

GaN Based Power Devices Introduce a New Era in High Density, Highly Efficient Cost Effective Power Conversion



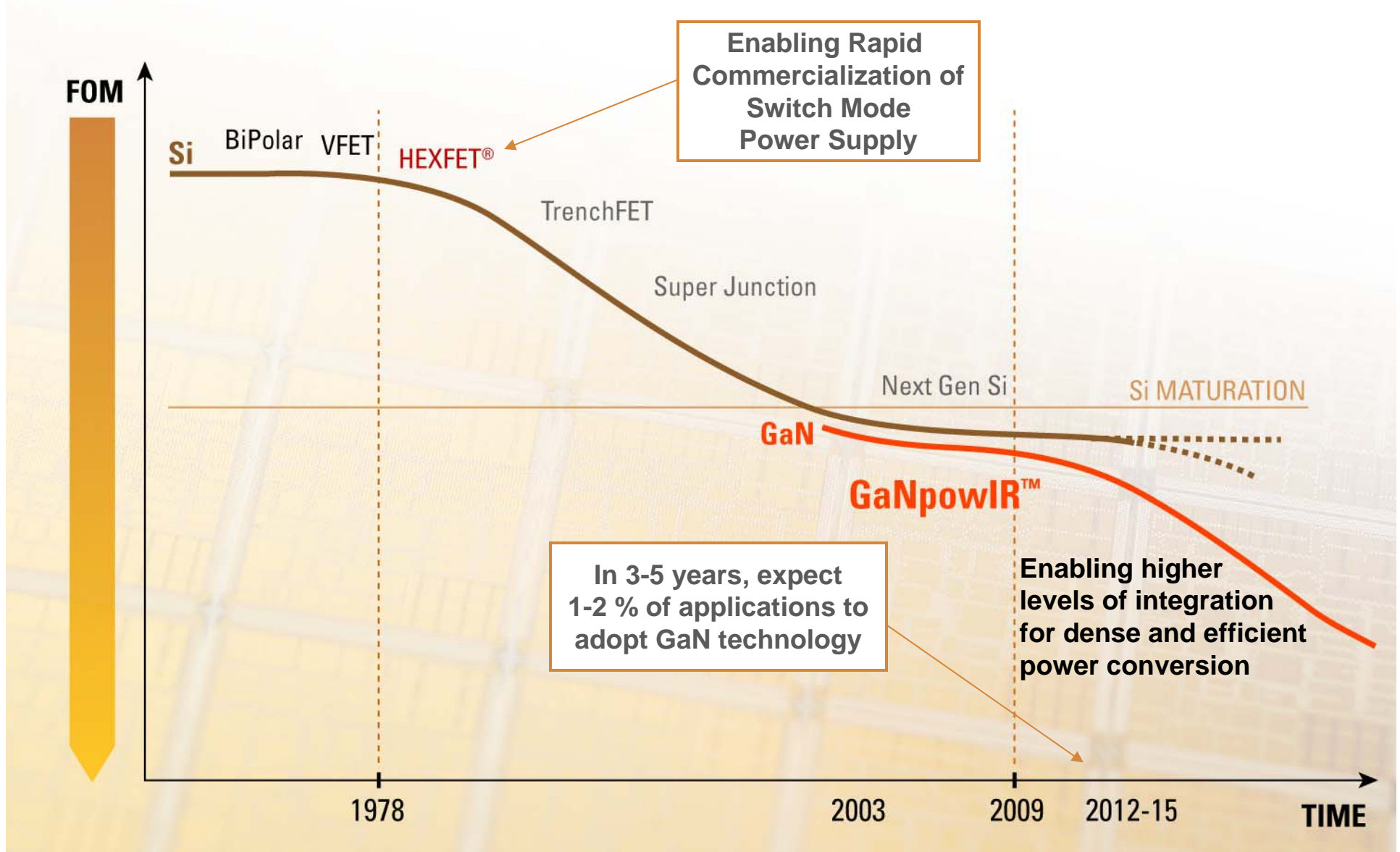
International
IOR Rectifier

November 2009

Outline

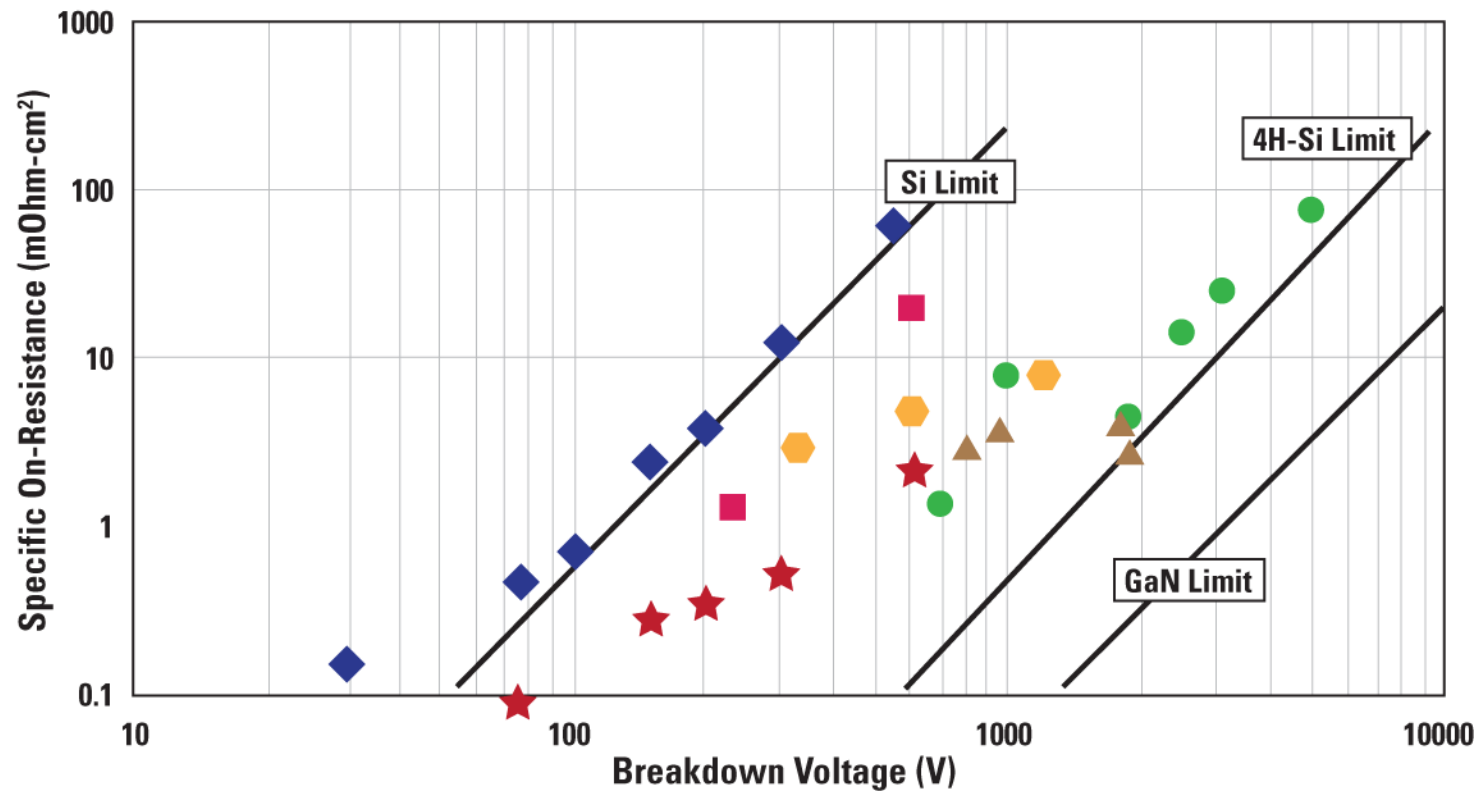
- Anatomy of Power Device Driven Revolutions in Power Electronics
- GaNpowIR – An Introduction
- Improving Power Device Figure of Merit
- GaN Characteristics
- First IR New GaNpowIR product (Efficiency measurements)
- GaN High Frequency performance measurements
- Mid Voltage FOM & Prototypes
- 600V Power Solution Prototypes
- Enabling a Revolution: Benefits of GaNpowIR for several applications

Anatomy of a power device driven revolution in power electronics



- A Commercially Viable GaN-based power device platform**
- Based on Proprietary GaN-on-Si Hetero-epitaxy**
- Utilizes low cost high quality 150 mm Si wafer substrates**
- Device manufacturing process is CMOS compatible**
- Standard high volume manufacturing disciplines applied**
- Industry standard quality systems utilized**
- Extensive intrinsic reliability studies performed**
- Standard product reliability tests applied to device qualification**

Comparison of R_{on} for Si, SiC, and GaN



◆ Si
 ■ Si SJ
 ⬡ IGBT
 ● SiC
 ▲ GaN HFET
 ★ IR GaN

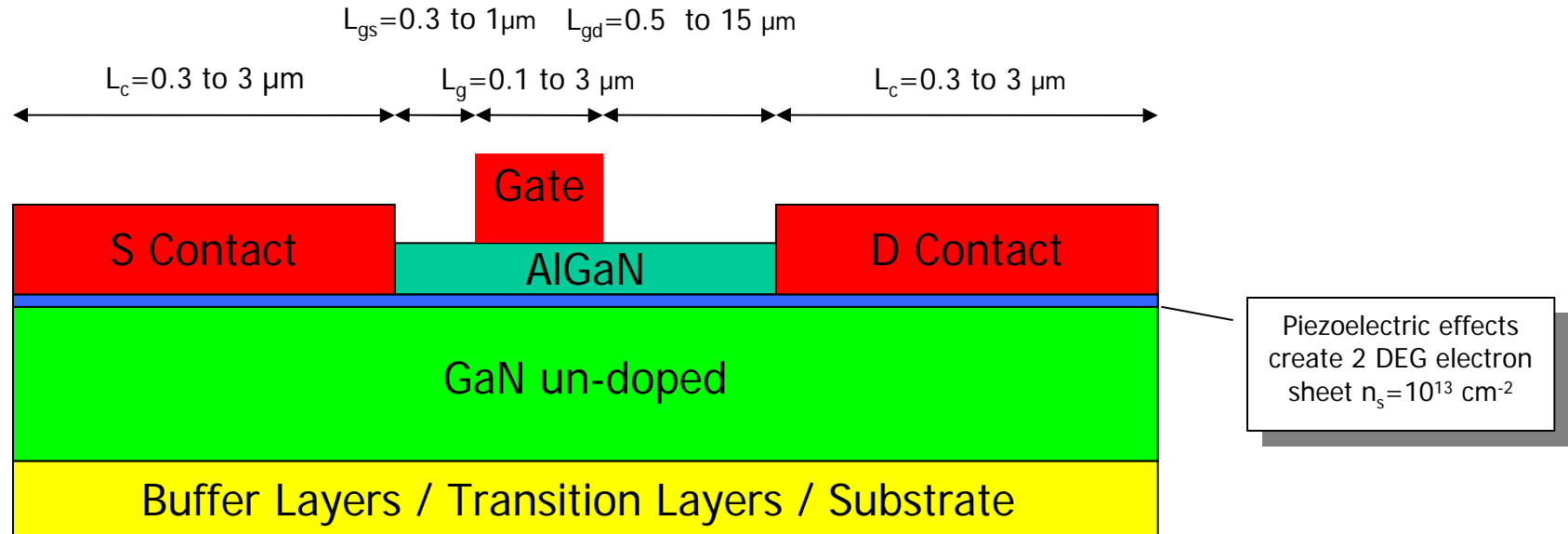
Measured data

Ecrit : Si = 20 V/ μm , GaN = 300 V/ μm

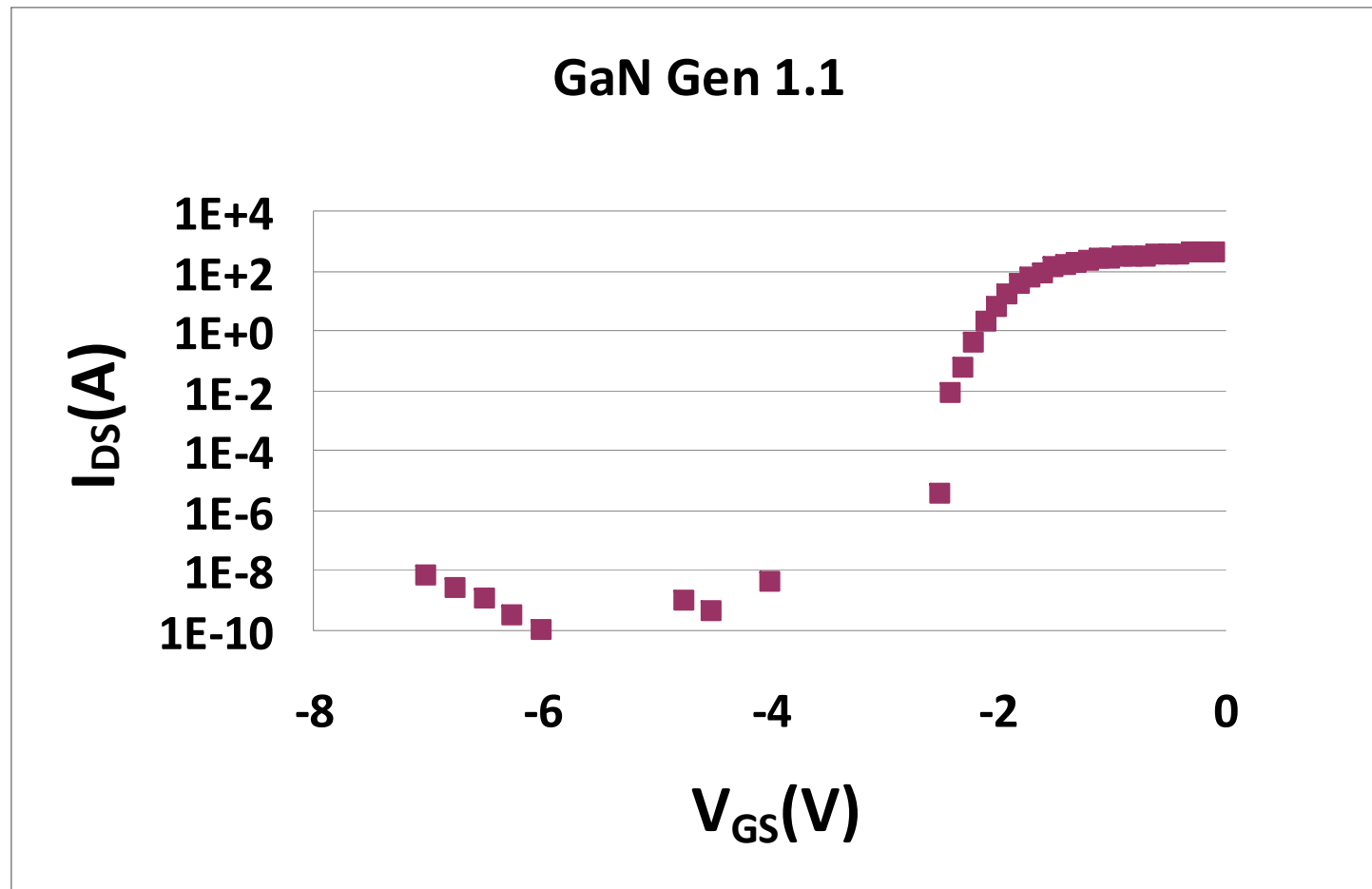
Ref: N. Ikeda et.al. ISPSD 2008 p.289

GaN HEMT FET Characteristics

- 2DEG region is formed due to bandgap difference between GaN and AlGaN materials and polar behavior of AlGaN.
- No impurity scattering and 2DEG confinement resulting in high mobility
- Depletion mode Device – Normally ON
- No inherent body diode
- Lateral structure (all terminals on one side)
- Multiple device integration



High Current Device, $I_d > 100$ A

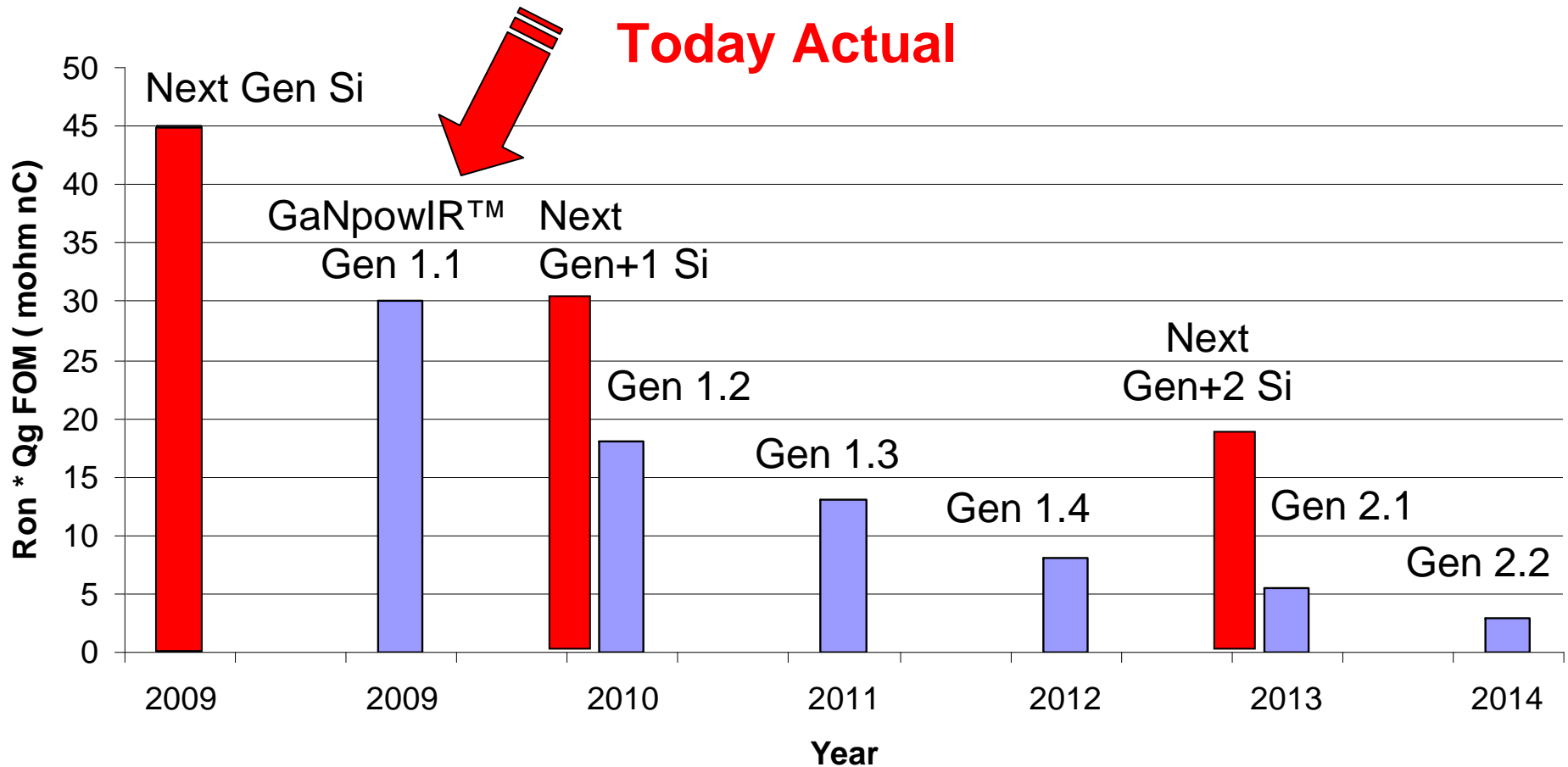


$I_{ds\ off} < 100$ nA, $I_{on}/I_{off} > 10^9$!! I_g (leak) < 100 nA !
($W_g/L_g=2.5m/0.3\mu m$), $AA = 11$ mm² $T_a = 25$ °C

Projected GaN LV Figure of Merit Projection vs. Time



$R_{ON} * Q_G$ FOM for 30V Mosfet



GaN: 10x improvement in 5 years

POL- Early Prototypes realize potential of GaN



5 times Higher Frequency over Si Solution with similar efficiency !

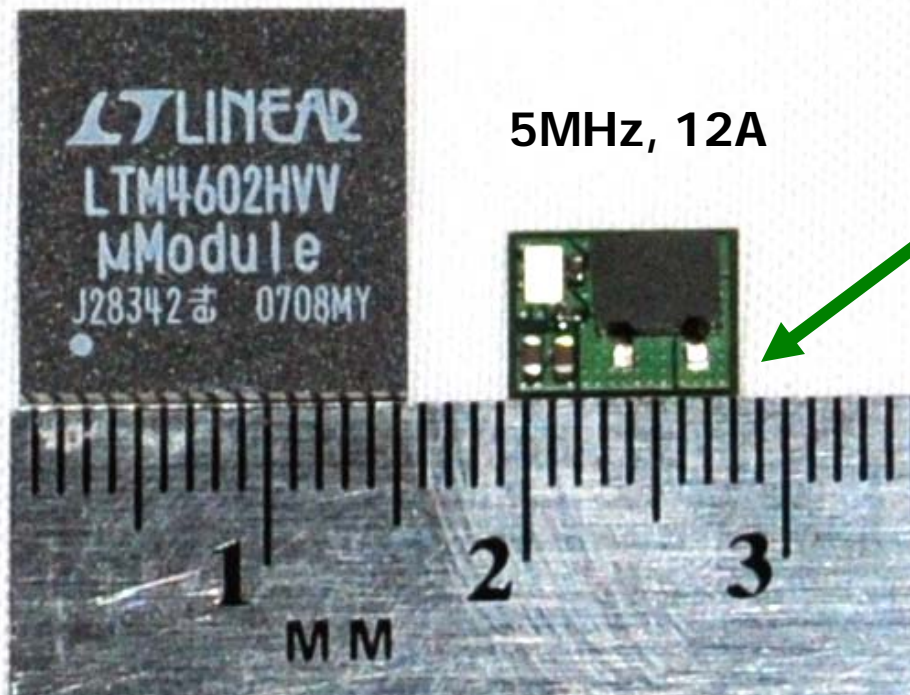
Si POL Solution:
15 mm x 15 mm

IR GaNpowIR
Gen 1.1 Solution:
7 mm x 9 mm....

70% Smaller!

1MHz, 10A

5MHz, 12A

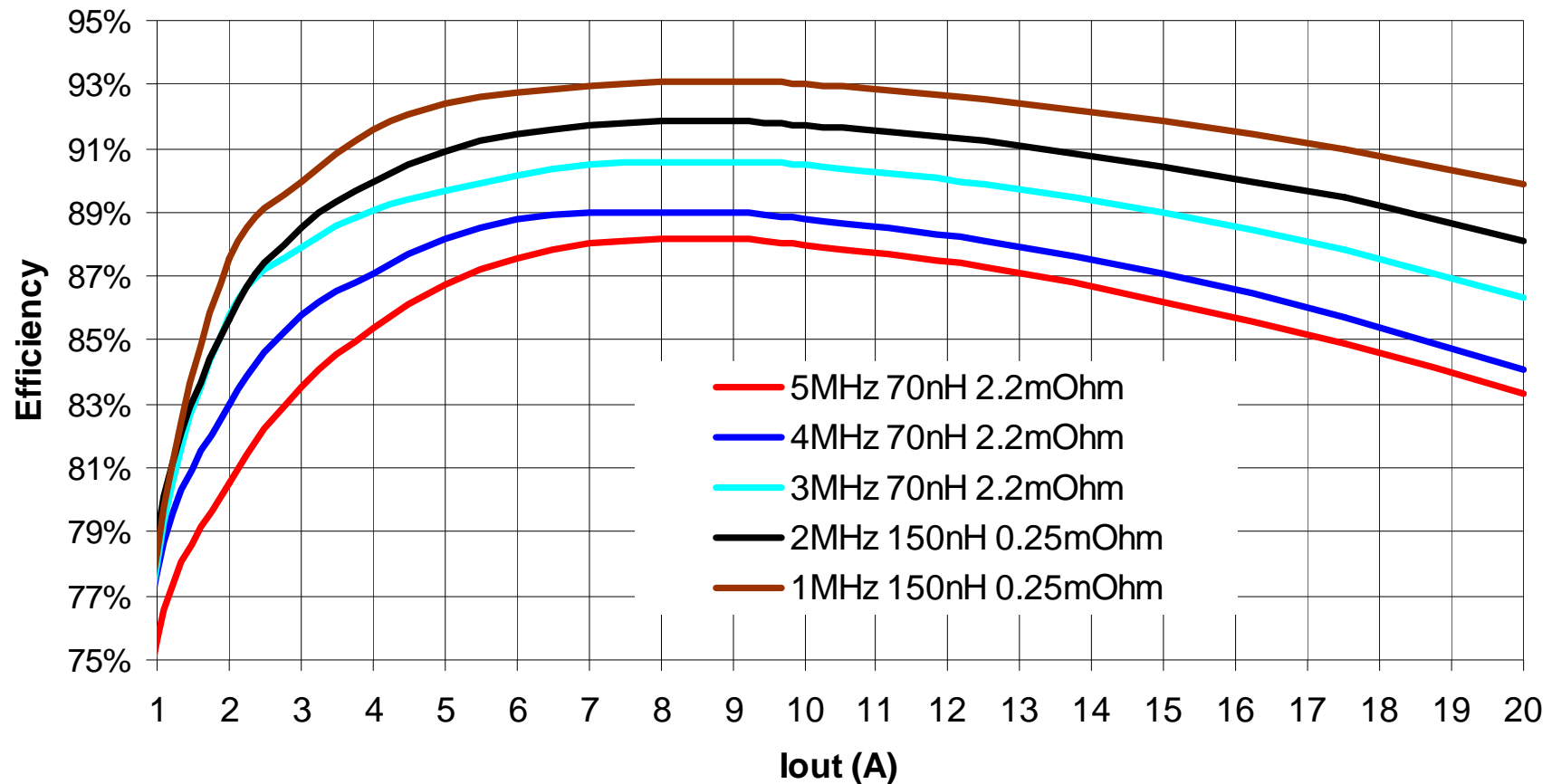


Output Inductor
Integrated with
Power Stage
 $\eta = 85 \%$
12 V to 1.2 V

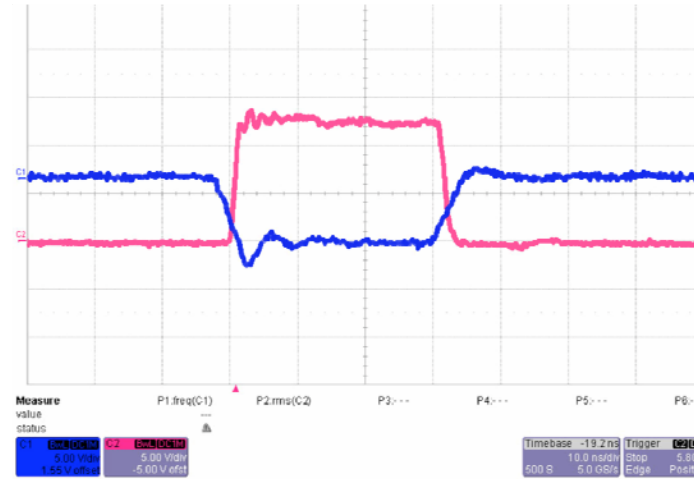
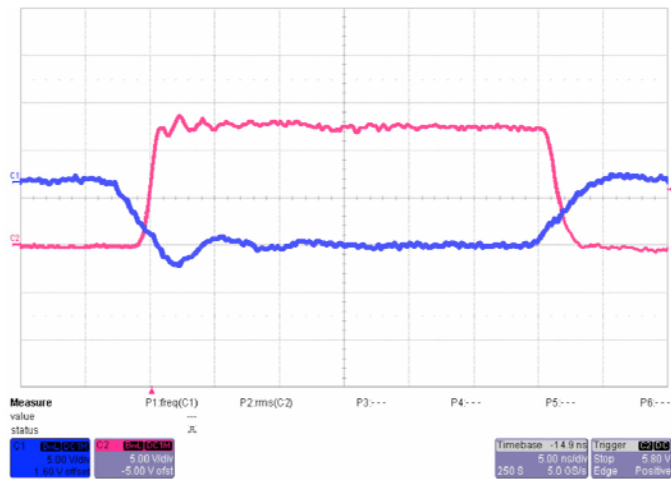
Measured High Frequency Buck Converter Efficiency



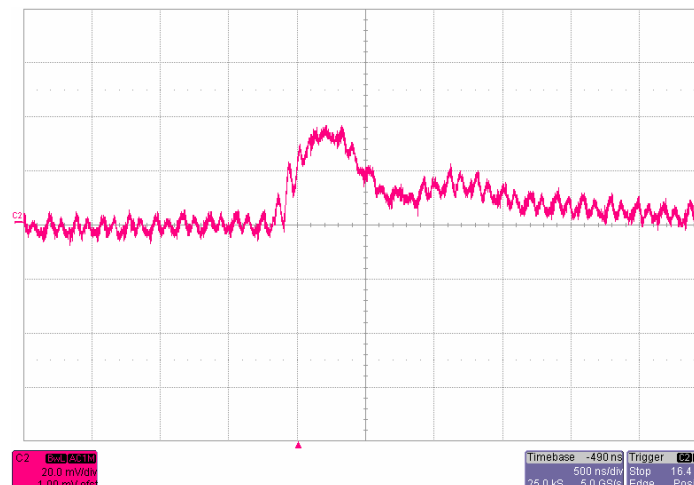
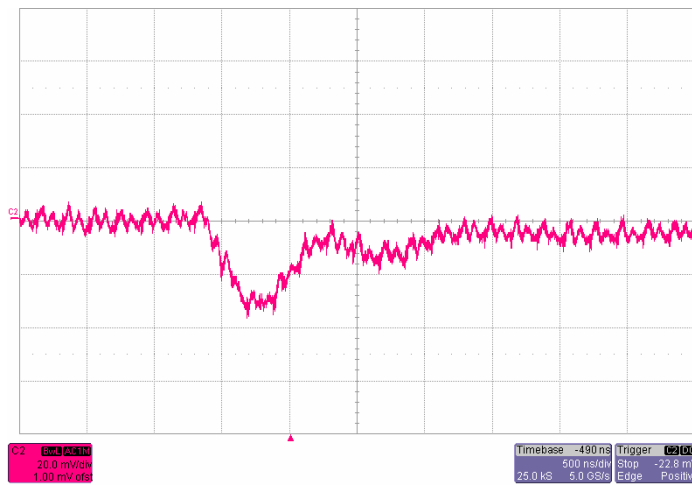
12 Vin to 1.8 Vout POL (includes driver, switch, Inductor, PCB losses)



5MHz DCDC μ Module Waveforms



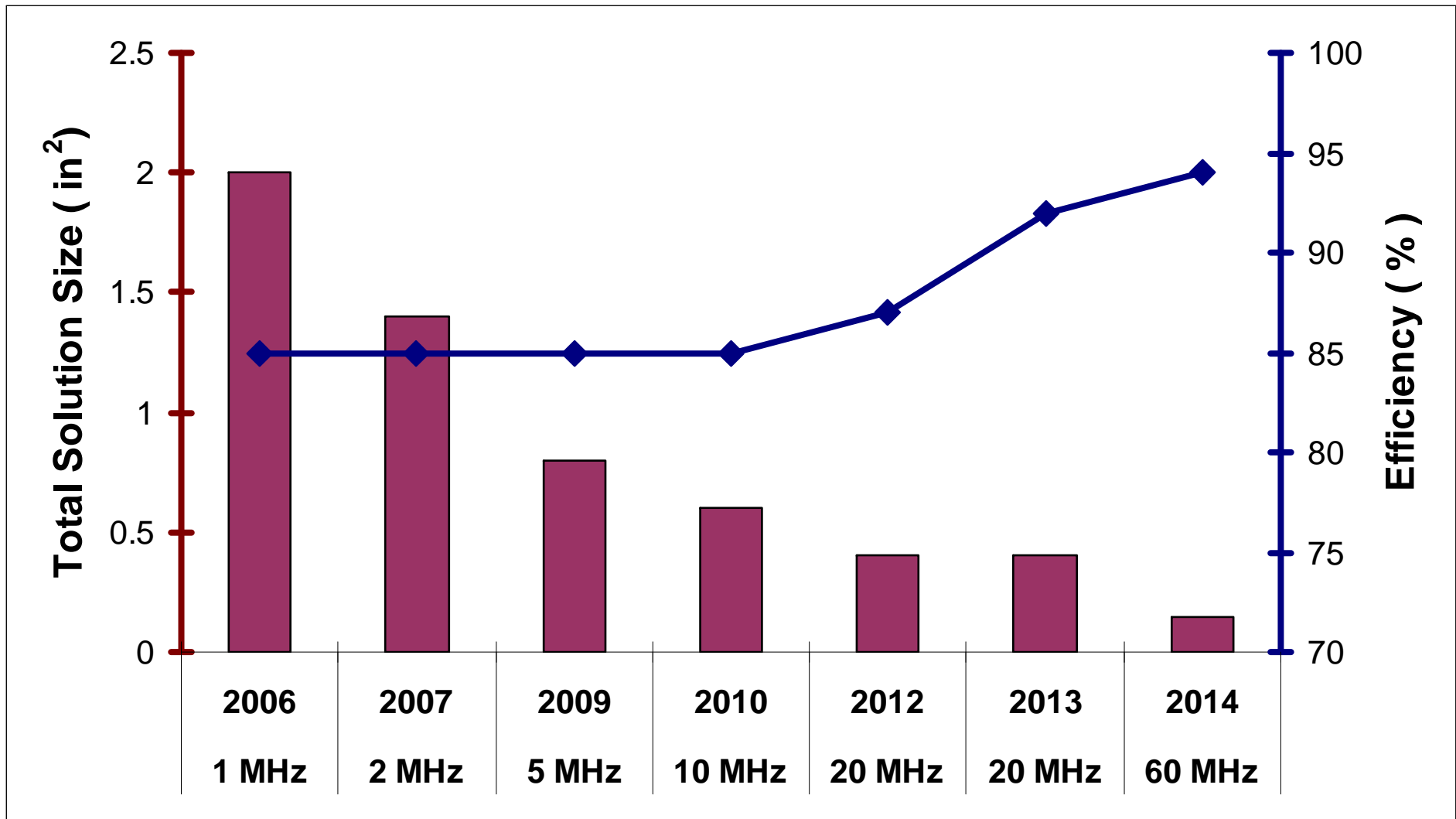
5MHz Vsw and LGD Waveforms



700kHz bandwidth, 5A transient, 1000A/ μ s, 30mV voltage droop and overshoot

Potential Power Stage Roadmap

Optimized Performance – Without tradeoff

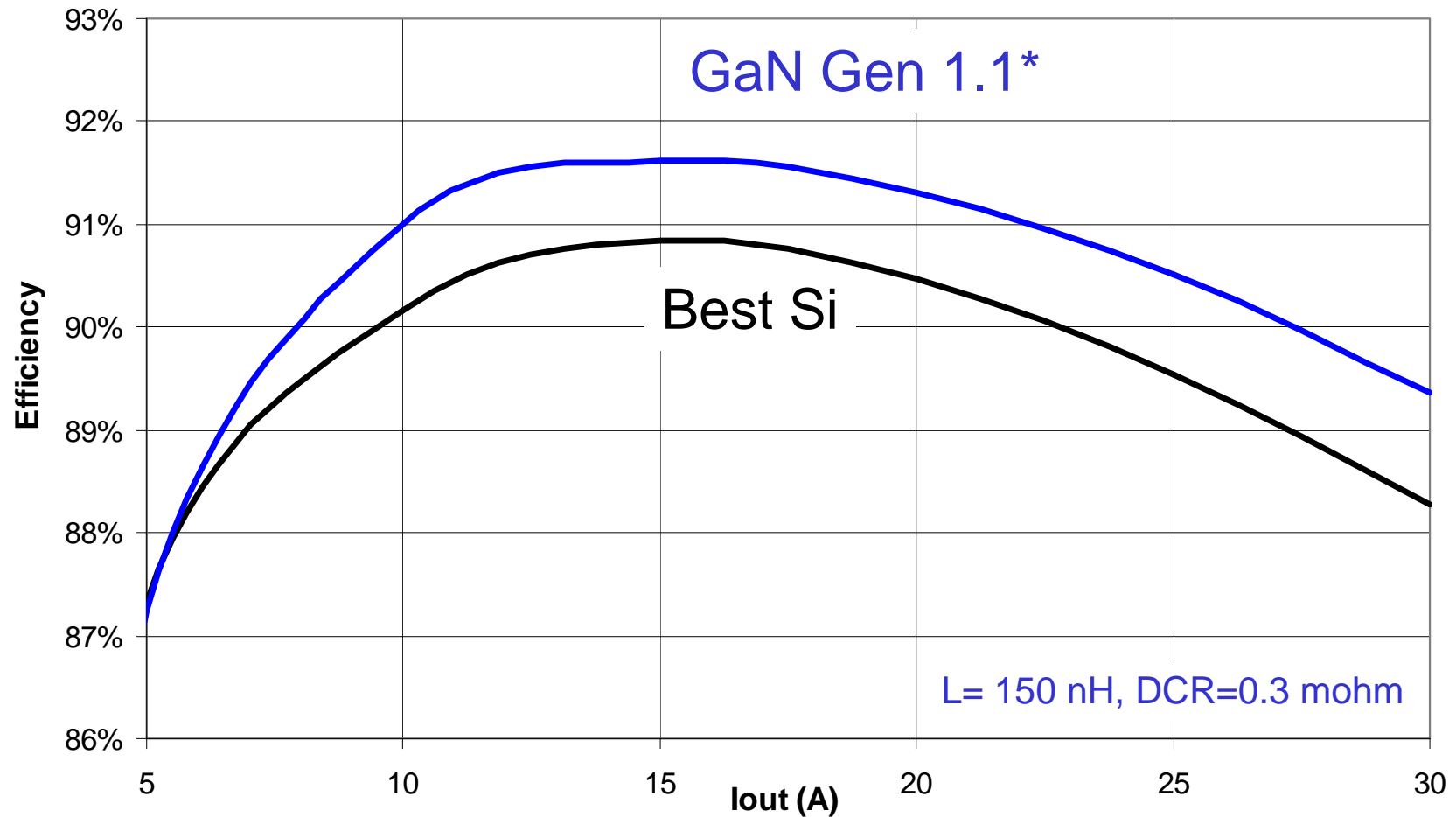


12Vin, 1.2Vout, 100A

Measured High Current LV POL (VRM)



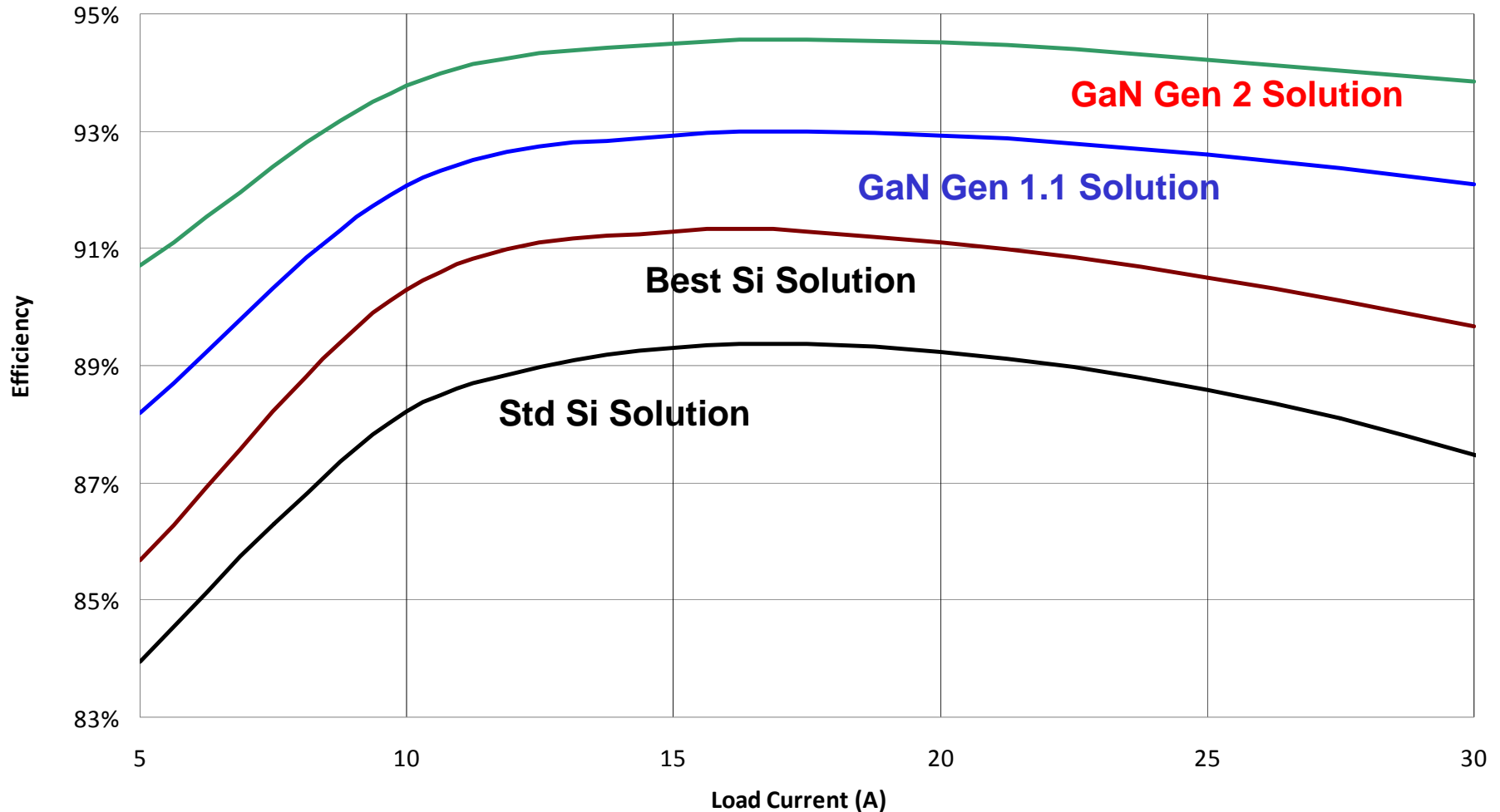
Measured 12Vin to 1.2Vout Conversion Efficiency 600kHz
Includes Driver, Switch, PCB and Inductor Losses



High Current LV POL (VRM) – Projected



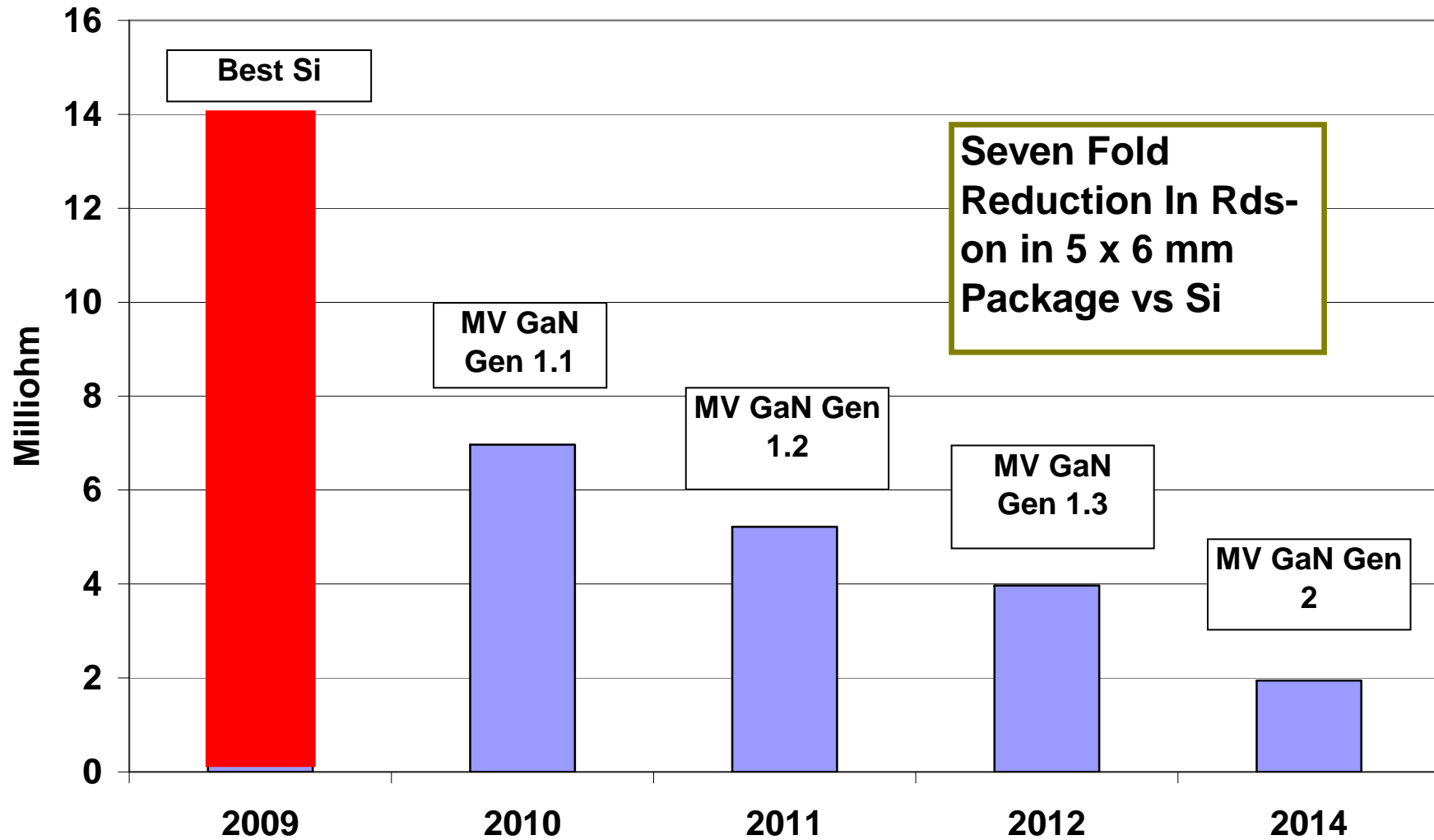
Can Achieve > 94% efficiency from 10A to 100A – 4 phase



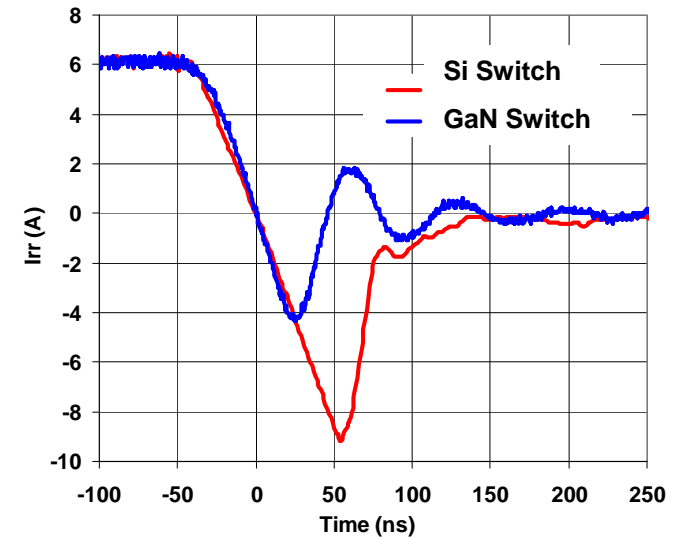
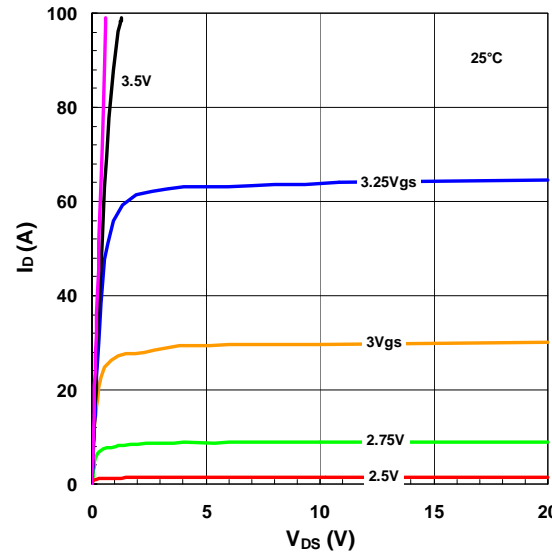
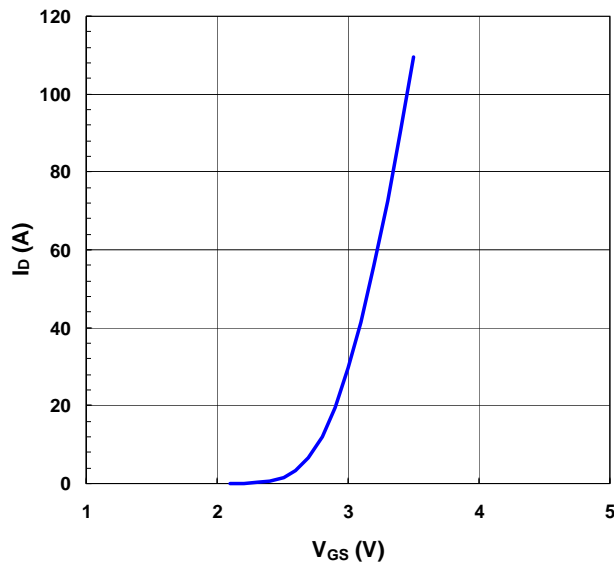
700 kHz $V_{in} = 12\text{ V}$, $V_{out} = 1.2\text{ V}$

Circuit Simulations

Rds-on in 5 x 6 mm Package (150V Normally off with free wheeling diode)



Mid-Voltage GaN based switch: Easy to use



Highlights:

- Normally Off operation
- Up to 10x better Figure-of-Merit than silicon equivalent

Compared to Si solutions:

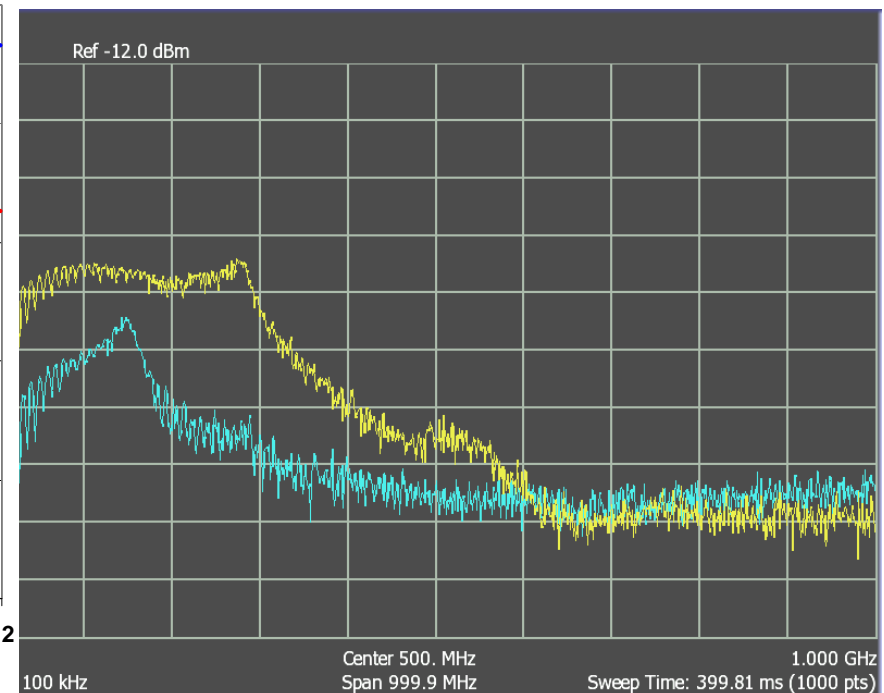
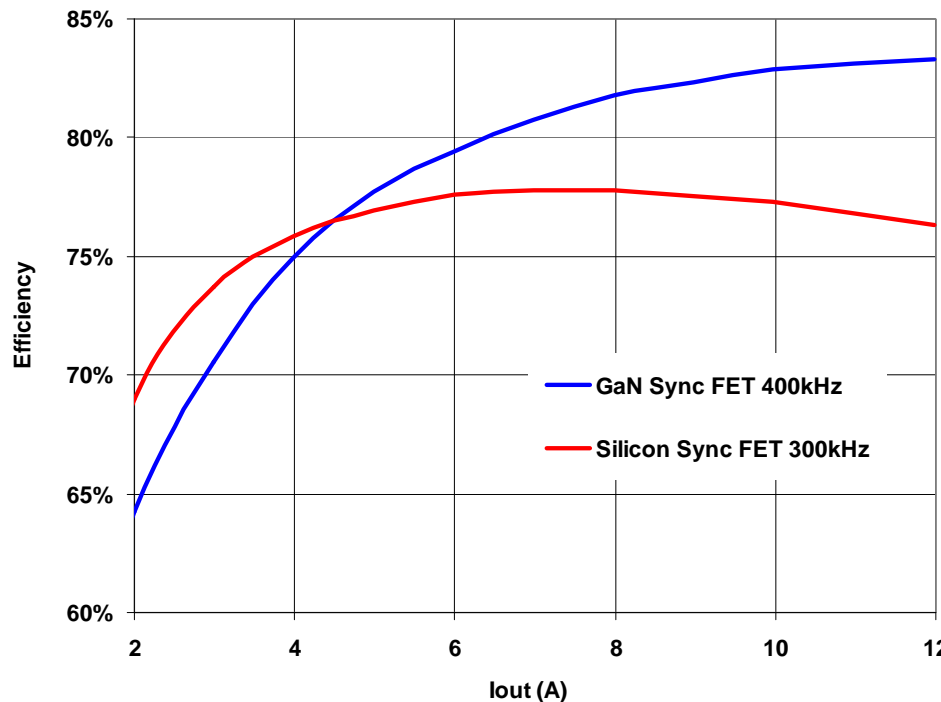
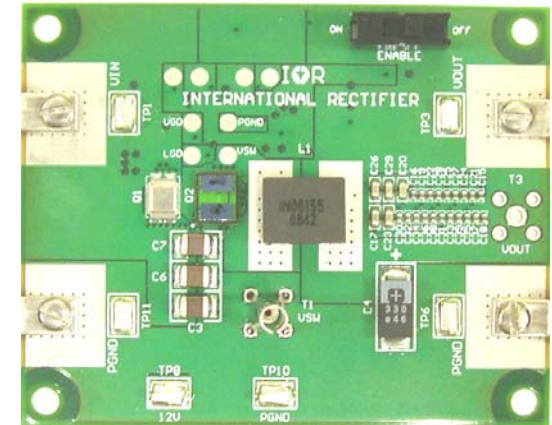
- Much Lower reverse recovery losses
- Lowest R_{dson} and Q_g in smaller package
- Lower EMI

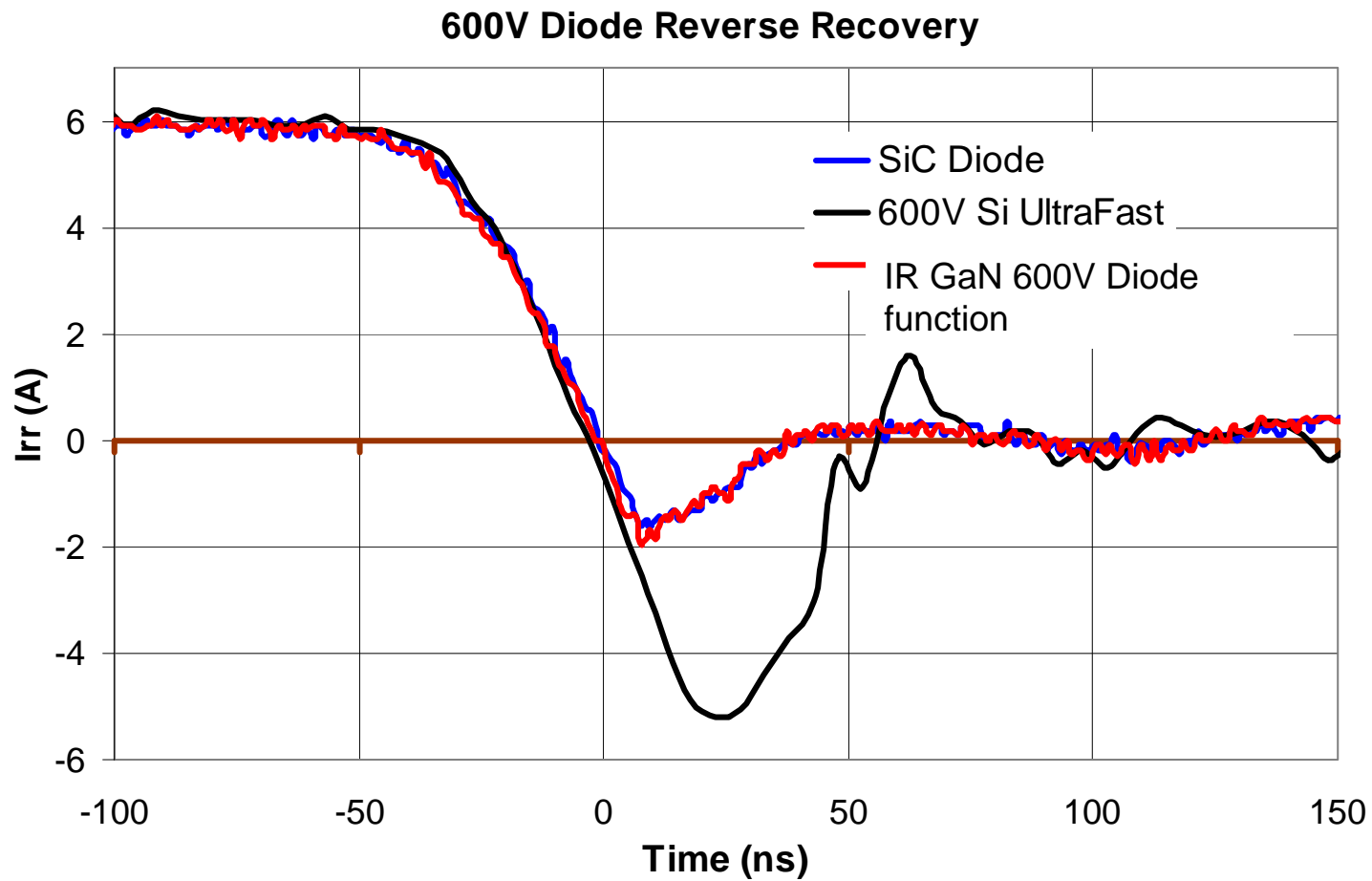
Mid-Voltage GaN based switch: Easy to use



48V to 2V Demoboard

- Drop-in replacement
- Efficiency improved by >7%
- Reduced Radiated EMI by >6db





Same Performance as SiC but at lower cost

- Silicon based power devices are reaching their inherent performance limitations.
- Power devices based on new materials such as GaN are leading candidates to achieve breakthrough performance gains
- GaNpowIR platform has been developed for wide spread commercialization: first products to be released by early 2010.
- Efficient High Frequency Power Conversion (>90 % at > 5 MHz) is Realizable using GaN based Power Devices
- Today's Low voltage GaN technology delivers dramatically improved efficiency at high frequency or can offer highest efficiency at lower frequency.
- Mid Voltage and High Voltage devices demonstrated to outperform any of current available solutions.
- GaN has great room for even higher performance improvement.
- GaN based devices offer improved efficiency, density (higher frequency), and cost compared to Silicon or other solutions.