CS INTERNATIONAL CONFERENCE

ANGELTECH

18TH-19TH APRIL 2023, BRUSSELS, BELGIUM

Innoscience

Mass volume manufacturing of 8-inch GaN-on-Si discrete and Integrated power devices: bringing efficiency and operating frequency to the next level

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CS International Conference

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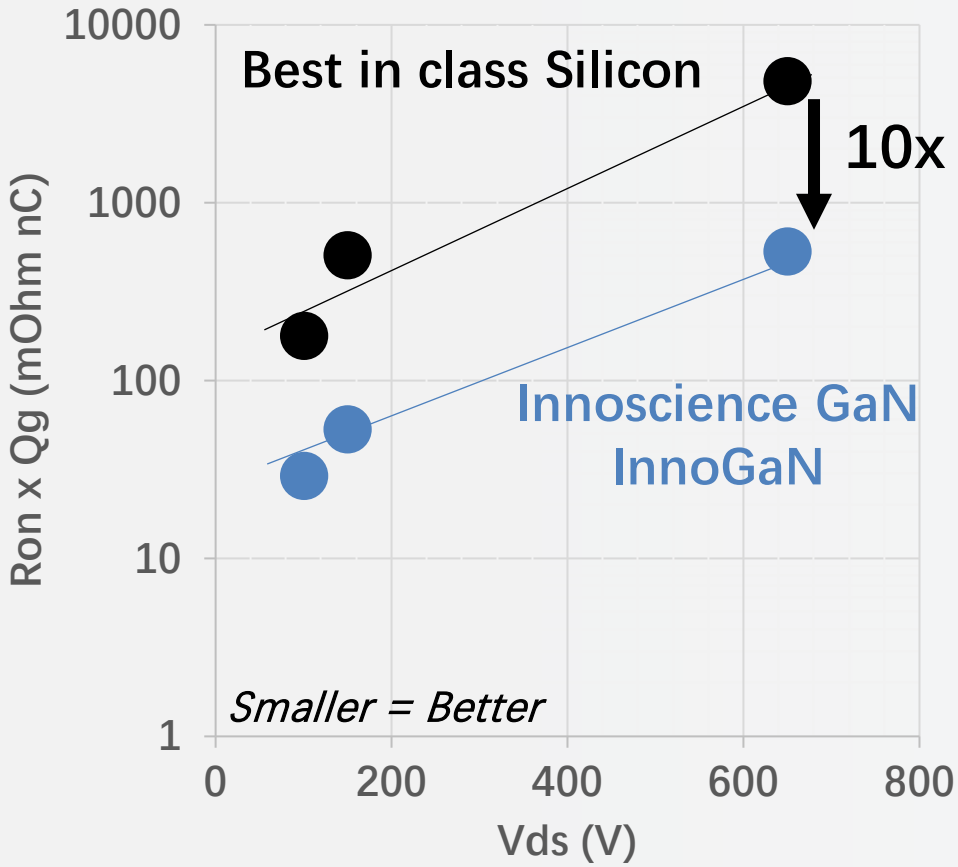
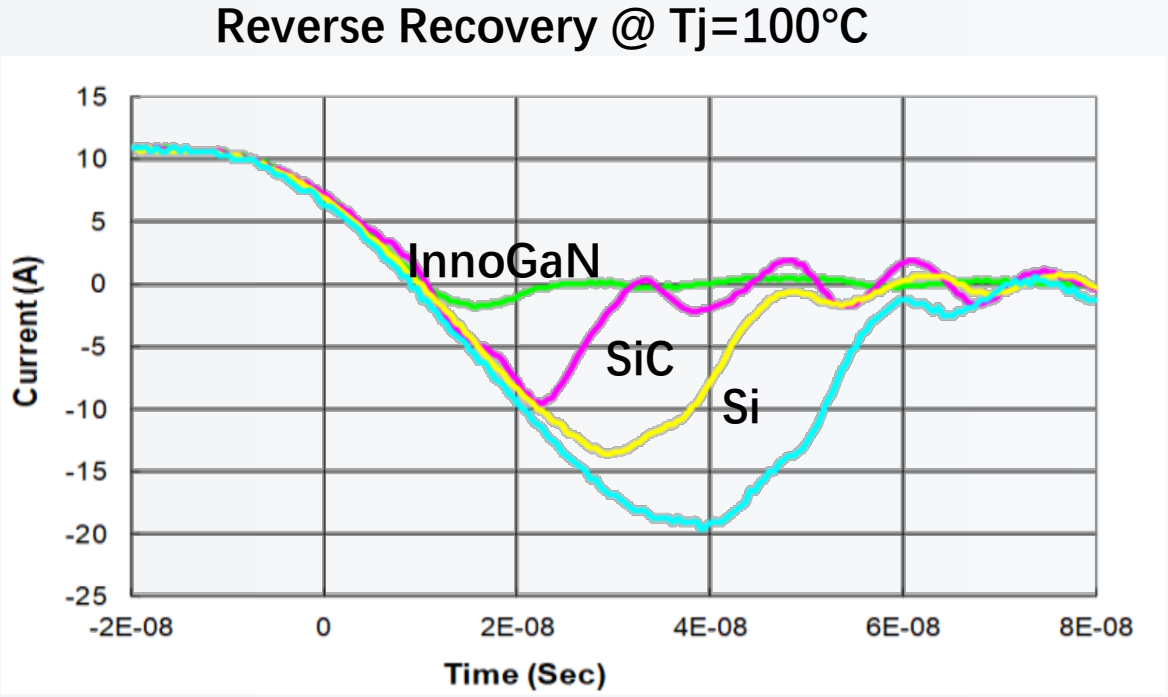
The beauty of GaN-based power devices





Ron x Qg is 10x better than Silicon

⇩

Efficiency is maintained at high frequency

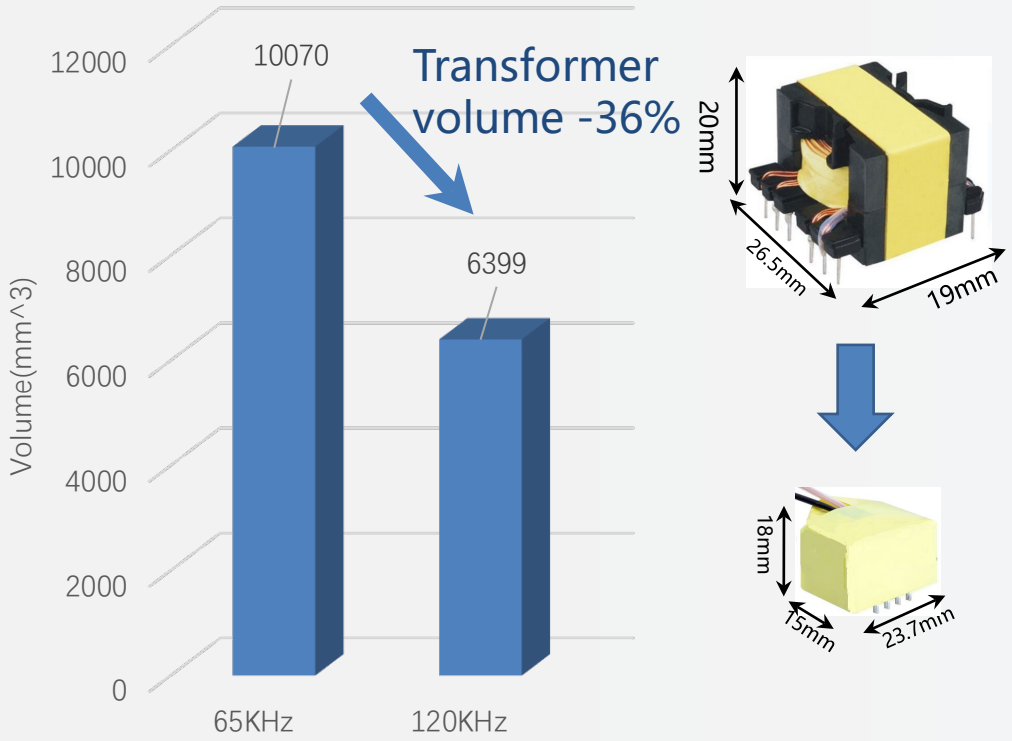
Absence of the body diode

⇩

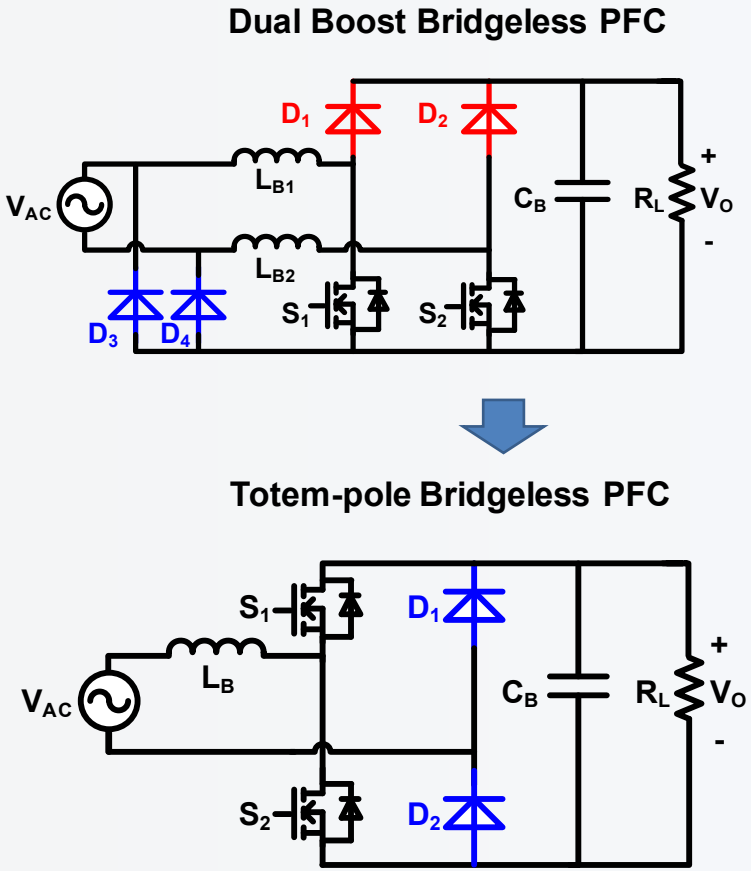
No reverse recovery current

What does this mean?

Higher switching frequency means shirking of the passives components



No reverse recovery means simpler and cheaper system topology



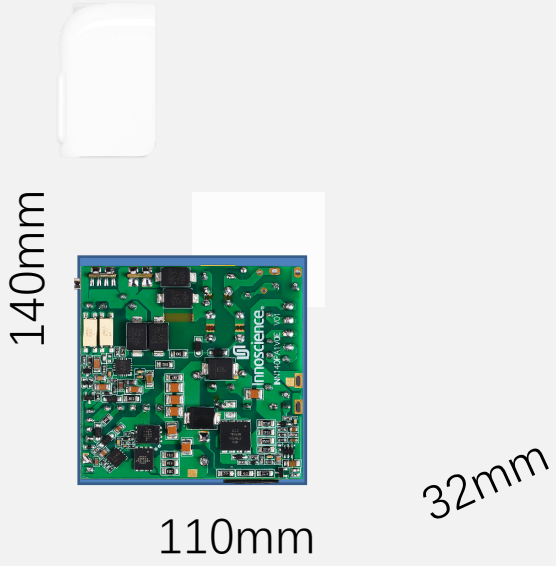
Complex

Simpler and efficient thanks to GaN

Let me give you a concrete example: 140W charger

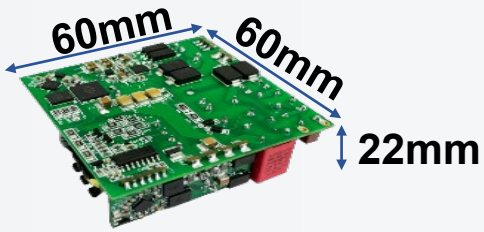
State-of-the-art 140W charger[1]

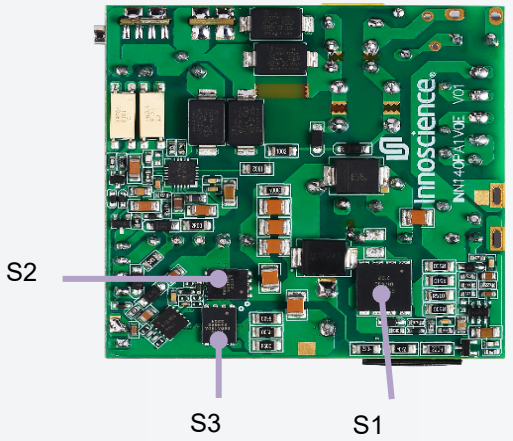
11.41W/in³
0.7W/cm³

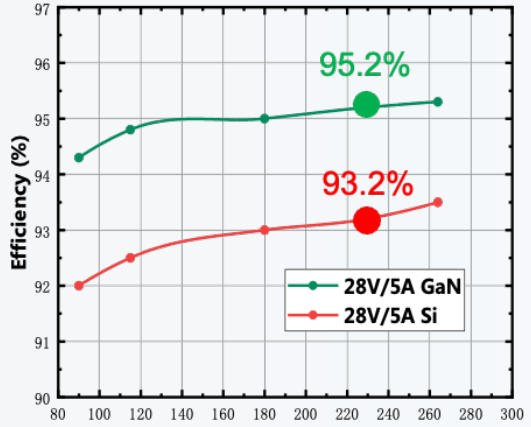


InnoGaN solution: power density of 1.76W/cm³ (29W/in³)

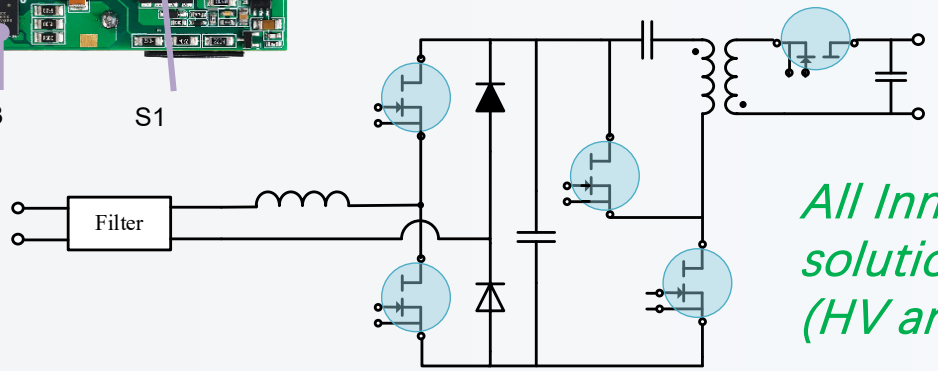
More >2x higher power density wrt Si commercial solution







Totem pole PFC + AHB



All InnoGaN solution (HV and LV)

[1] https://inf.news/en/digital/15977116257b89b184ae41f0d65dbb7a.html

GaN market & applications examples

Consumer

Mobile

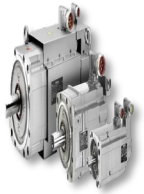
Charger

Computing

Class-D Audio

Industrial

Motor control



PV & Storage

PFC & Power Supplies

Communication

48V Bus

Server

Base stations

E-Mobility

Fast chargers

Motor Drives

BMS

LED Lighting

Smart Building

Street Lighting

Smart Agriculture

Automotive

Lidar

OBC

48V Aux Power

*GaN brings **efficiency** and **power density** to the next level with **optimum solution cost** !*

Status of GaN power device suppliers (today)

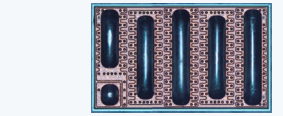
- Limits the ability to differentiate
- How to add value to a discrete device in a foundry process?
- Inherent trend to innovate by adding on-GaN functionality
- **Constraining GaN growth**

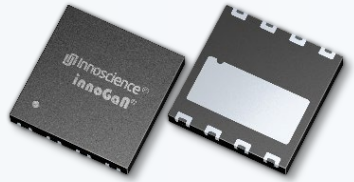
	100% GaN focus	Legacy Si products	Technology development	Product innovation	High volume cost effective GaN production
Fabless startups					
Si power IDMs					
Innoscience: 100% GaN IDM					

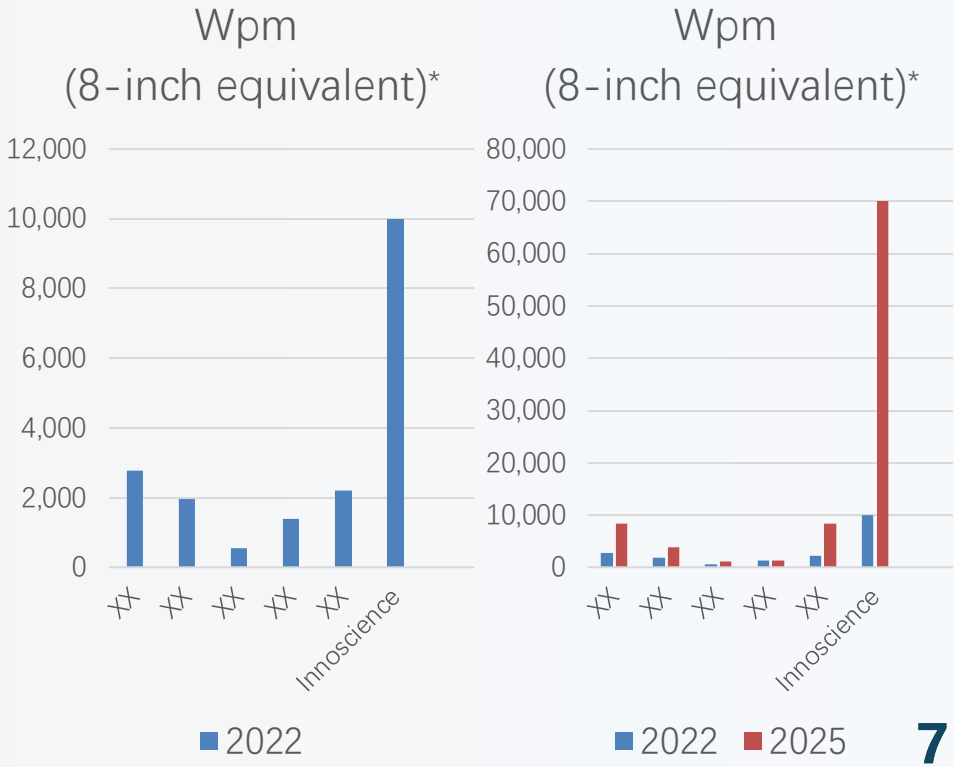
- Internal competition
- Prioritization
- Not enough cost competitive
- Limited production capacity
- **Constraining GaN growth**

Innoscience is the GaN game changer: 100% GaN IDM

- Wide portfolio: **HV (650V), MV (100V-150V) and LV (<100V) GaN** power devices
- **#2** large **8-inch** Silicon-like **high-throughput fabs**: largest GaN capacity worldwide
- **>1500 people** 100% focused on GaN
- **>100Mpcs** shipped so far
- 8-inch + Economy of scale to **slash the cost of GaN** (adoption barrier)





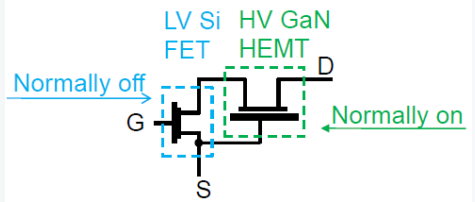


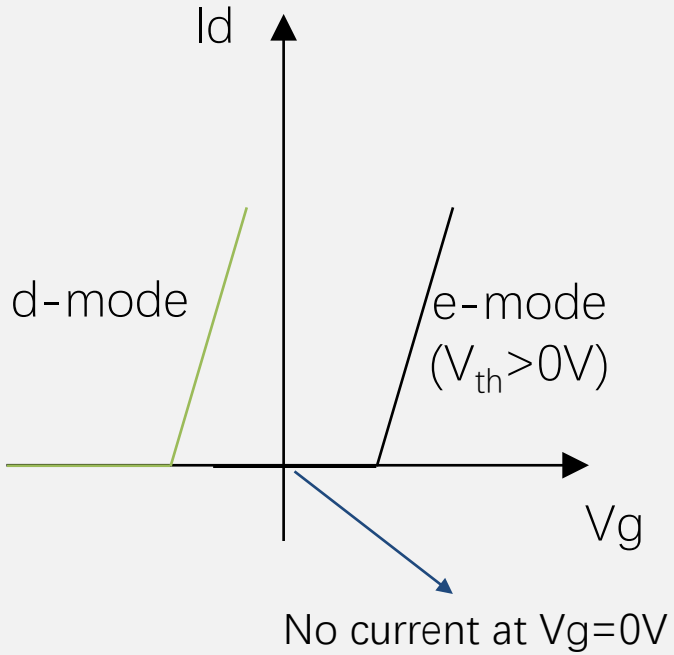
*Source: Yole report, "GaN Power 2021: Epitaxy, Devices, Applications and Technology Trends"

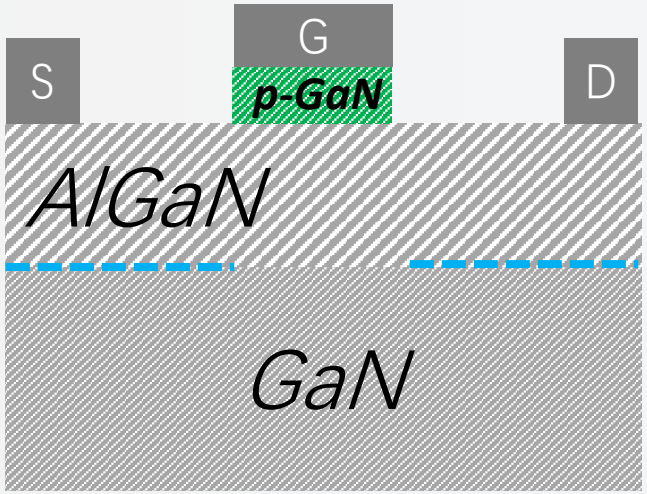
InnoGaN is normally-off/e-mode

- GaN-based devices are naturally normally-on/depletion mode (d-mode)
- **Power device market demands normally-off devices:**
  - Co-packaging of the GaN d-mode with a LV Si MOS or other Si IC
  - True normally-off/enhancement mode (e-mode) device technology
- **Innoscience device technology is normally-off/enhancement-mode (E-mode) based on p-GaN**

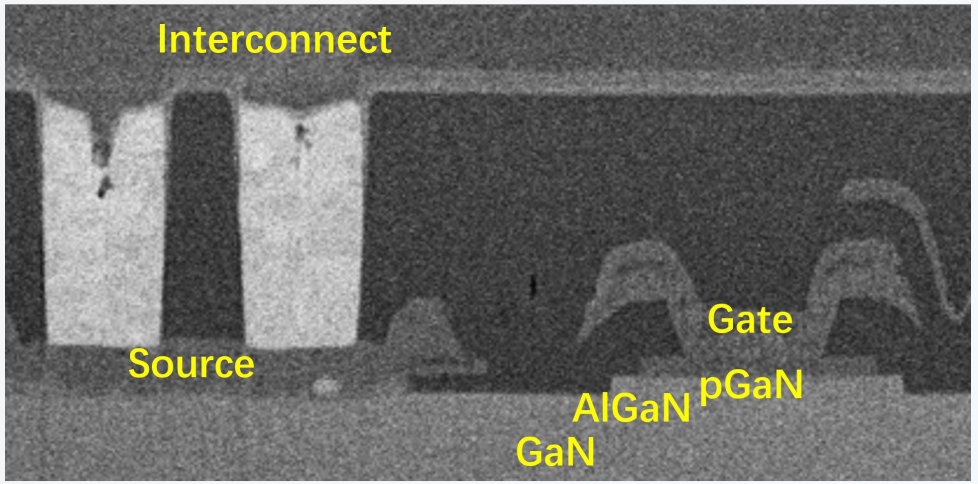
Cascode solution







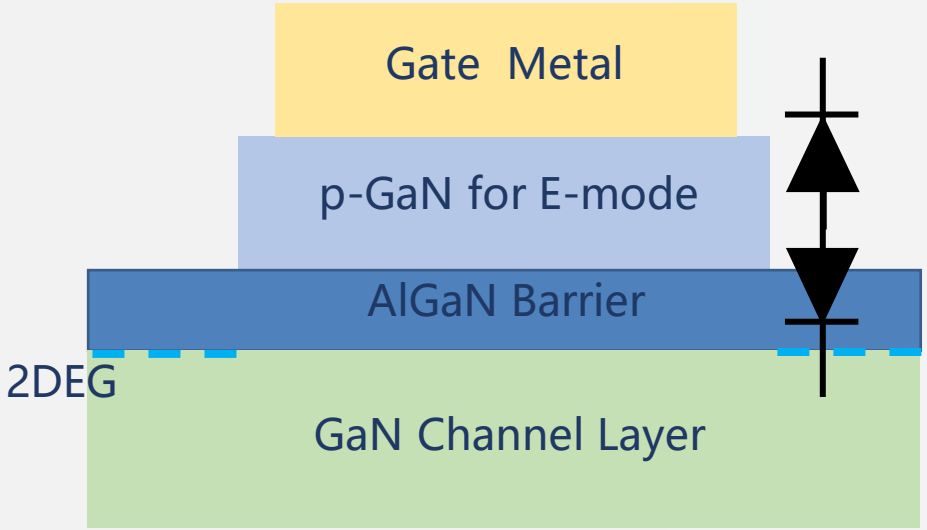
A p-GaN layer below the gate lift-up the conduction band (from the Fermi level) only below the gate to realize e-mode operation.

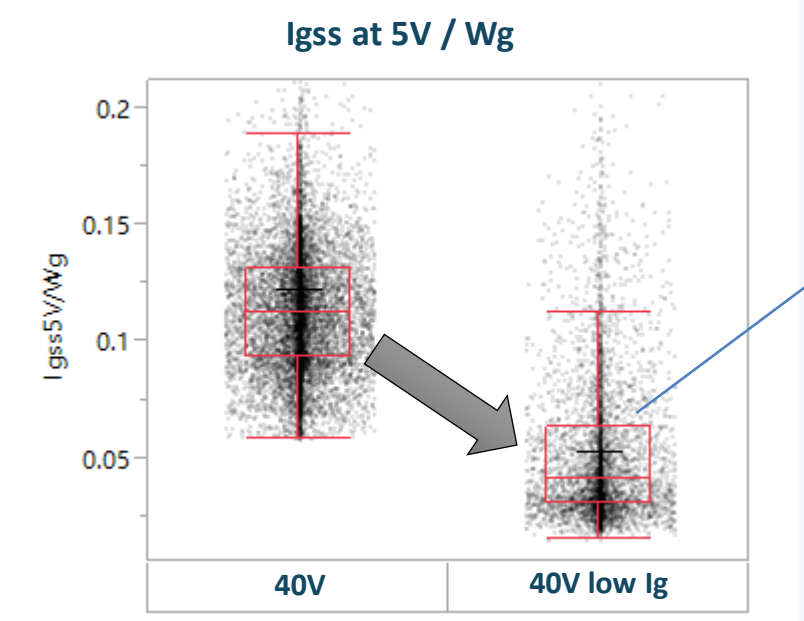


Why IDM? Gate leakage breakthrough on E-mode GaN

p-GaN HEMT Gate structure

(Back-to-back diodes in series)

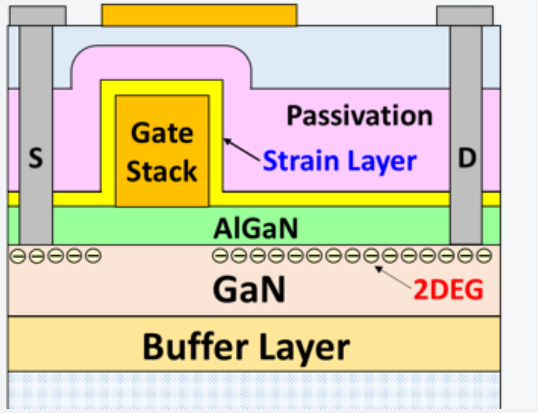




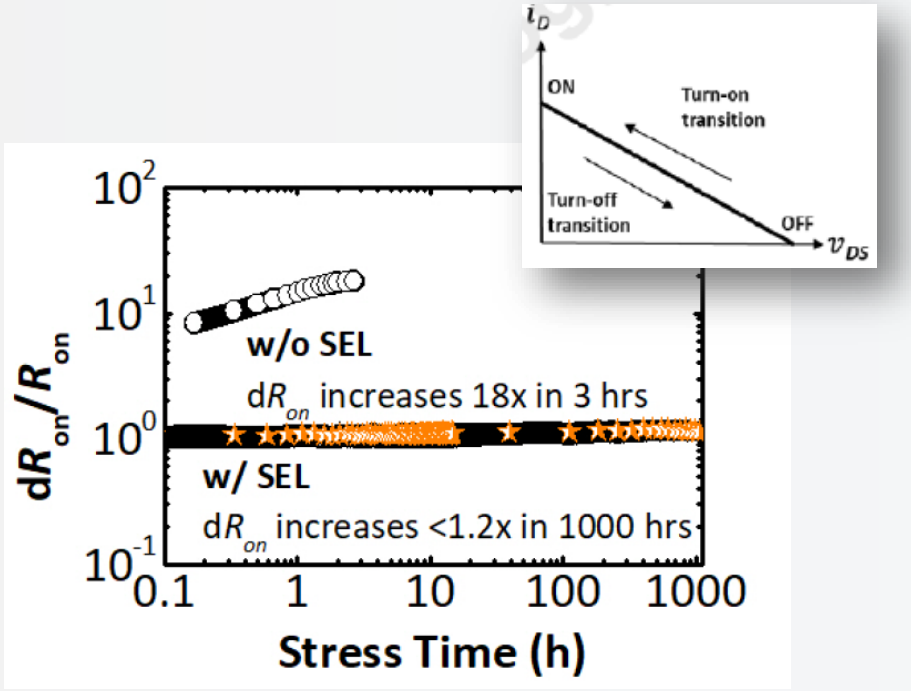
- Epitaxy
- Transistor processing
- Transistor architecture
- Design

- E-mode GaN devices do not have an oxide below the gate
- Need to co-optimize epi, processing, architecture, design etc..
- **~10x reduction of gate leakage**
  - **<3 µA at 85 °C throughout the device lifetime → ok inside smartphone**

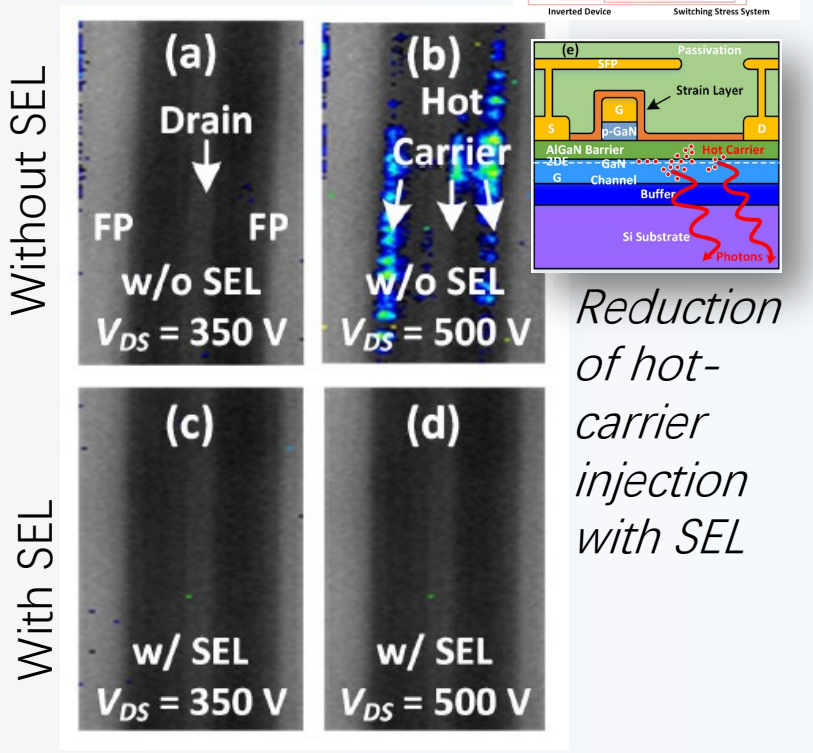
Technology differentiator: strain enhance layer (SEL)



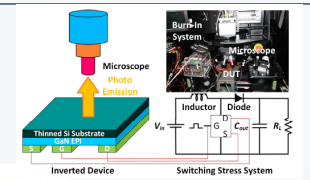
- Gate Formation
- **Strain Enhancement Layer Deposition**
- Passivation Deposition
- Ohmic Contact Formation
- Inter-layer Dielectric Deposition
- Interconnect Contact Formation
- Metal-1 Formation
- Inter-metal Dielectric Deposition
- Via and Substrate Contact Formation
- Metal-2 Formation
- Passivation Formation



Comparison of dR_{on} without and with the SEL under the HS test with V_{DS} = 600 V, V_{GS} = 6 V, and f_s = 100 kHz.



Reduction of hot-carrier injection with SEL



Wafer-level switching strain system embedded into the Emission Microscope (EMMI) to detect the electroluminescence of device in situ.

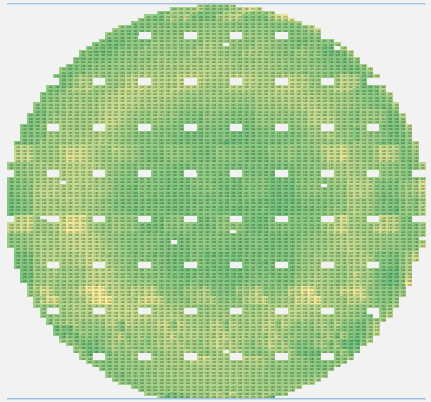
Roy K.-Y. Wong, *et. al.* "High Performance GaN-on-Si Power Devices with Ultralow Specific On-resistance Using Novel Strain Method Fabricated on 200 mm CMOS-Compatible Process Platform" , ISPSD 2019.

Roy K.-Y. Wong, *et. al.* "Comprehensive GaN-on-Si power device platform: epitaxy, device, reliability and Application" , Semicond. Sci. Technol. 36 (2021) 064001, https://doi.org/10.1088/1361-6641/abe551

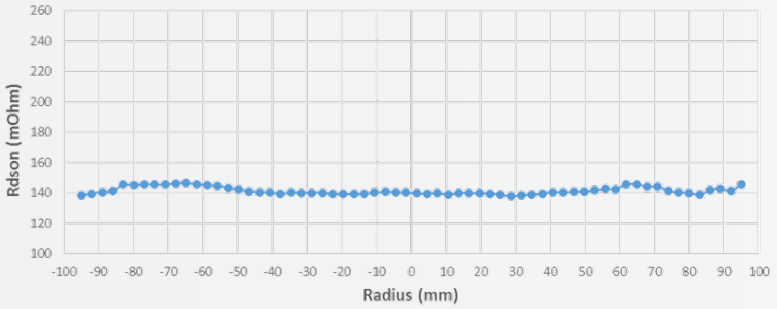
Technology maturity

Both Epitaxy as well as Device processing have been optimized to obtain high reproducibility and yield

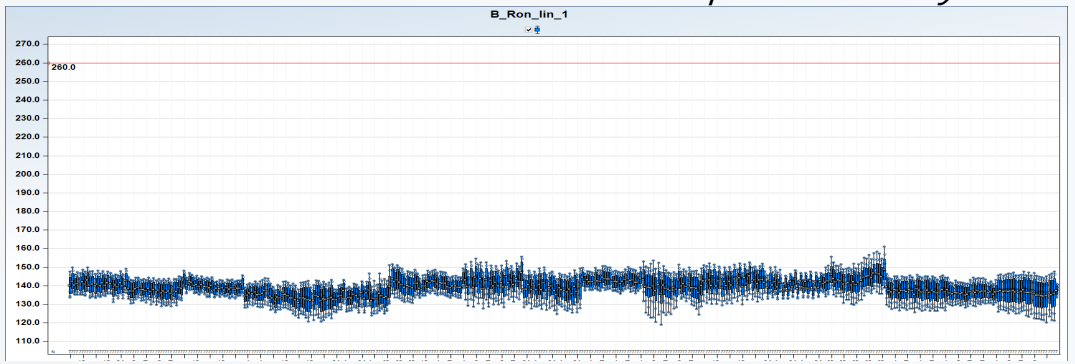
$R_{DS(on)}$



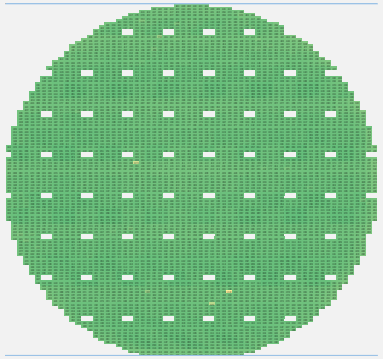
Excellent within wafer uniformity

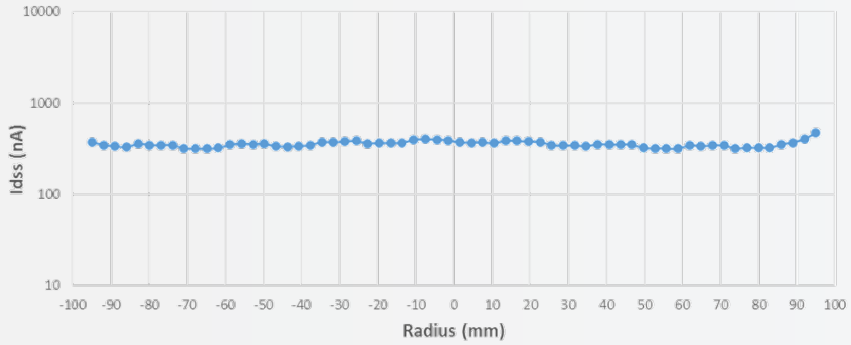


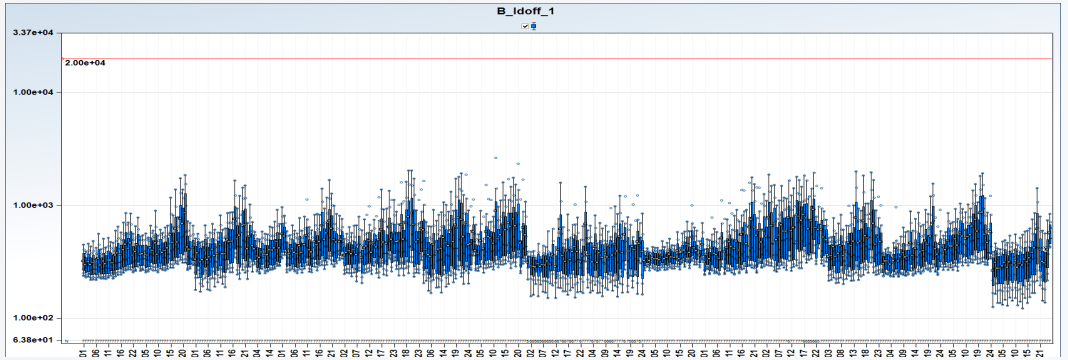
Excellent wafer-to-wafer reproducibility



I_{dss}

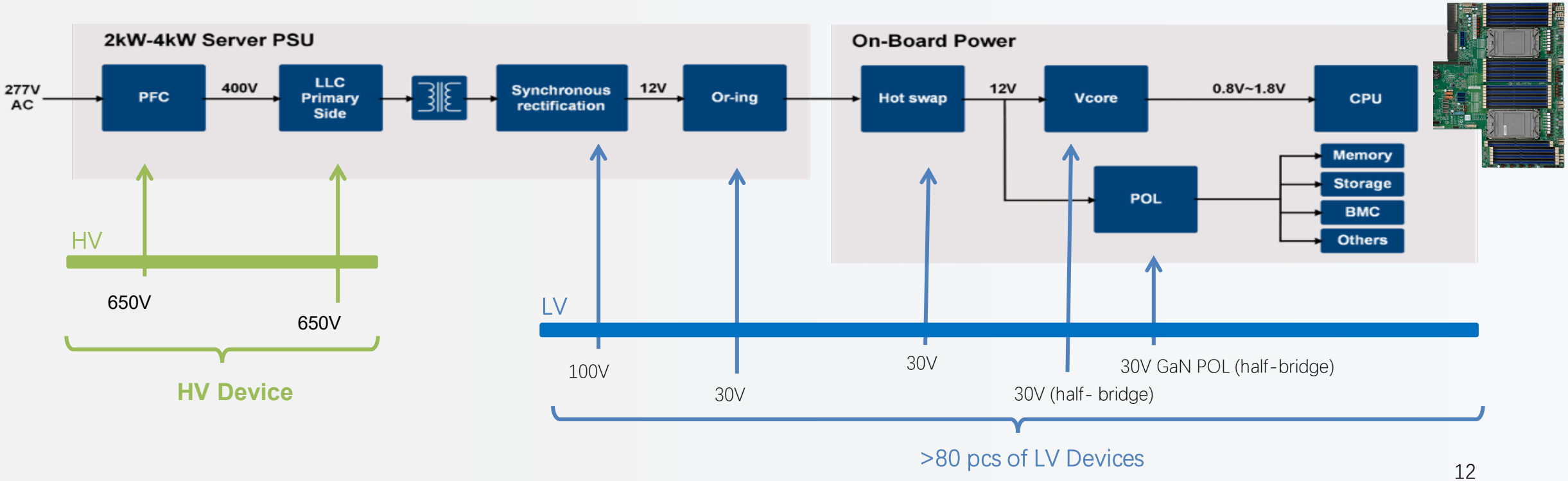






Case study: Data center

- Data center is a huge and growing market
- Power hungry → efficiency is top priority (save CO_2 and $$$)
- Solution Size is important too (more space for computing unit)
- In need of big volume capacity and price competitiveness



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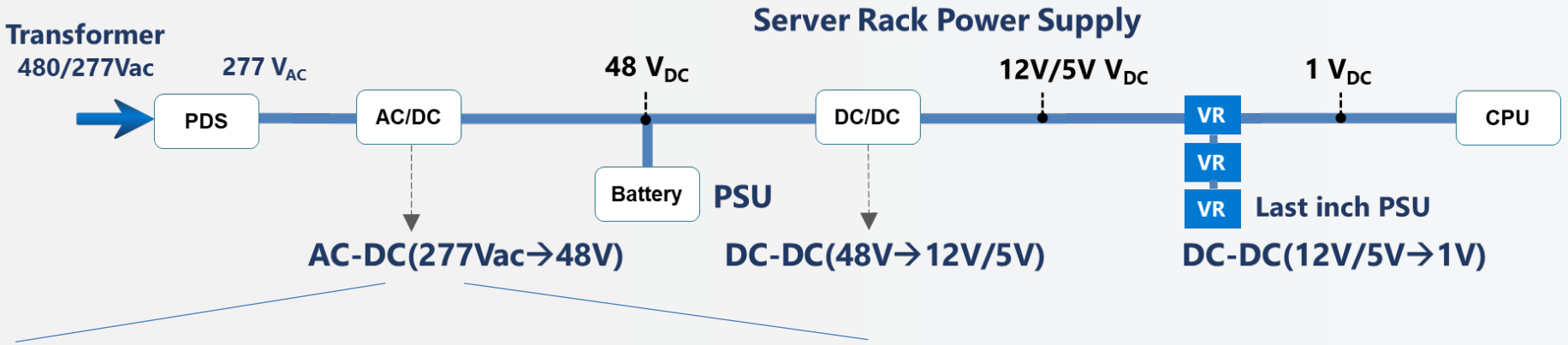
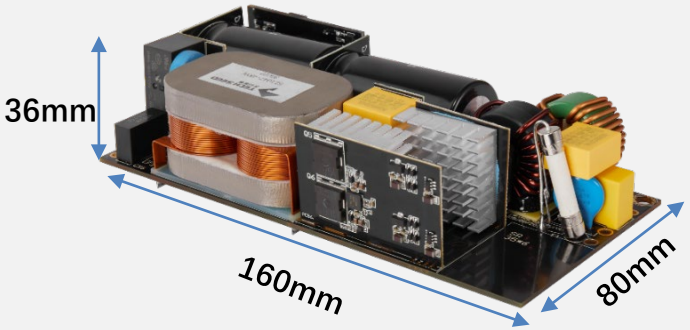
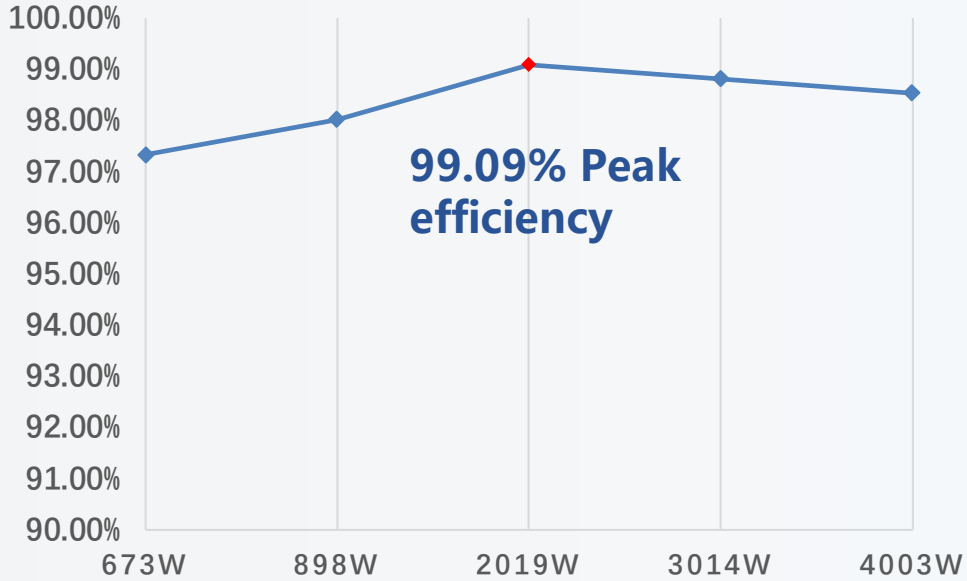
InnoGaN in datacenters: AC-DC conversion





142W/in³

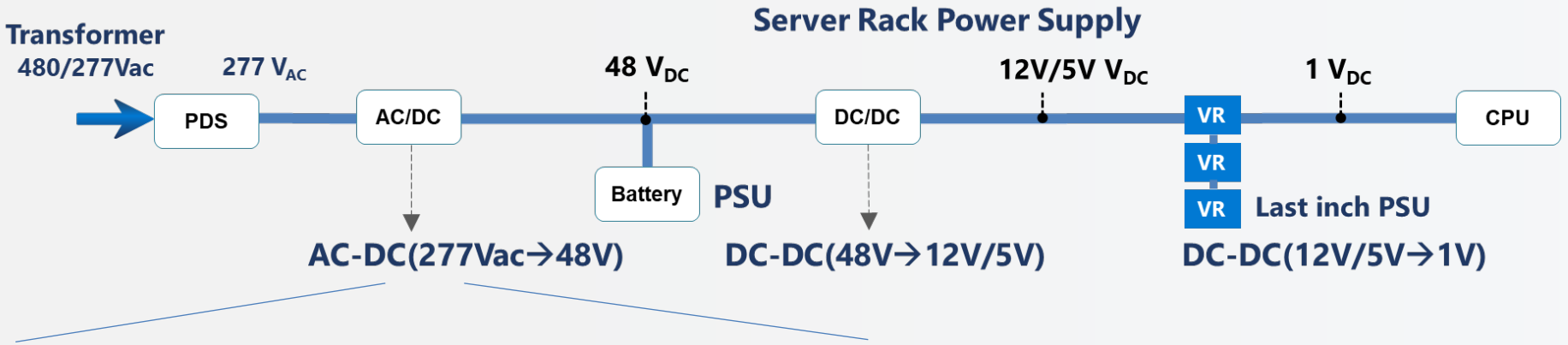
650V/30mOhm

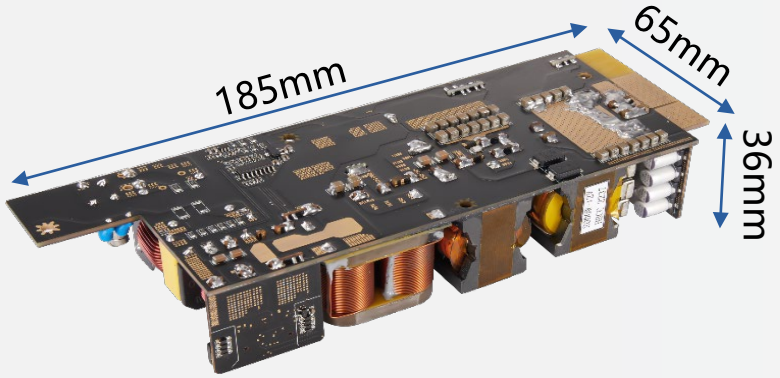


Totem Pole PFC

Standard packages DFN and TOLL

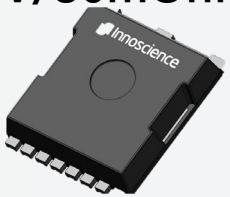
InnoGaN in datacenters: AC-DC conversion



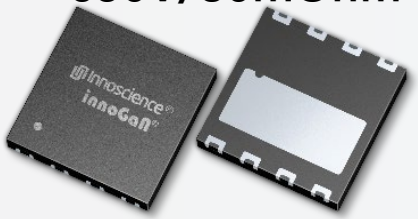


Totem Pole PFC+LLC

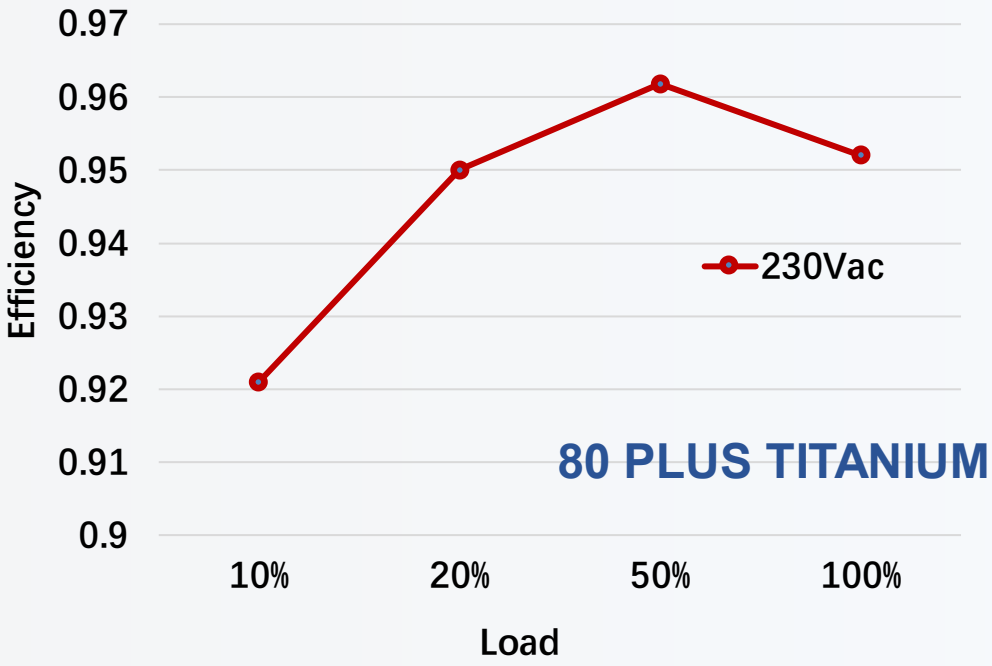
650V/30mOhm



650V/80mOhm

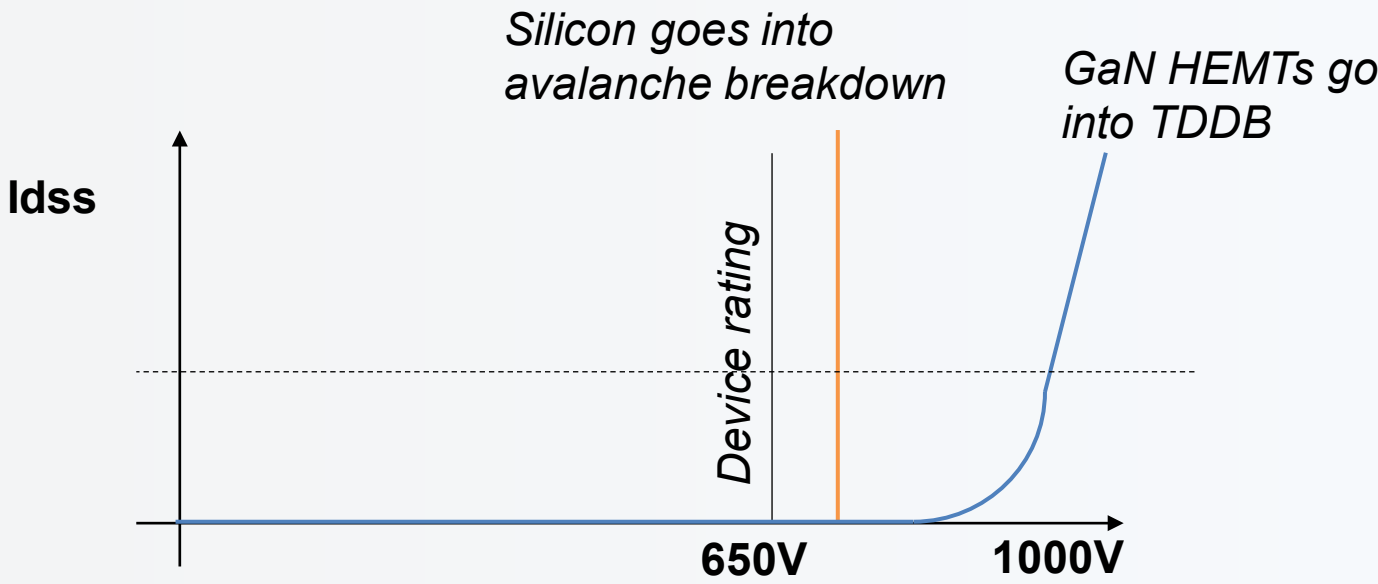


Standard packages
DFN and TOLL



Transient voltage rating

- In power switching system transient voltages or spikes beyond the device rating are expected
- Silicon has avalanche rating but not in today GaN HEMTs
- Yet, GaN HEMTs need to have the ability to sustain transient voltage and spikes



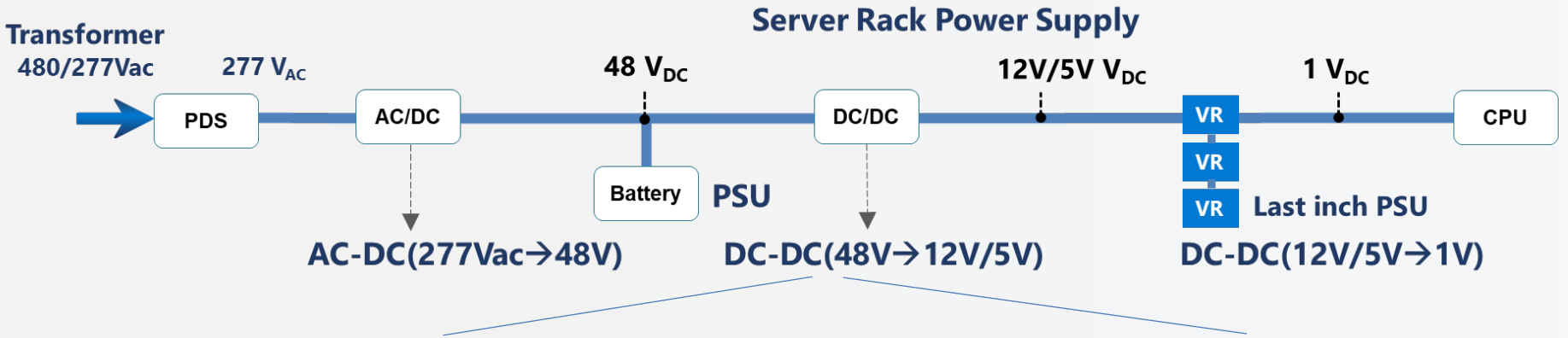
Parameter	Symbol	Values	Unit	Note/Test Condition
Drain source voltage	$V_{DS, max}$	700	V	V_{GS} = 0 V, T_j = -55 °C to 150 °C
Drain source voltage transient [1]	$V_{DS, transient}$	800	V	V_{GS} = 0 V
Drain source voltage, pulsed [2]	$V_{DS, pulse}$	750	V	T_j = 25 °C; total time < 10 h
				T_j = 125 °C; total time < 1 h

InnoGaN can be safely used and sustain transient voltages well above their maximum rating

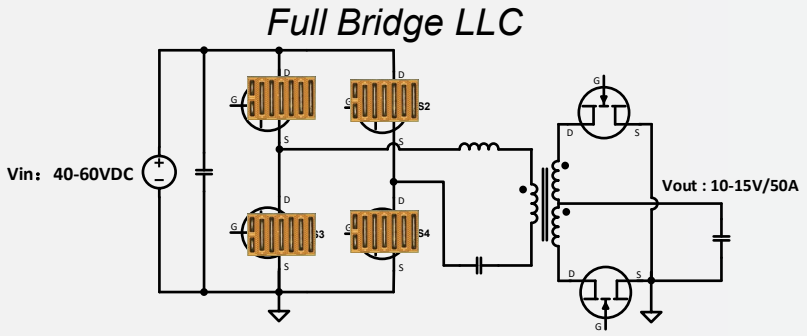
1. $V_{DS, transient}$ is intended for non-repetitive events, t_{PULSE} < 200 µs.
2. $V_{DS, pulse}$ is intended for repetitive pulse, t_{PULSE} < 100 ns.

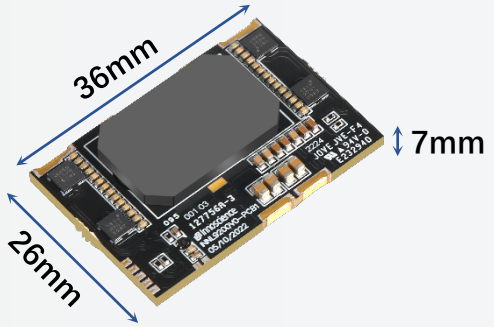
Source: Making GaN fit for industrial applications, O. Haberlen, Bodo WBG 2022

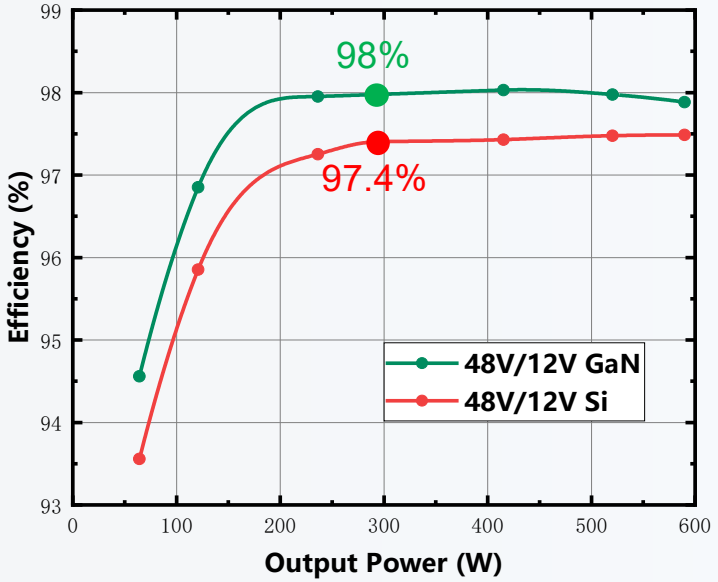
InnoGaN in datacenters: 48V-12V conversion



600W DC-DC 48V to 12V 1MHz Power Module

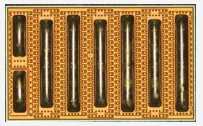






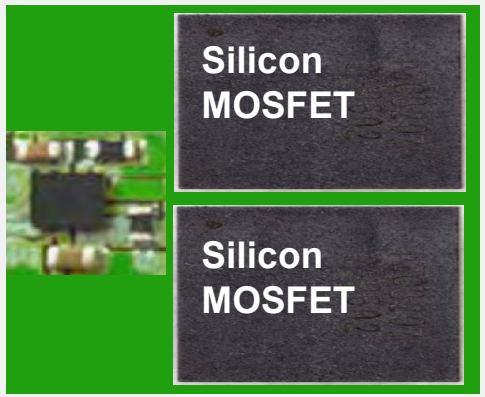
	INN100W032A
V_{DS}(V)	100
R_{DSON} (mΩ)	2.4/3.2
R_{DSON}*Q_g (mR*nC)	29.4
Die Size(mm)	3.5 x 2.1

Higher Power Density: 2100W/in^3



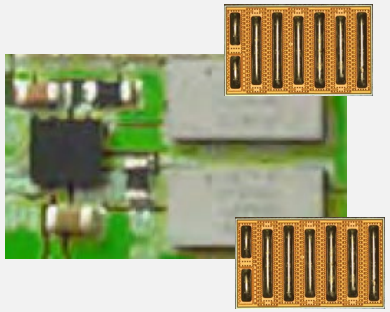
100V/3.2mOhm

Introduction to ISG3201: Half-bridge and driver in one package



Discrete Si
11mmx11mm

Down 65%

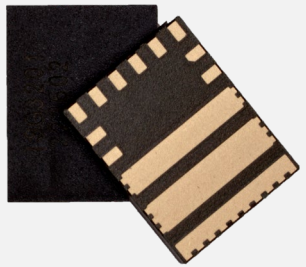


Discrete GaN
8mmx5mm

Performance and flexibility

Down 73%

Down 20%

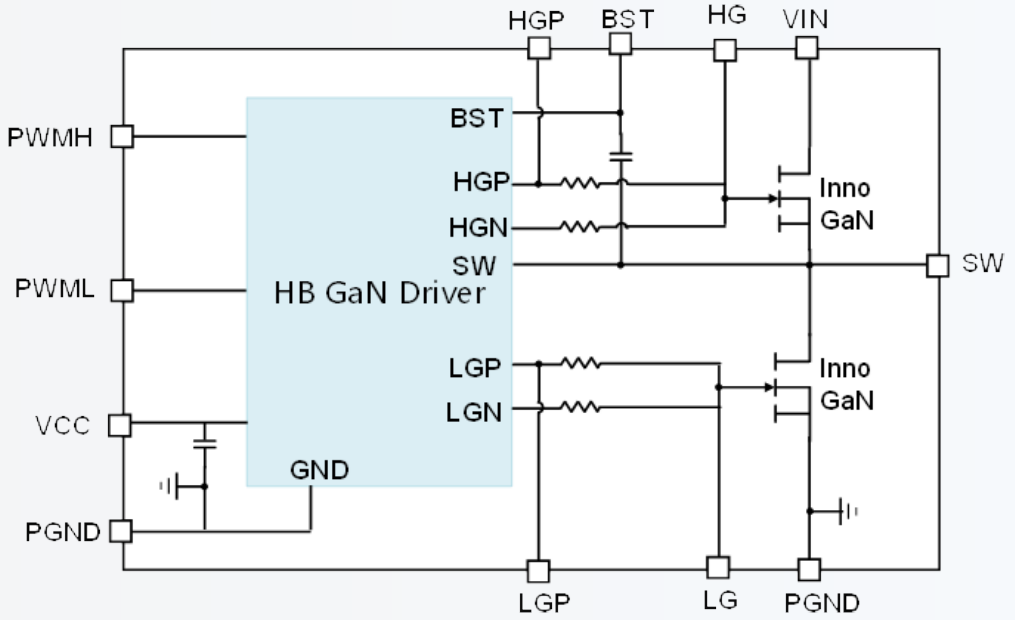


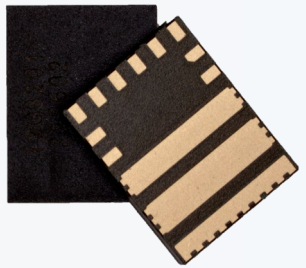
ISG3201
6.5mmx5mm

(even higher) Performance and easy to use /soldering

ISG3201

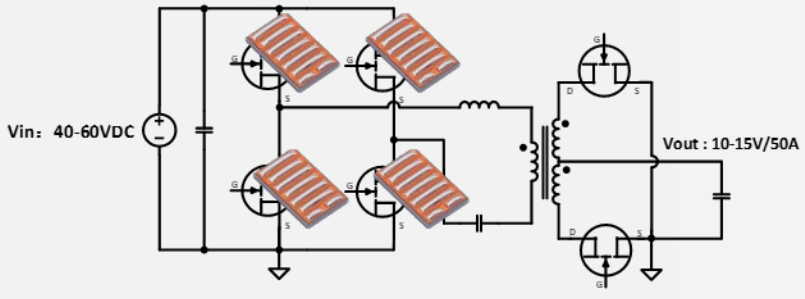
Half-bridge (3.2mOhm+3.2mOhm) + Driver

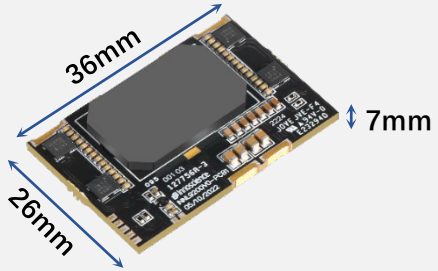




Increasing the performance with SolidGaN

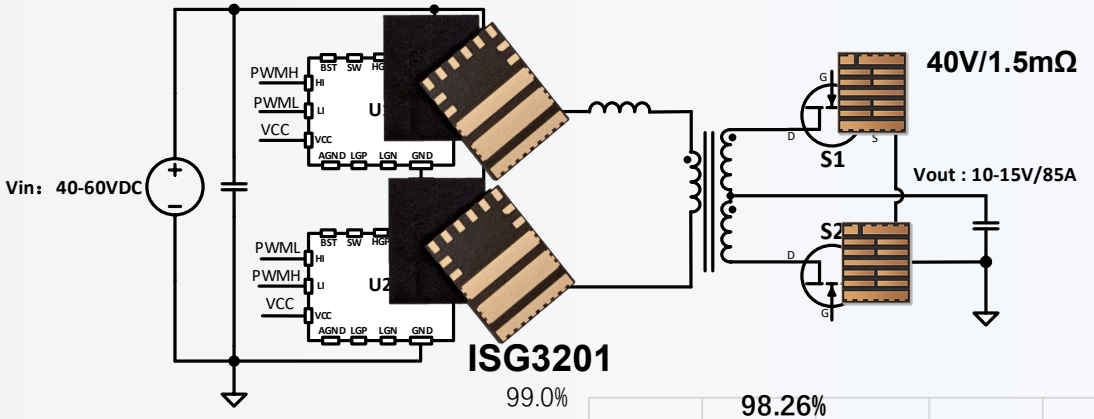
600W DC-DC 48V to 12V 1MHz

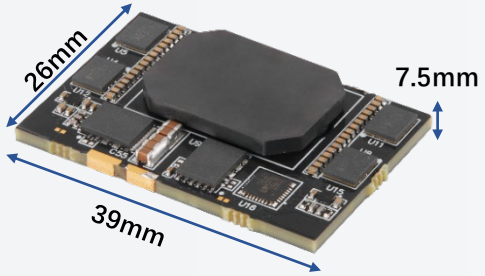




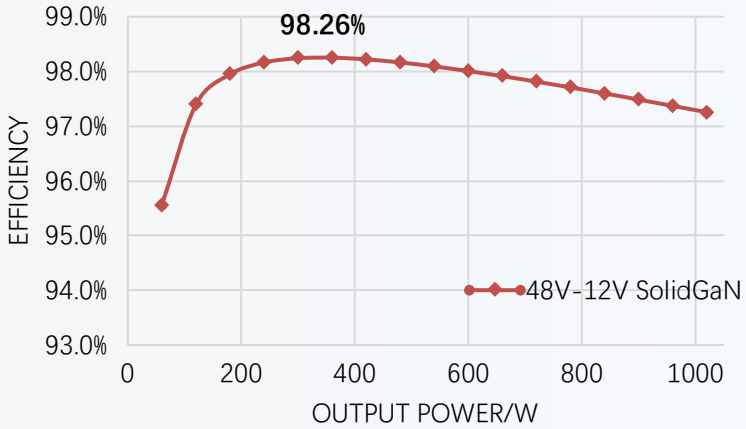
Higher Power Density: 2100W/in^3
Peak Effiency: 98%

1000W 48V-12V DC-DC Power Module 1MHz





High Power Density: 2150W/in^3



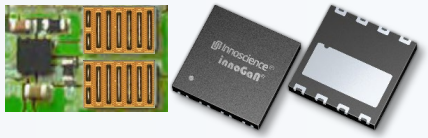
Conclusion

- **GaN power devices are a (much) better switch than Silicon devices**

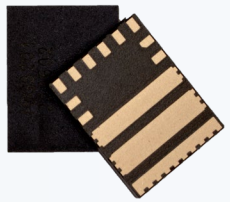
- **Any power conversion system can be made smaller, more efficient and even cheaper with GaN power devices**

- **Innoscience is the game changer bringing GaN power devices into mass production**
  - 100% focused IDM
  - Large 8-inch high-throughput manufacturing facilities
  - Slashing price and addressing mass volume needs

- **InnoGaN devices are robust and reliable**
  - e.g. Avalanche rating is tackled by transient voltage rating specifications



- **Discrete ~~vs~~ AND Integrated solutions: engineers select what they like**



Thank you

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