



**NITRONEX**  
CORPORATION

**A 36mm GaN-on-Si HFET Producing  
368W at 60V with 70% Drain Efficiency**

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**IEDM 2005**

# Overview

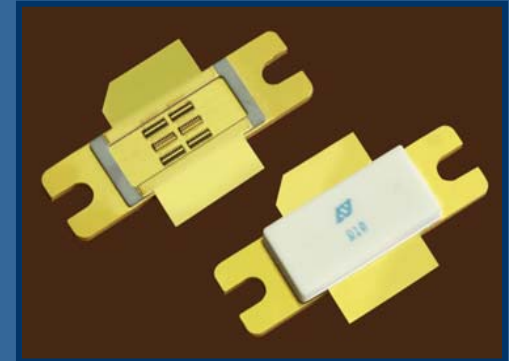
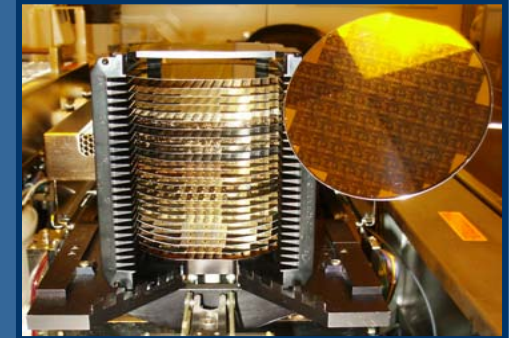
## >> Technology Overview

- Epitaxial layers
- Device Fabrication
- Process Capability
- Device Layout
- Simulation

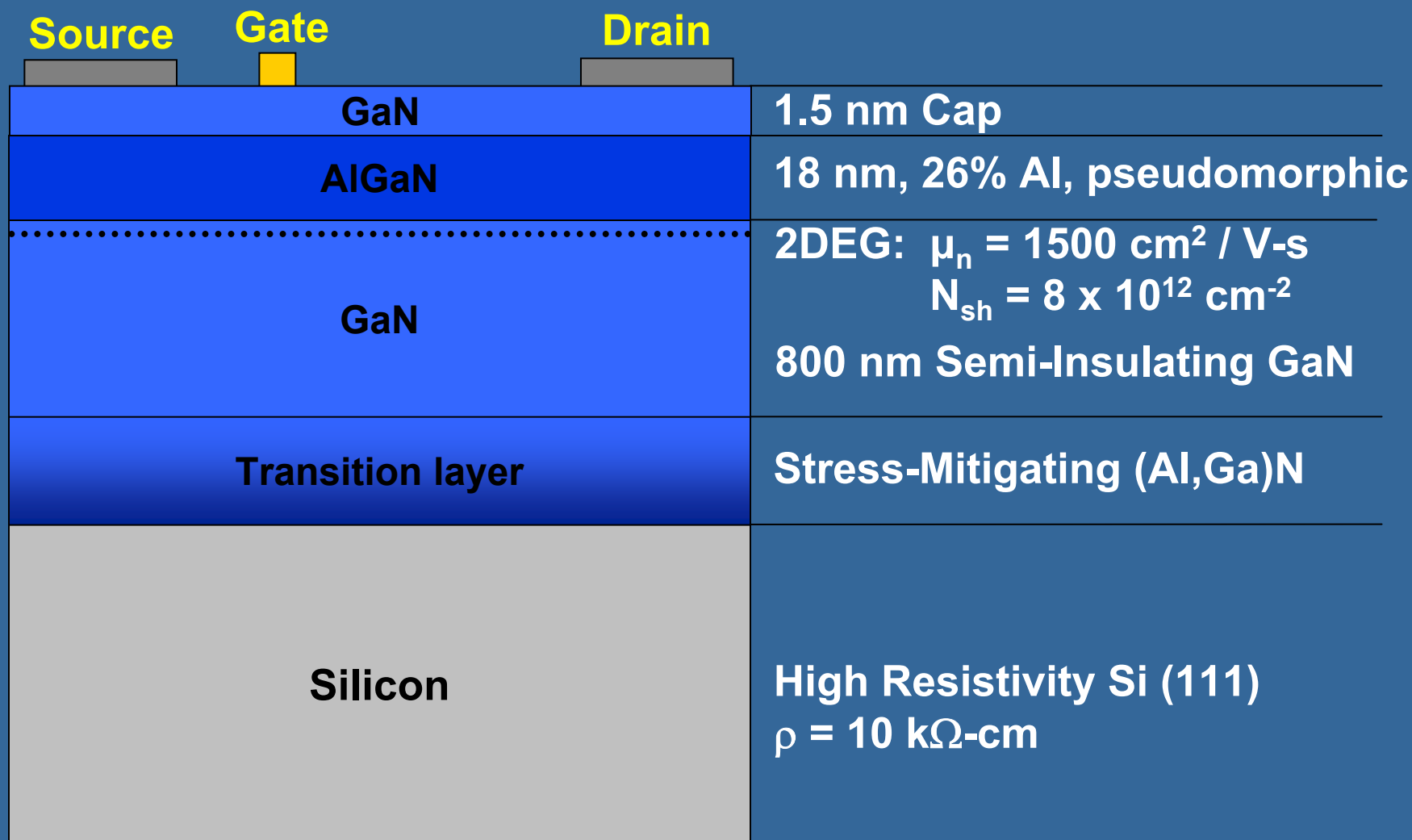
## >> Device Performance

- DC Characteristics
- Small Signal Characteristics
- Pulsed RF Characteristics
- Application Specific Performance
- Reliability

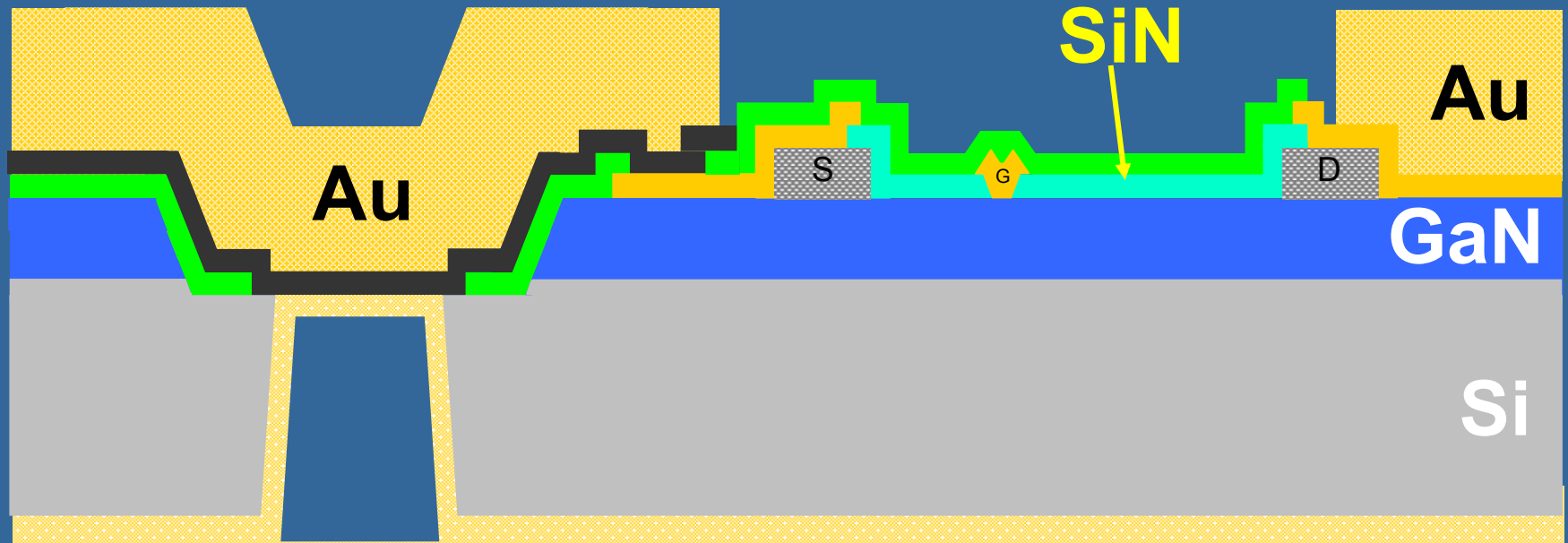
## >> Summary



# GaN HFET Device Structure



# Cross-Sectional Schematic



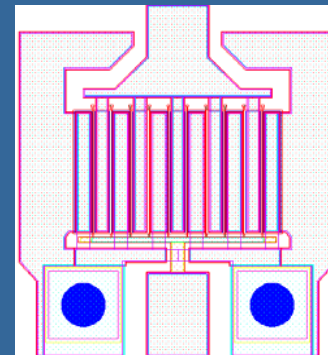
## ► Design Dimensions

- 0.7 μm gate length
- 200 μm unit gate width
- 3 μm gate-drain spacing
- 1 μm gate-source spacing
- 30 μm gate pitch

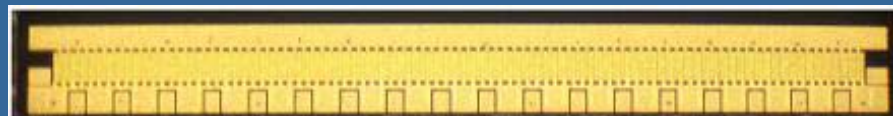
# Technology

## Die Description

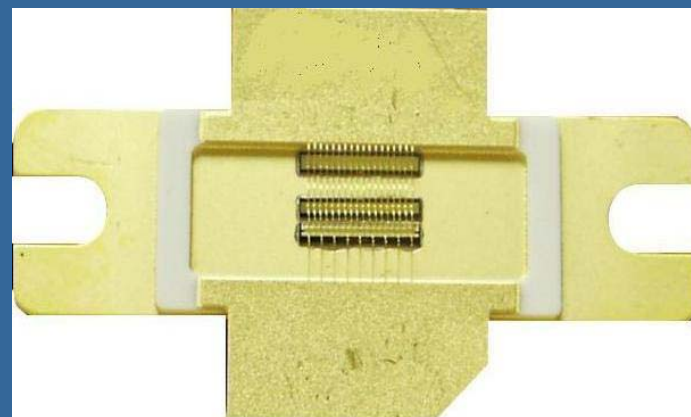
- ▶ 2mm CPW devices for on wafer testing
- ▶ 36mm periphery parts in package



## Attached using a Au-Si eutectic onto a Au-plated CuW flange

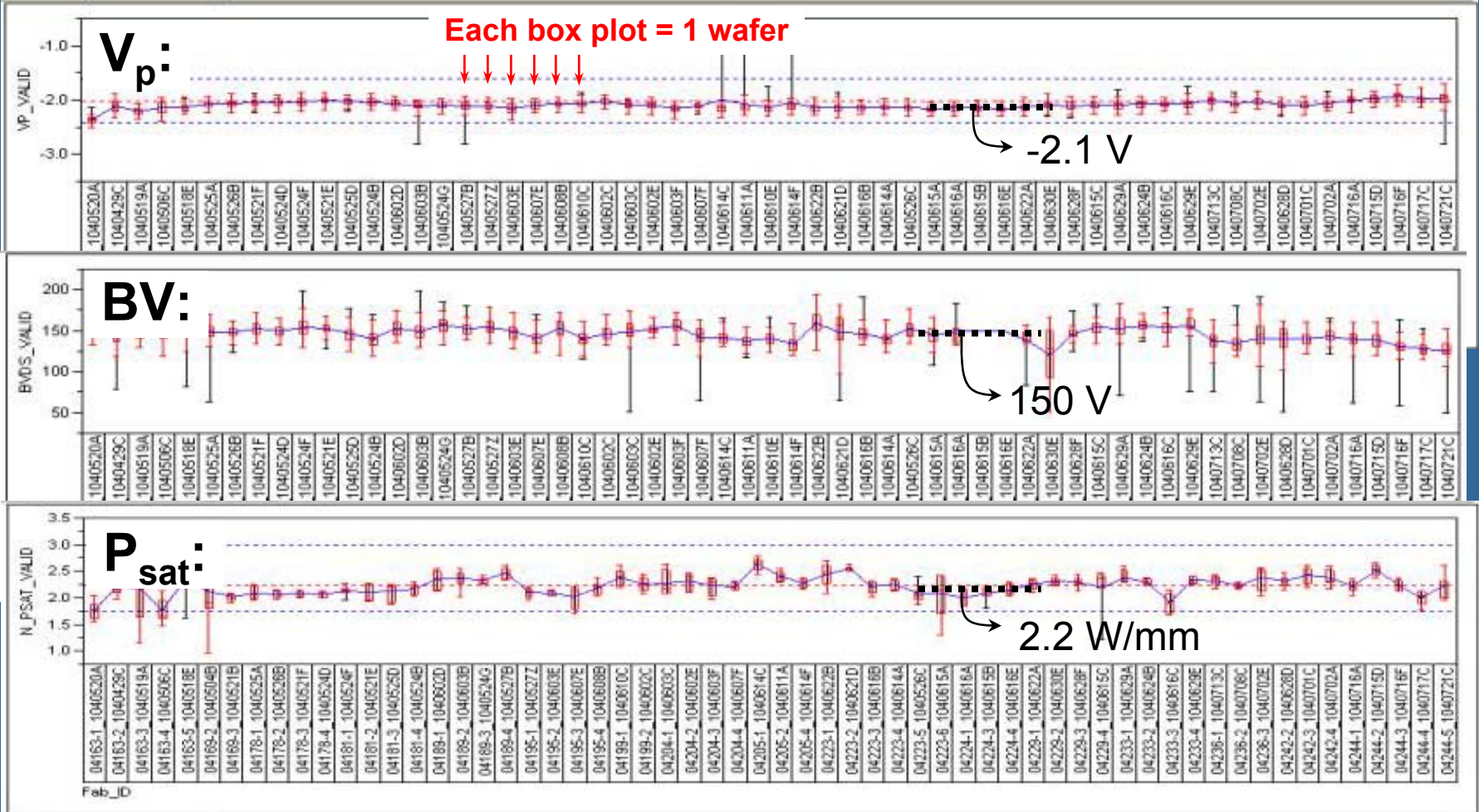


## Two stage input match using MOS capacitors

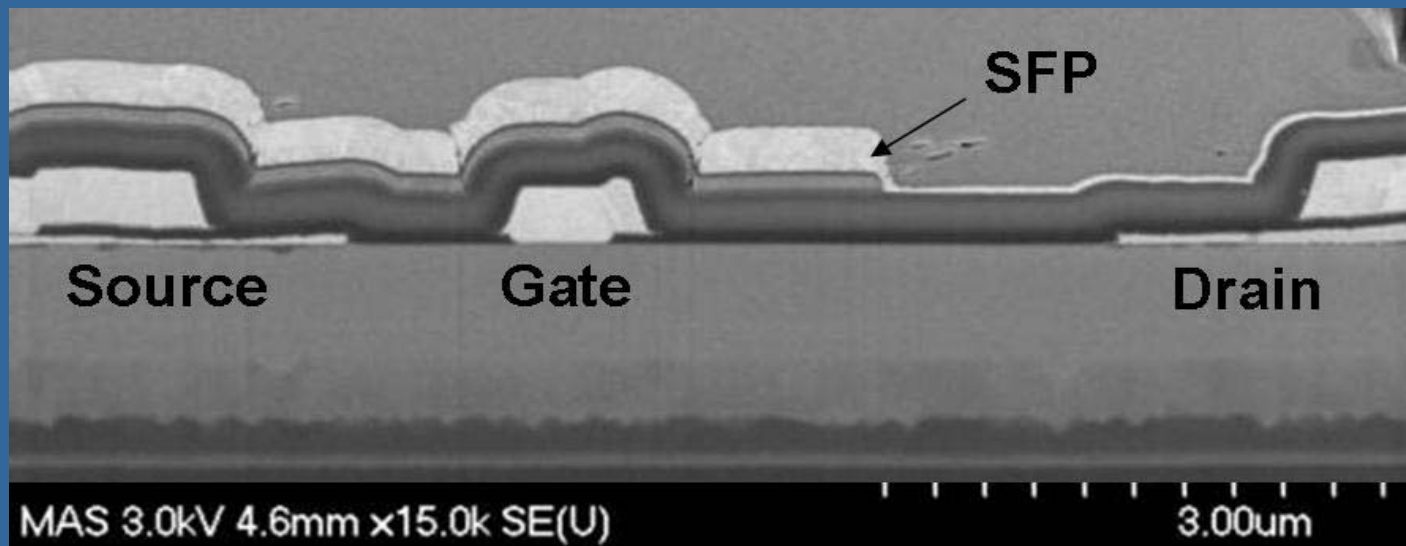
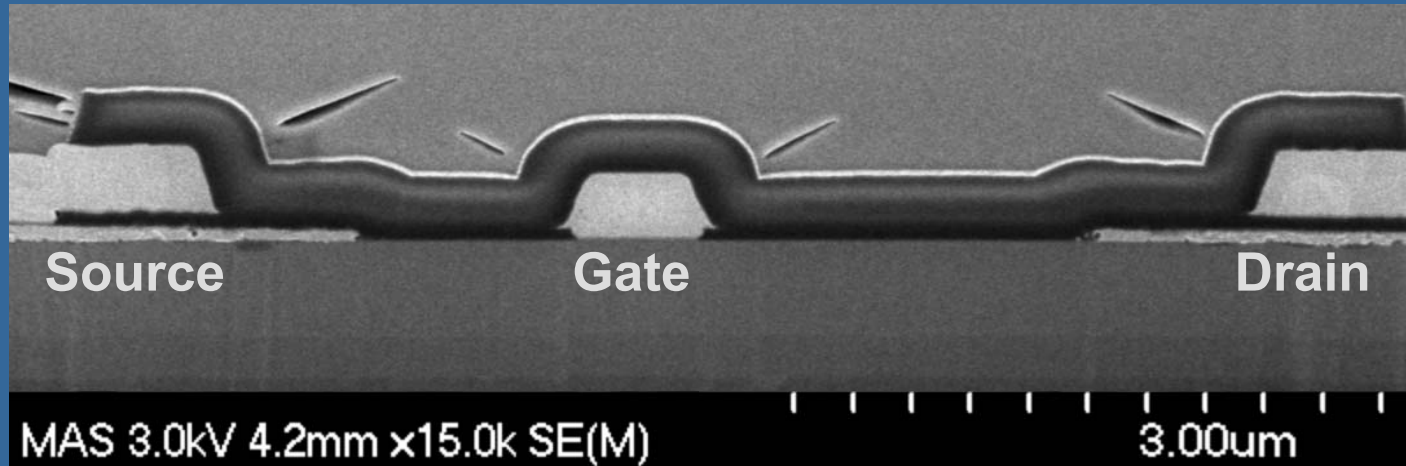


## No internal output matching

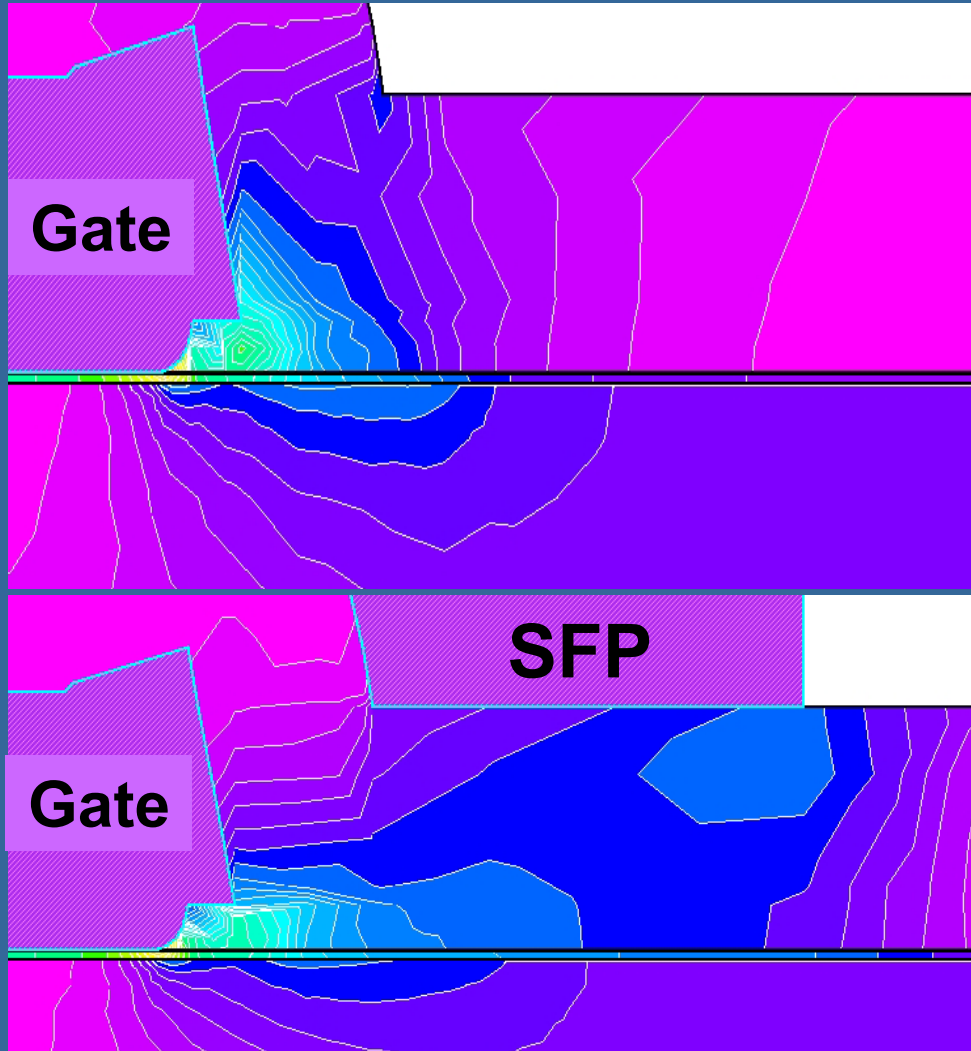
# DC and RF Process Control



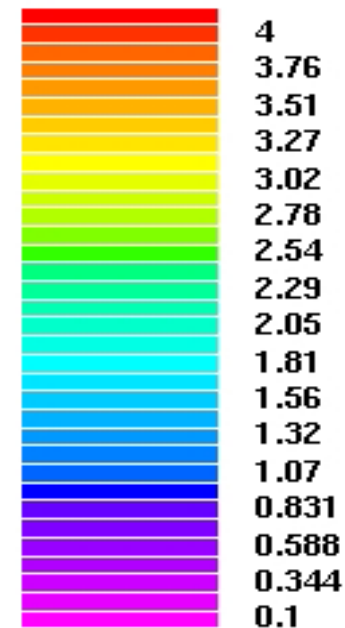
# Addition of the Source Field Plate



# E-field Simulations

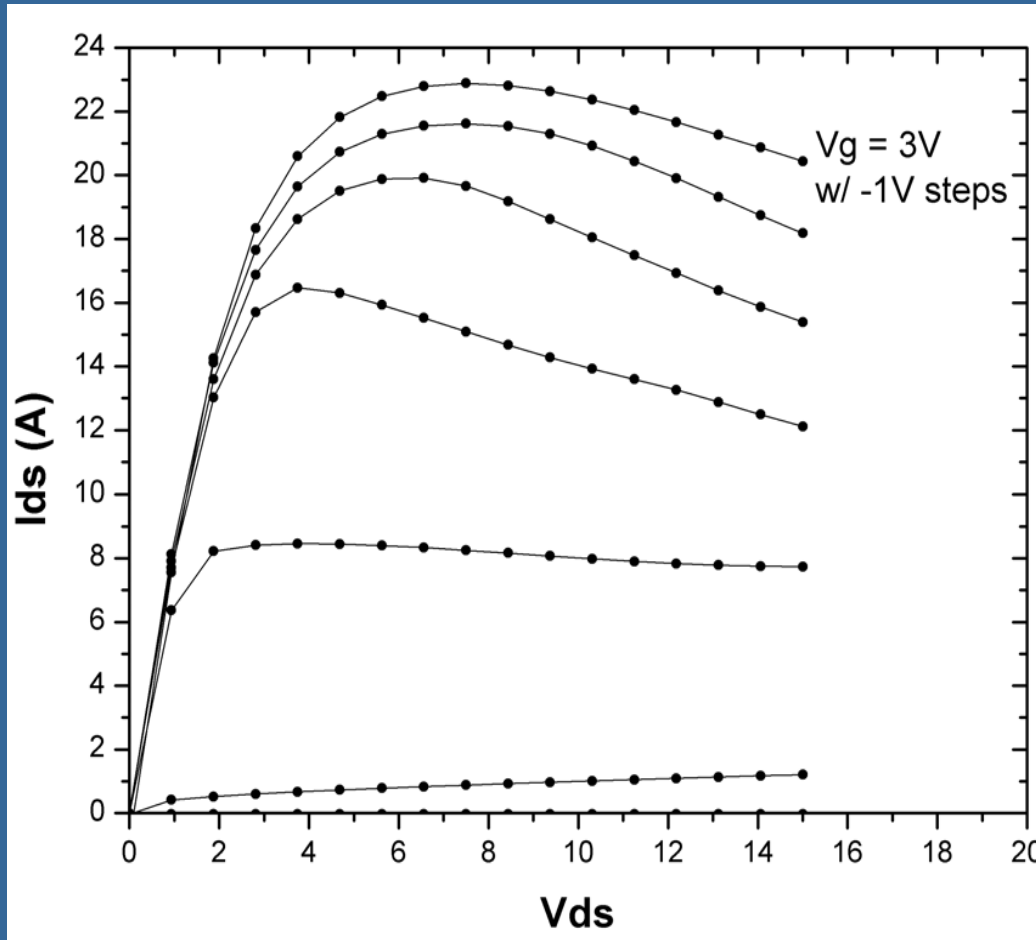


Electric Field (MV/cm)



- ☞ SFP provides:
  - ▶ E-field redistribution
  - ▶ ~2x reduction in peak E-field

# DC Characteristics



Data Taken with a  $300\mu s$  pulse

>> DC Performance of the SFP and non SFP designs are very similar

>> Typical 36mm performance

▶  $I_{max} \sim 23 A$

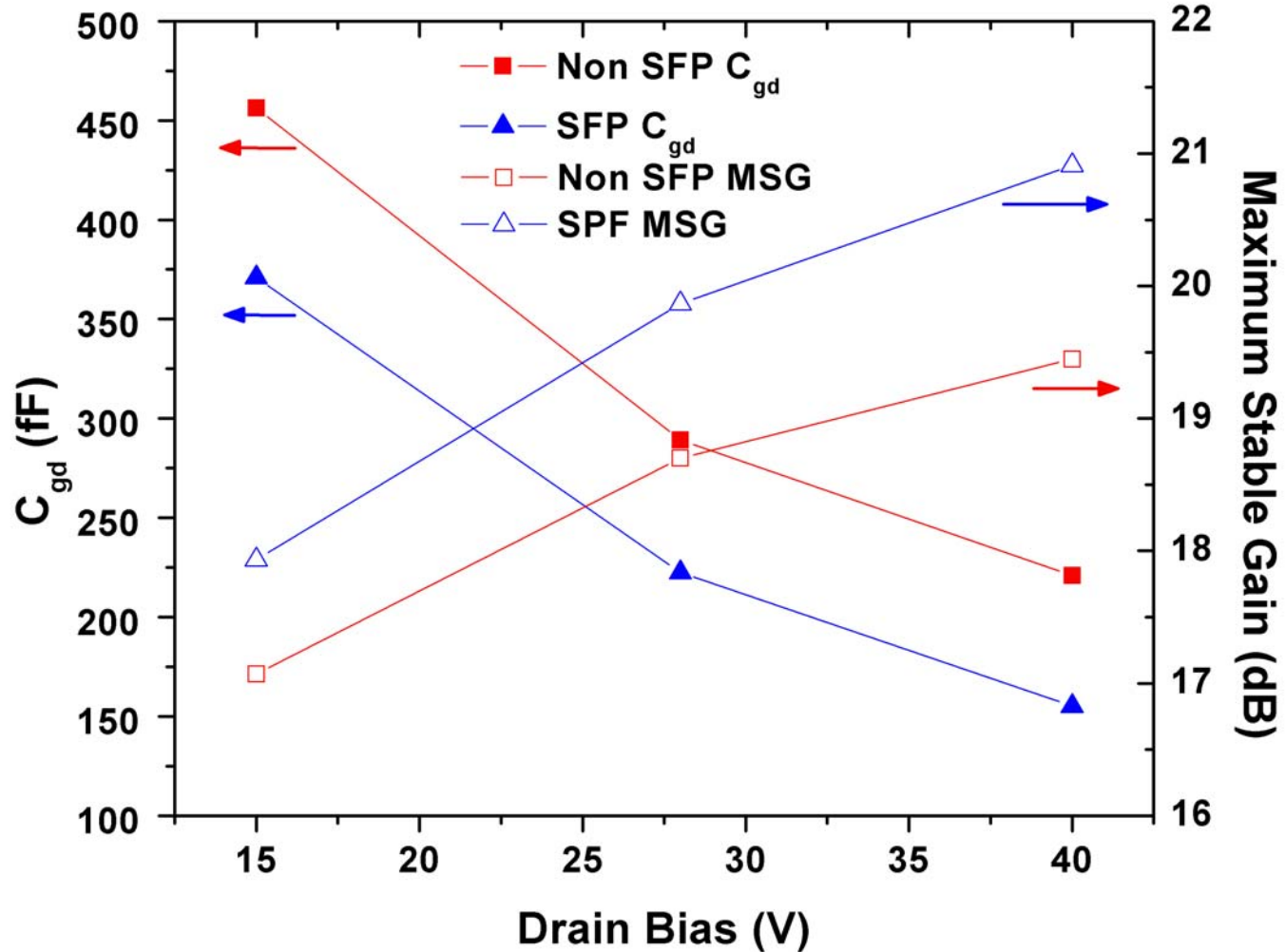
▶  $V_p \sim -2.2 V$

▶  $g_{max} \sim 8 S$

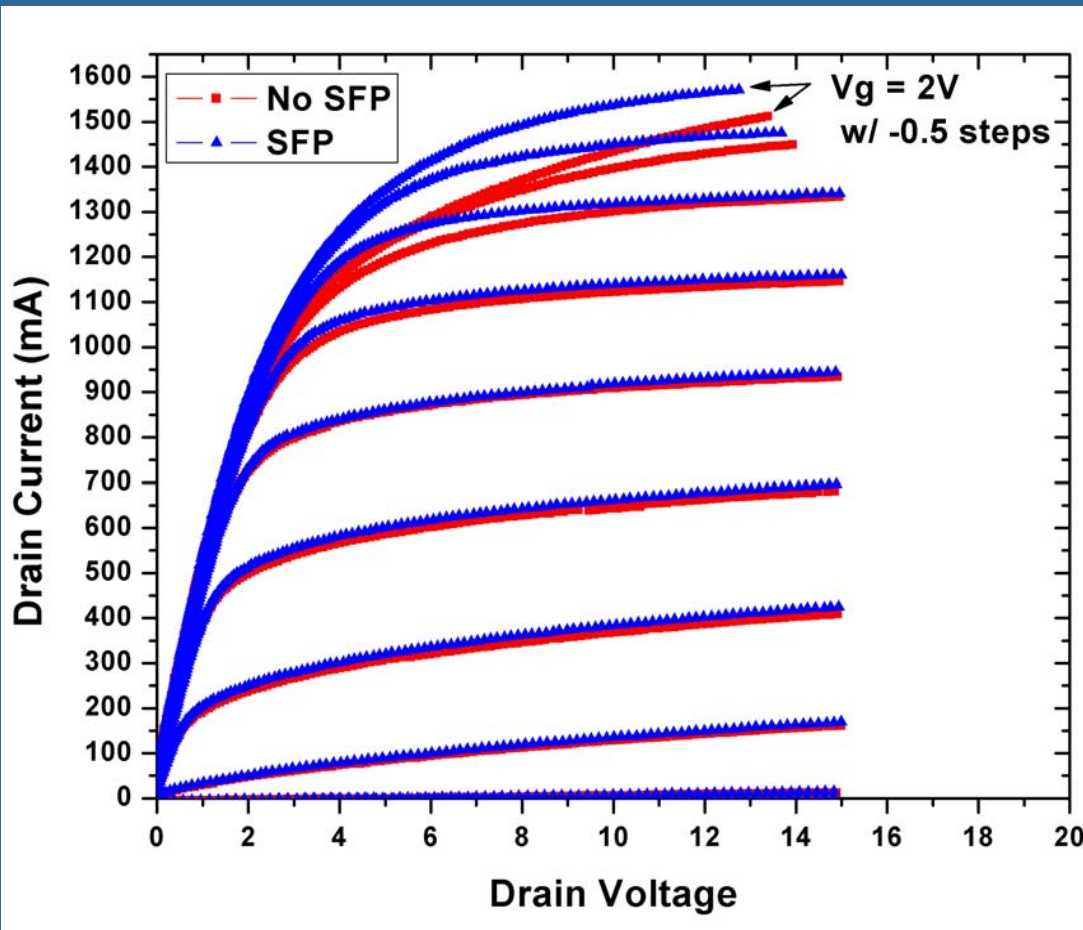
▶  $R_{on} \sim 2.2\Omega \cdot mm$

▶  $BV > 120V$

# Small Signal Analysis



# Pulsed IV Comparison

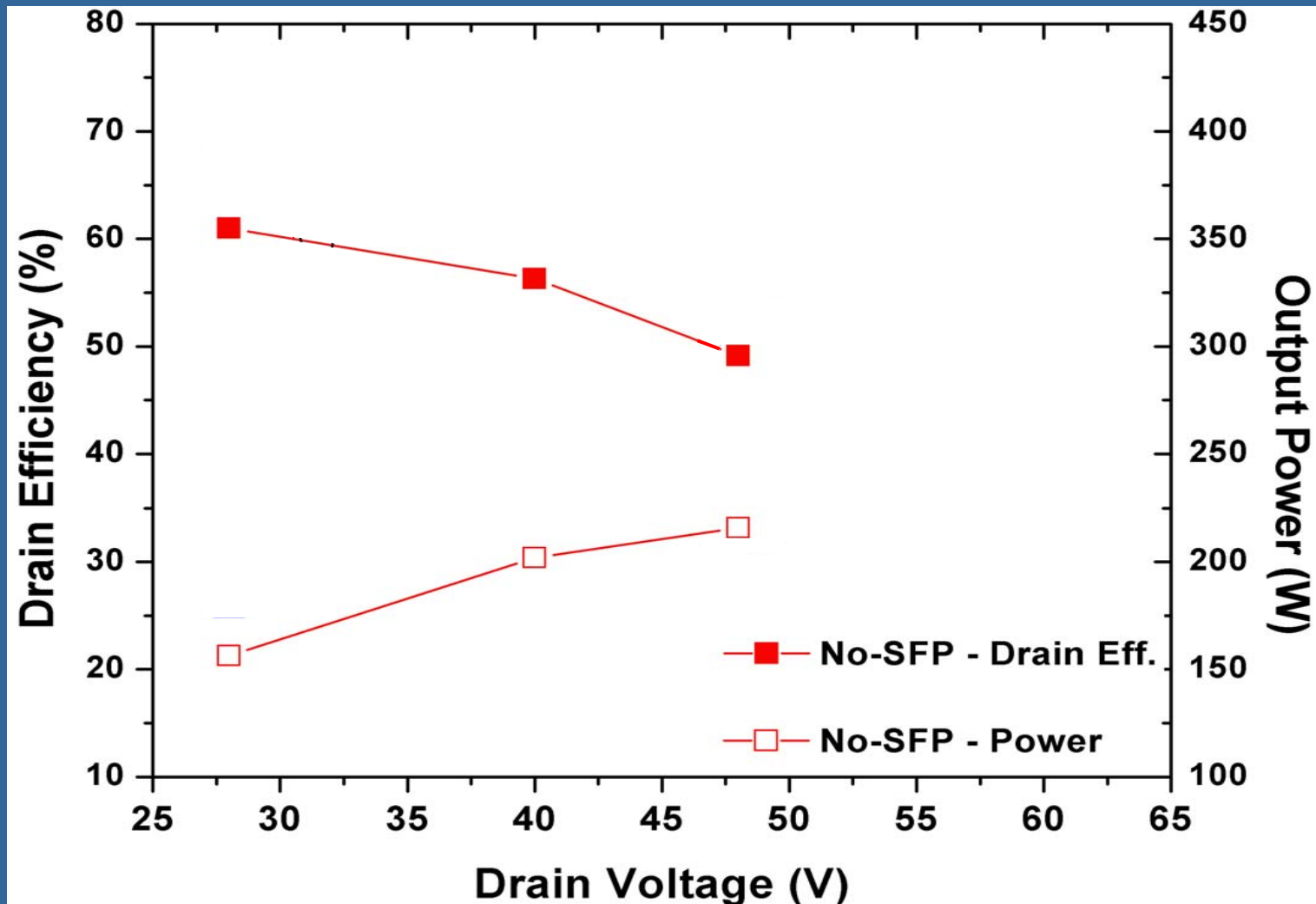


➤ Data taken on adjacent 2mm CPW device

➤ The devices were pulsed from  
 $V_D = 50V$   
 $V_g = -5V$

➤ 200 ns pulse

# Pulsed RF Characteristics



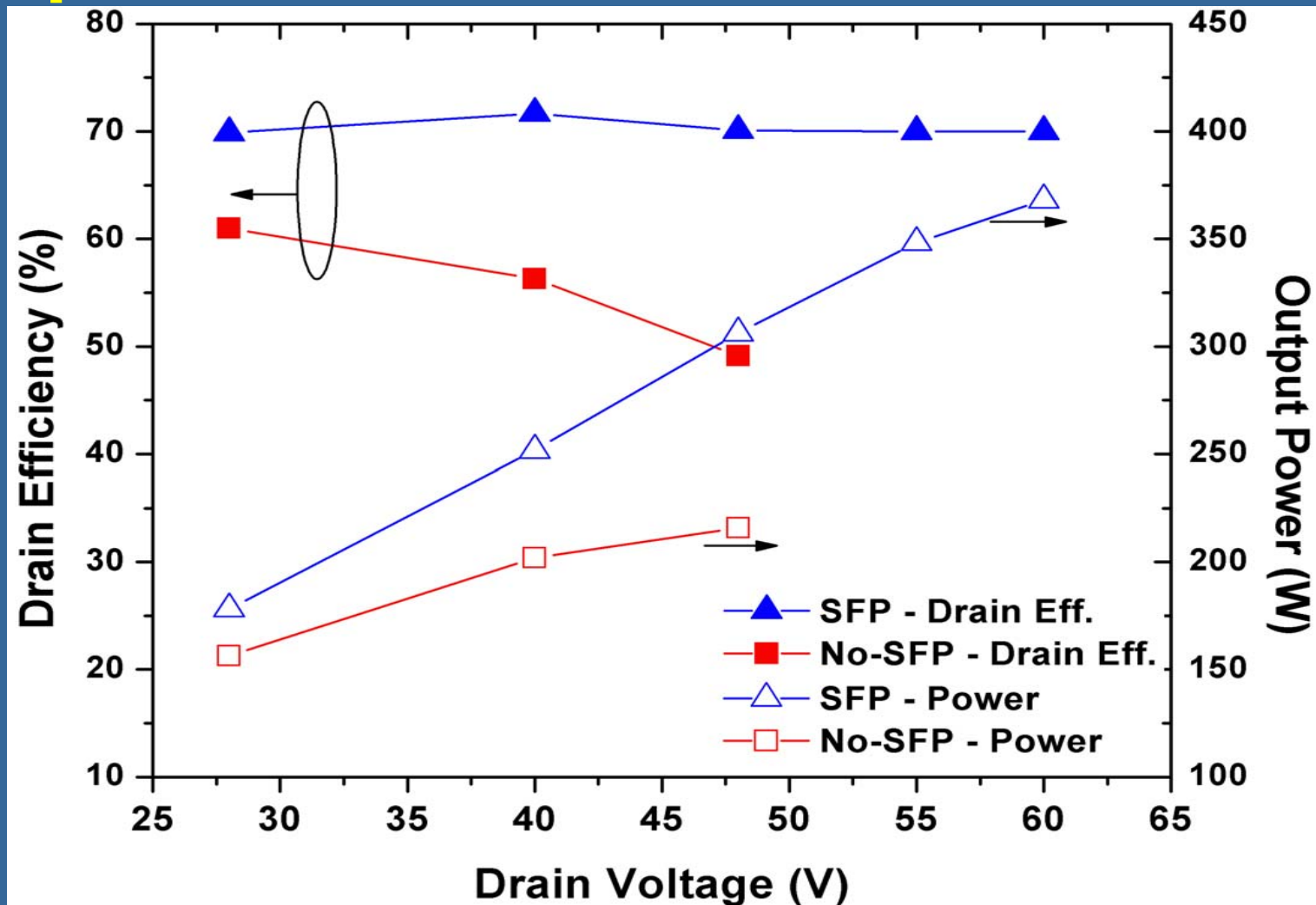
$I_{DQ} = 1A$

Freq = 2.14 GHz

300 $\mu$ s pulse width

1% Duty cycle

# Comparison of Pulsed RF Characteristics



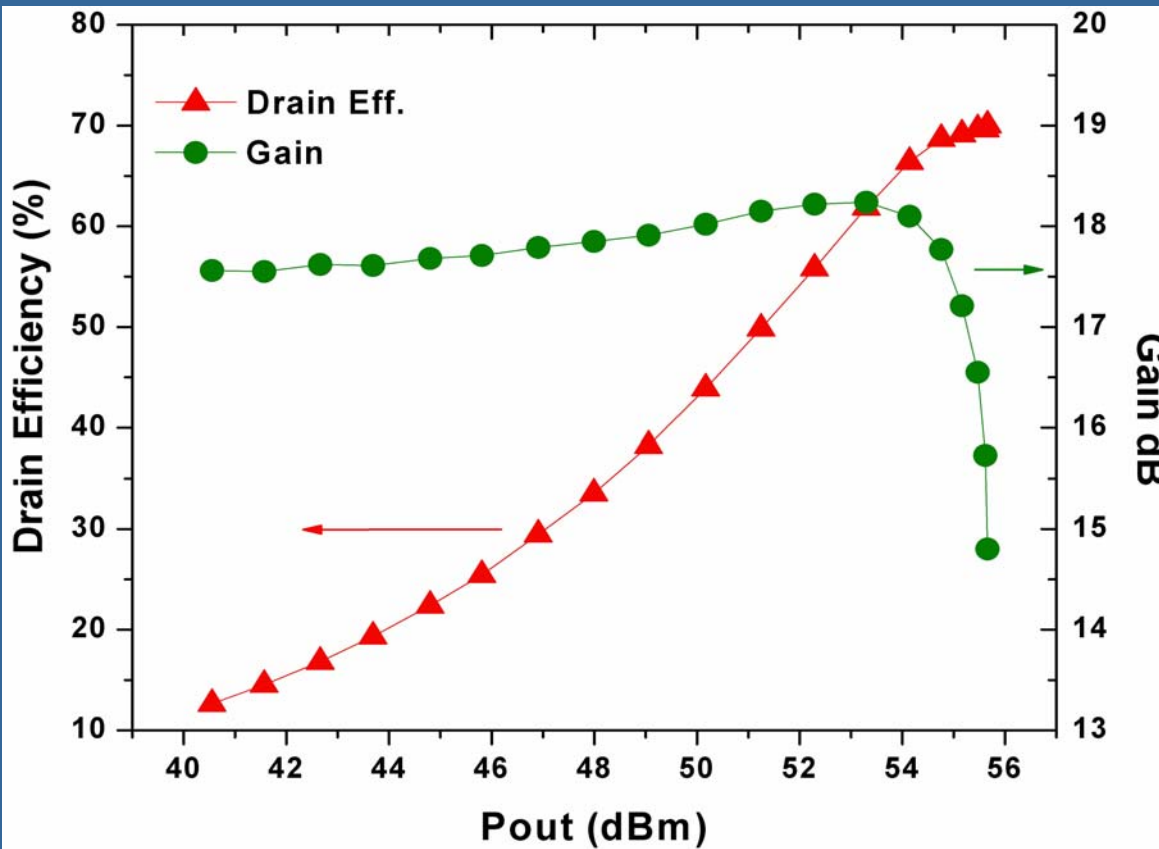
$I_{DQ} = 1A$

Freq = 2.14 GHz

300 $\mu$ s pulse width

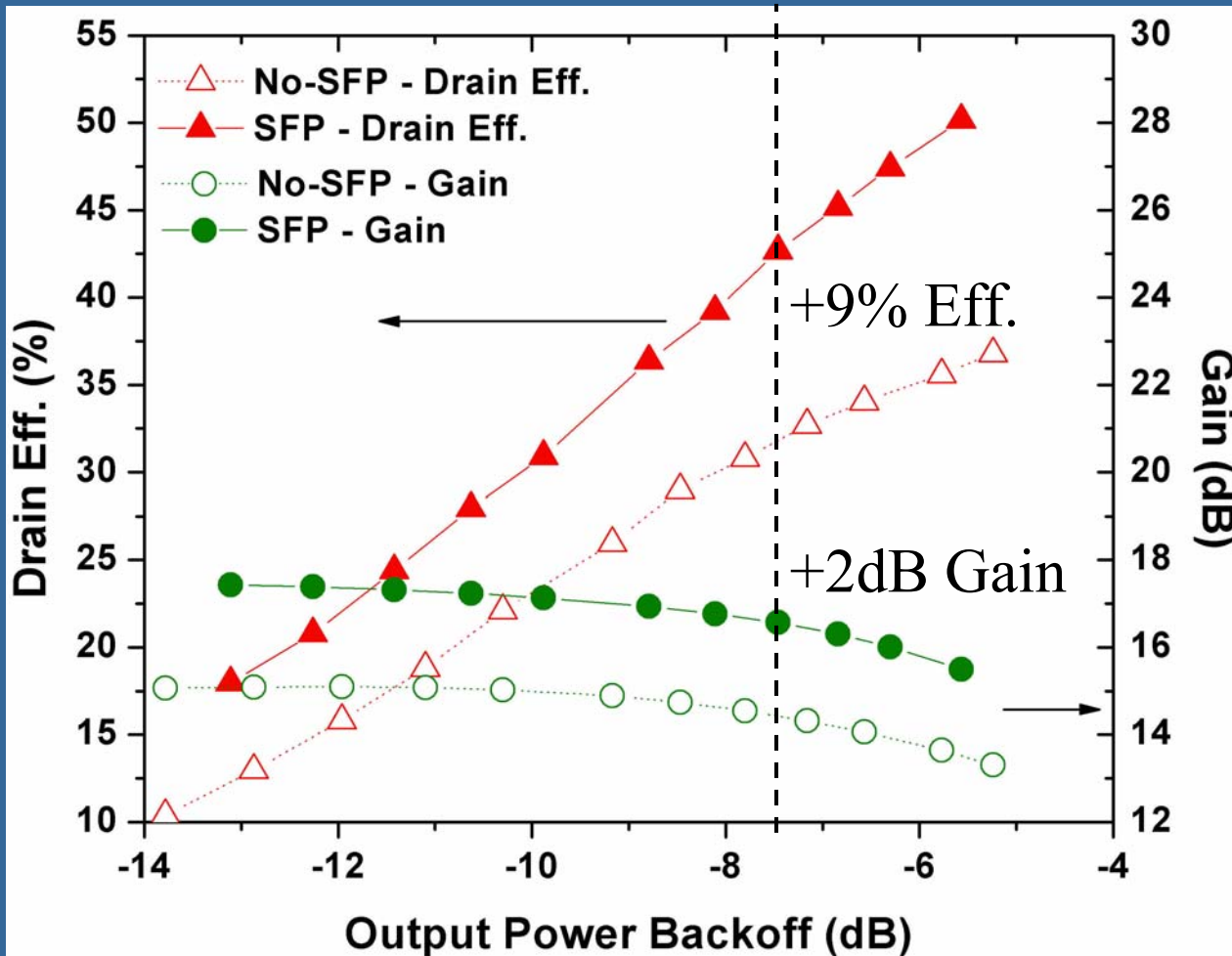
1% Duty cycle

# RF Performance of SFP Device at 60V



- $P_{\text{sat}}$  - 368W  
(10.2 W/mm)
- $\eta_{\text{max}}$  - 70%
- $G_{\text{(small signal)}}$  17.5 dB
- Bias Conditions
  - ▶  $V_D = 60V$
  - ▶  $I_{DQ} = 1A$
- Pulse conditions
  - ▶ 300 $\mu$ s pulse width and a duty cycle of 1% at 2.14GHz

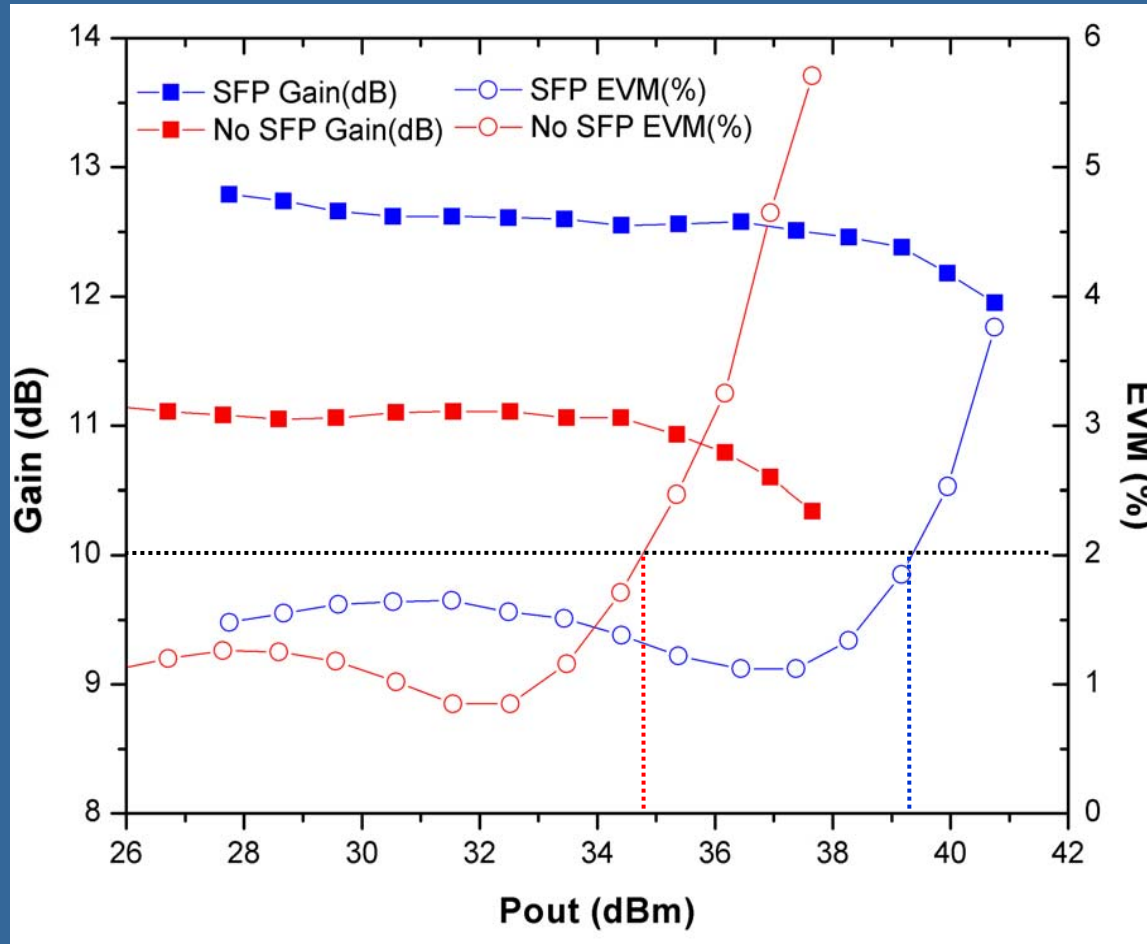
# WCDMA Performance Comparison



- Measured Under a 2 carrier WCDMA Waveform
- Power back-off is from  $P_{\text{sat}}$

36 mm chip, 2.14 GHz,  $I_{\text{dq}} = 1\text{A}$ ,  $V_{\text{D}} = 40\text{V}$

# WiMAX Performance Comparison



➤ Performance at 2% EVM

▶ No SFP

- 3W
- $\eta=14.5\%$
- Gain = 11.1dB

▶ SFP

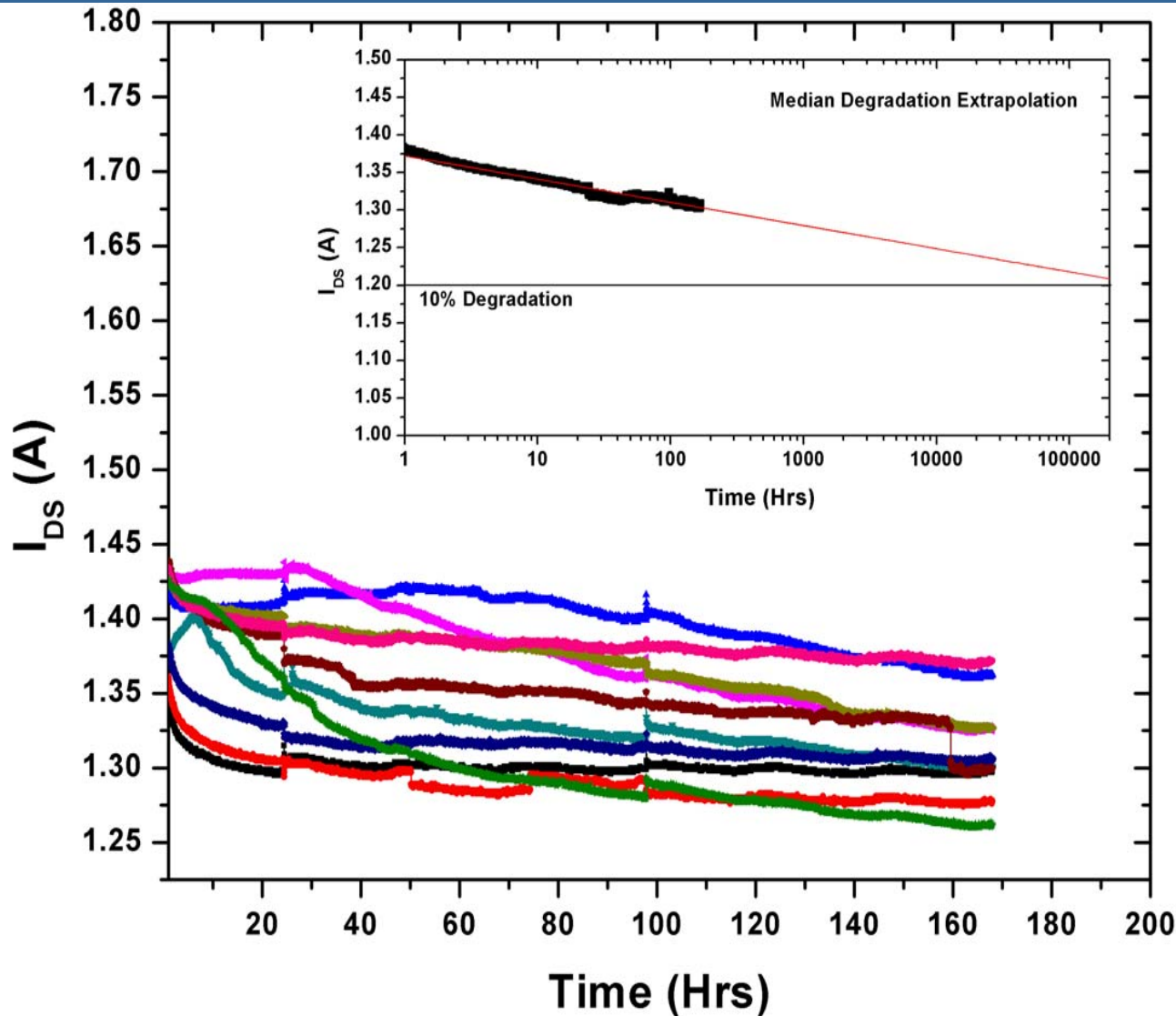
- 8.6W
- $\eta=31.2\%$
- Gain 12.3dB

➤ Twice as much power and  $\eta$

Measurements performed under an OFDM waveform at 3.5 GHz

$I_d = 900\text{mA}$   $V_d = 28\text{V}$

# Reliability



Extrapolated 20yr  
degradation <10%

$V_d = 48V$

$T_j = 200^\circ C$

# Summary

- Nitronex has developed a high performing and repeatable baseline process using GaN-on-Si
- The use of a source field plate enables performance gains in operational voltage, gain, power and efficiency
- These performance gains resulted in a 36mm device that produced 368W of pulsed output power