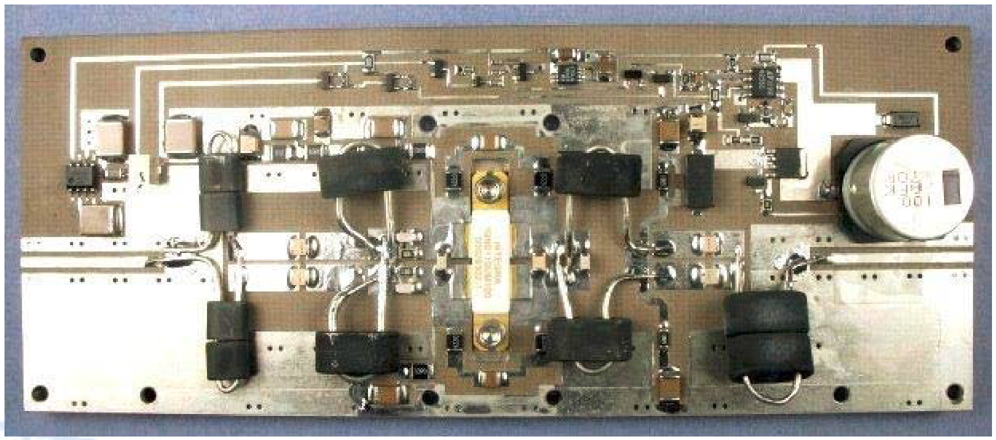
Test Conditions:
300µs, 10%
46V, I_{DQ}= 25mA

Typically 13dB gain, 50% efficiency, 10dB return loss

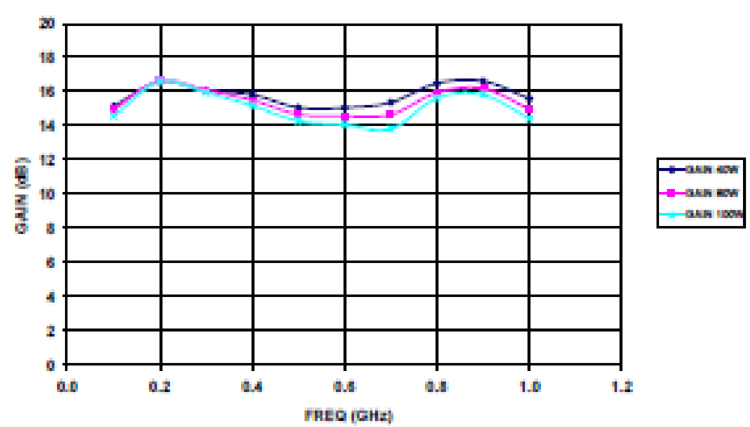
Typical application: phased array radar

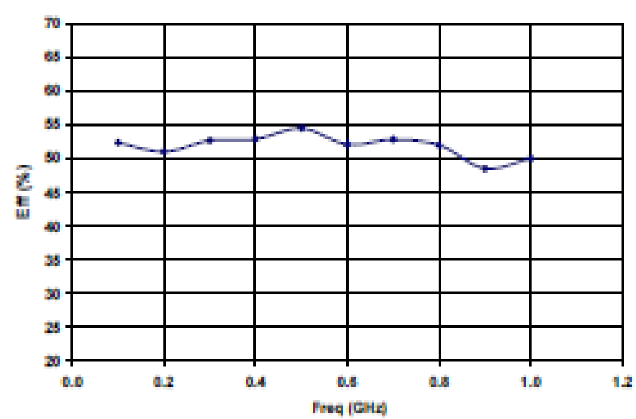


100W CW 100-1000MHz GaN Pallet

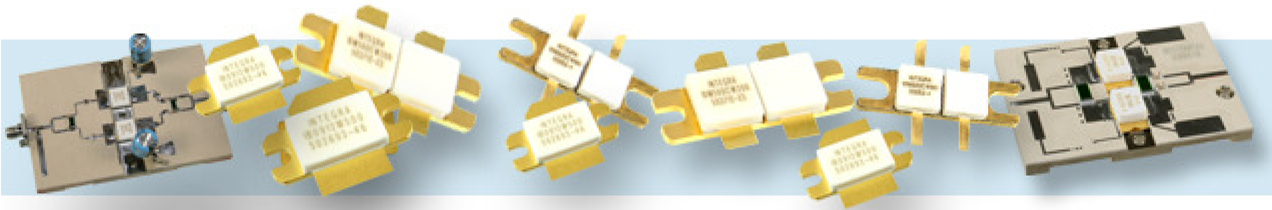


Test Conditions:
V_{ds}=28V
I_{DQ}= 480mA





Exploits low pF/W advantage of GaN



CONCLUSIONS

This paper has shown examples of state-of-the-art GaN products