University of Padova

Department of Information Engineering

Indirect Techniques For Channel Temperature Estimation Of Hemt Microwave Transistors: Comparison And Limits

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Outline

- Introduction
- Experimental results on pHEMT:
  - DC method
  - Pulsed method
  - IR thermal camera measurements
- Discussion about the results
- Experimental results on power amplifier
- Conclusion

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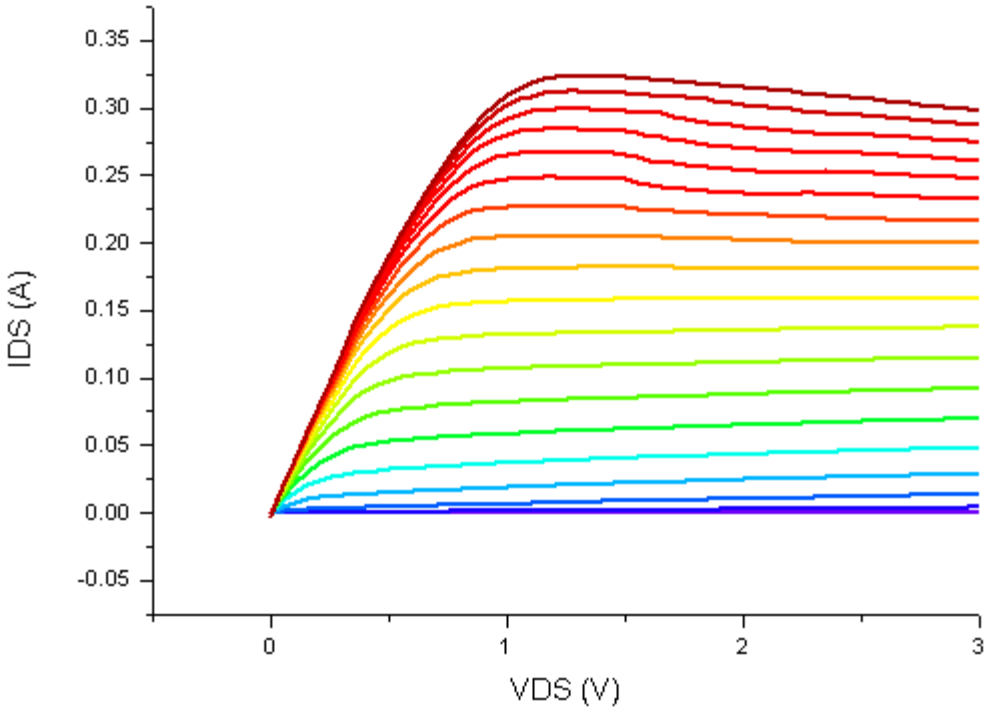
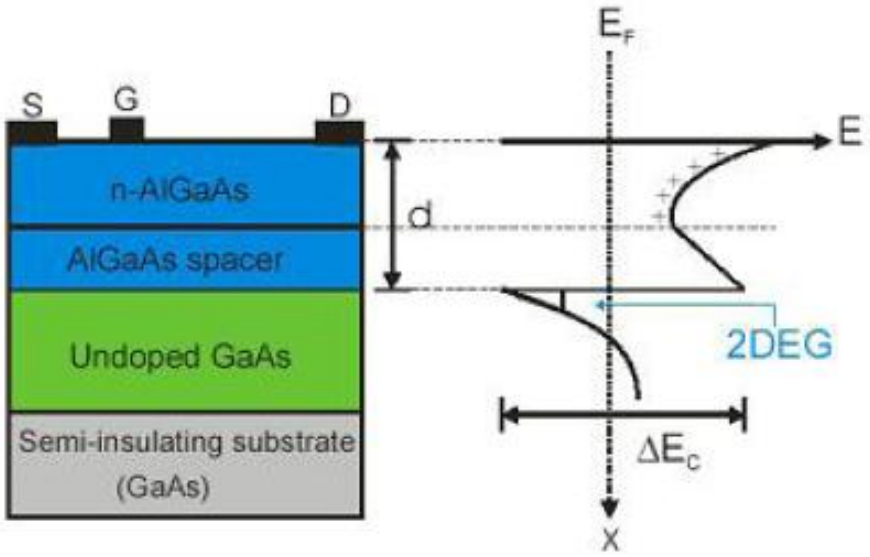
Introduction

HEMT

•High Electron mobility transistors: heterostructure composed by two layers (semiconductors with different properties).

• High frequency and high power applications:
telecommunications systems, radars, microwave power amplifiers, etc.





GaAs:

• Energy gap

• High mobility and saturation velocity

• Quite high reliability

Introduction

- Several techniques to estimate channel temperature:
  - Electrical measurements:
    - Evaluation and comparison of a temperature sensitive parameter: drain saturation current, on-state resistance, forward current of the GS diode.
    - Both pulsed and DC techniques can be considered.
  - Optical measurements:
    - Infrared thermography

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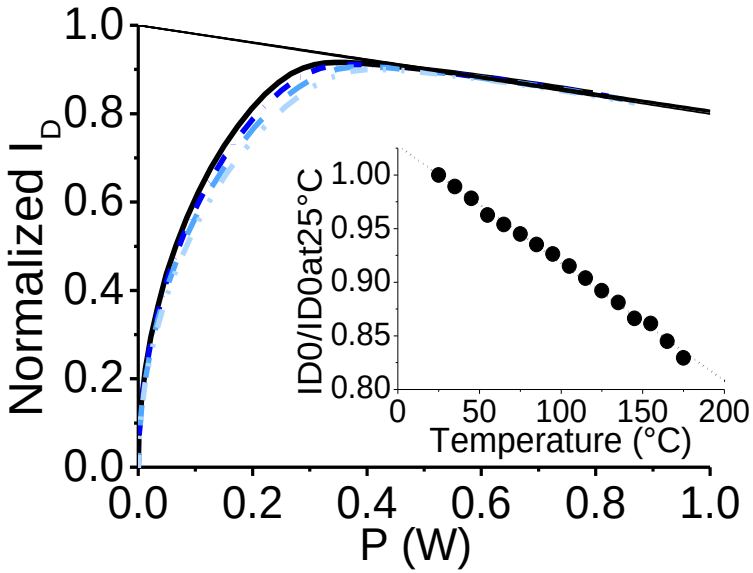
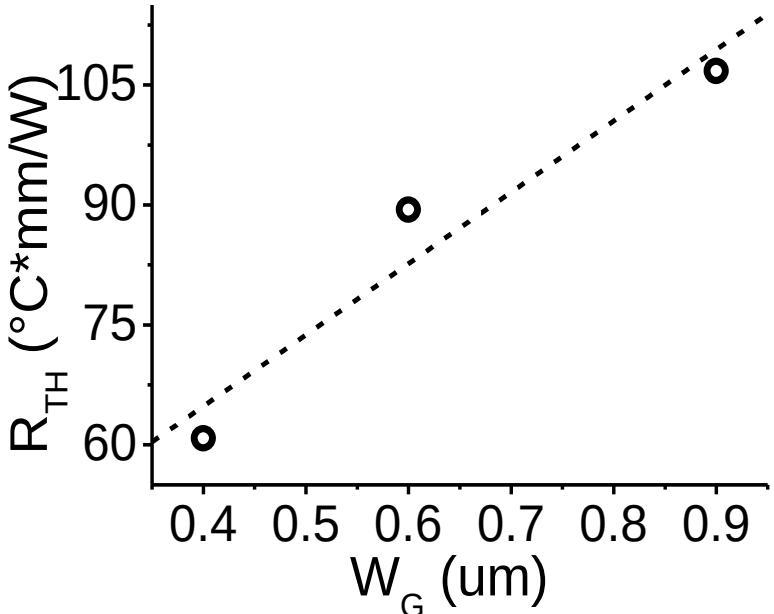
Experimental results: DC method

- Devices: pHEMT with L_G=0.25μM, gate pitch 20 μm, W_G from 0.4mm to 0.9mm.

- Drawbacks: oscillations (high periphery), no meaningful self heating (small devices)

- Measurement Technique:
  - two steps: (i) measurement step (TSP due to bias applied); (ii) calibration step (TSP due to ambient temperature).
  - Drain current when no added power is applied is used as TSP.
  - Calculation of the I_{DS} value from the intercept of the I_{DS} vs add.power curve.
  - R_{TH} definition from the I_{DS} variation due to ambient temperature and dissipated power

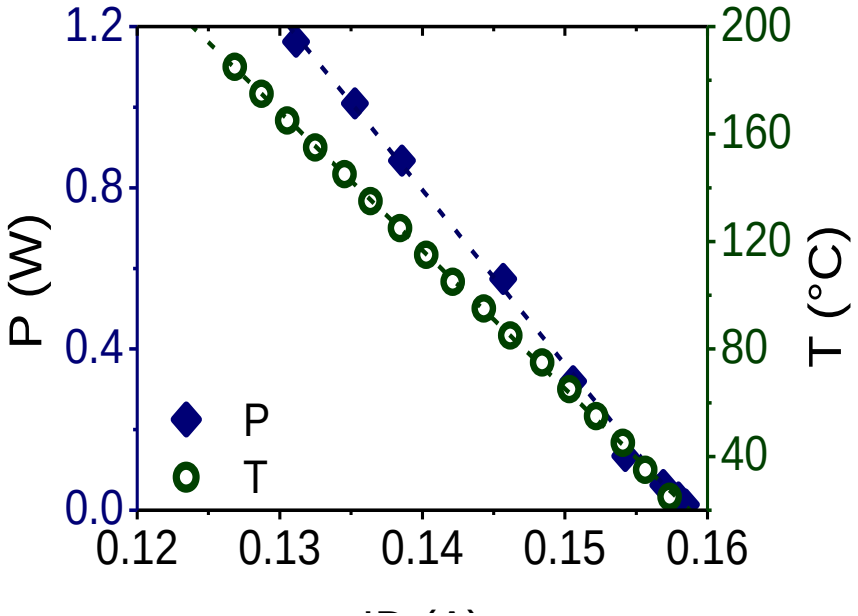


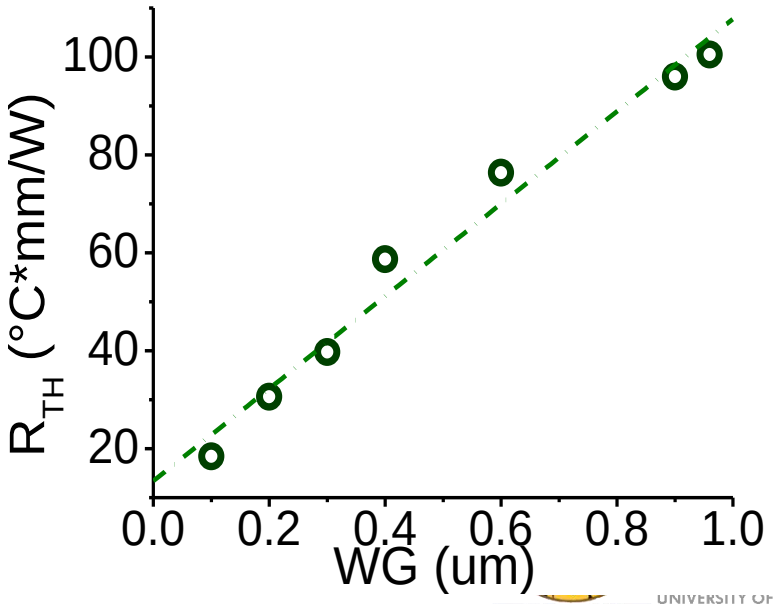


Experimental results: pulsed method

- Devices: pHEMT with L_G=0.25μm, gate pitch 20 μm, W_G from 0.1mm to 0.96mm.

- Measurement Technique:
  - two steps: (i) measurement step (TSP due to bias applied); (ii) calibration step (TSP due to ambient temperature).
  - Drain current is used as TSP. Pulse width and duty cycle definition to avoid self heating.
  - R_{TH} definition from the I_{DS} variation due to ambient temperature and dissipated power

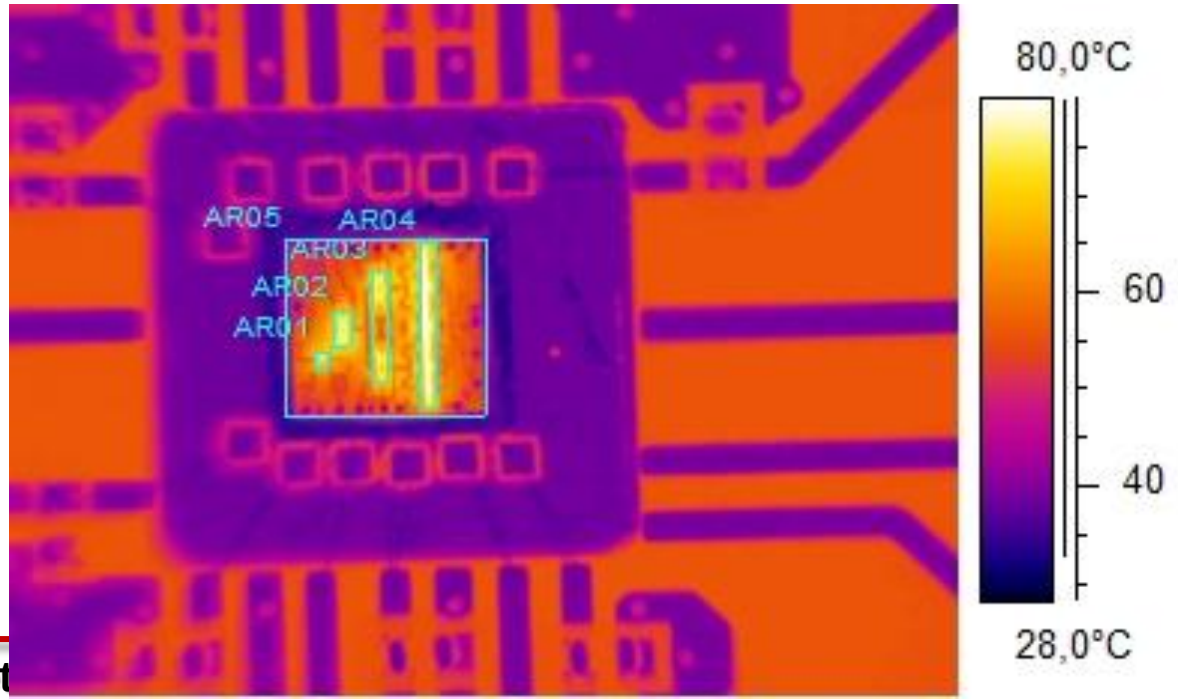




Experimental results: IR camera

- Devices: PHEMT with LG=0.25μM, gate pitch 20 μm, WG 0.6mm.
- Drawbacks: small dimensions (small devices), presence of air bridge (higher peripheries)

- Measurement Setup
  - FLIR 325 SC thermal camera. 2x magnification lens (50μm resolution)
- Measurement Technique:
  - Emissivity preliminary calculation
  - Device biased with power supply; junction temperature measured by IR thermal camera



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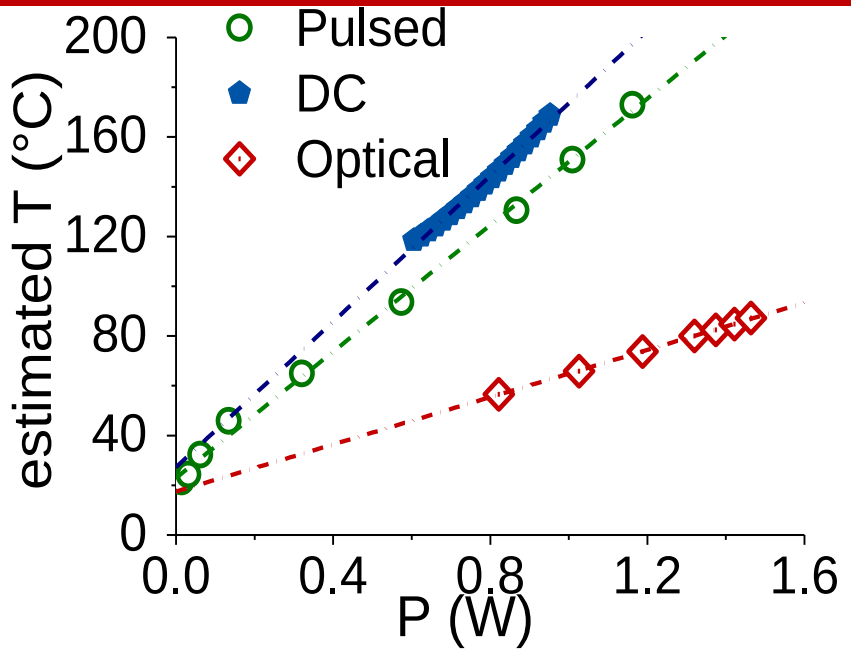
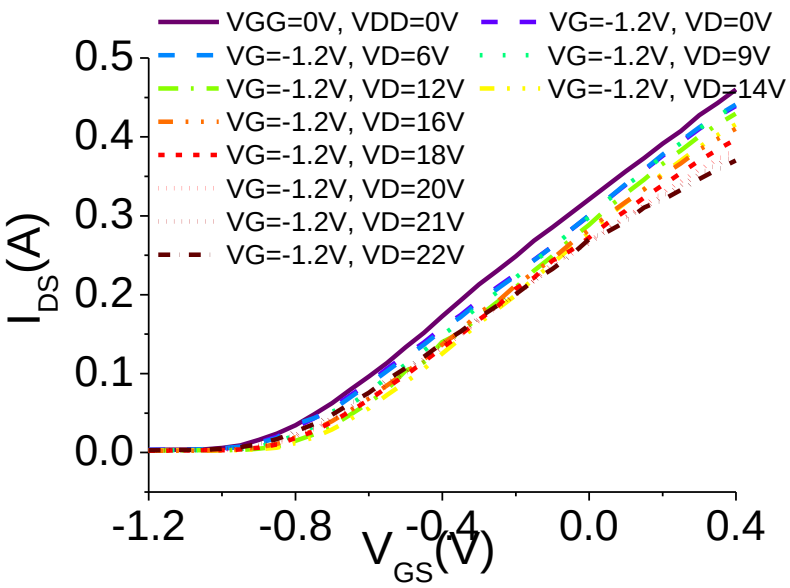
Discussion about results: pHEMT

- DC: slight overestimation
  - assumption that drain current linearly decrease with power
  - dissipated power calculation
  - DC trapping
  - consideration of a small range of dissipated power

- Pulsed: slight underestimation
  - duty cycle choice
  - trapping effects
  - dissipated power calculation

- IR thermal camera: underestimation
  - thermal camera resolution
  - device small dimensions
  - presence of metallization
  - emissivity calculation



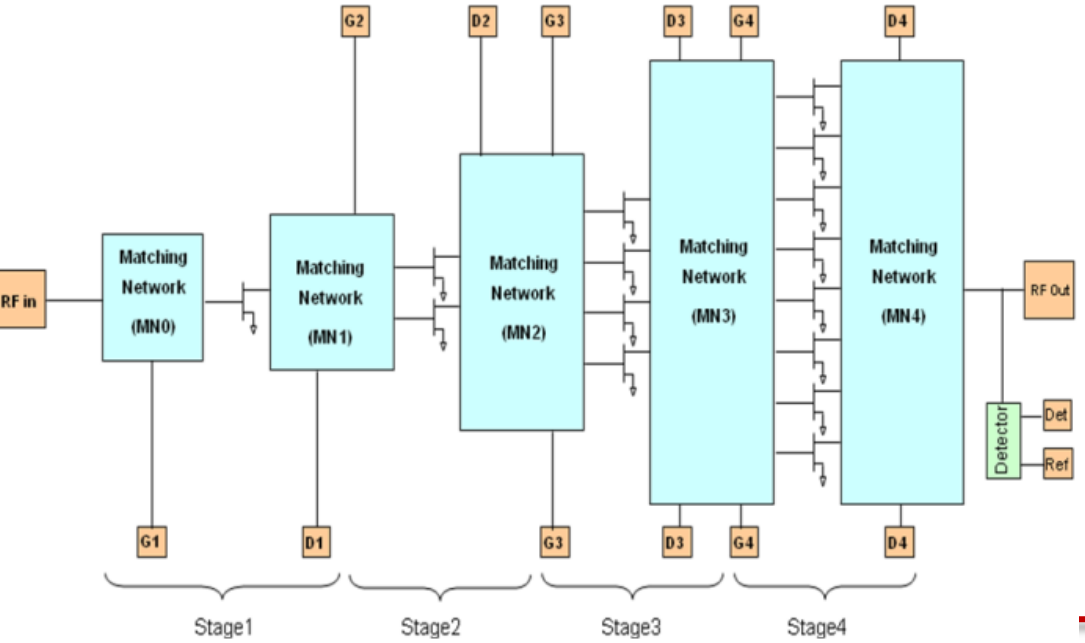


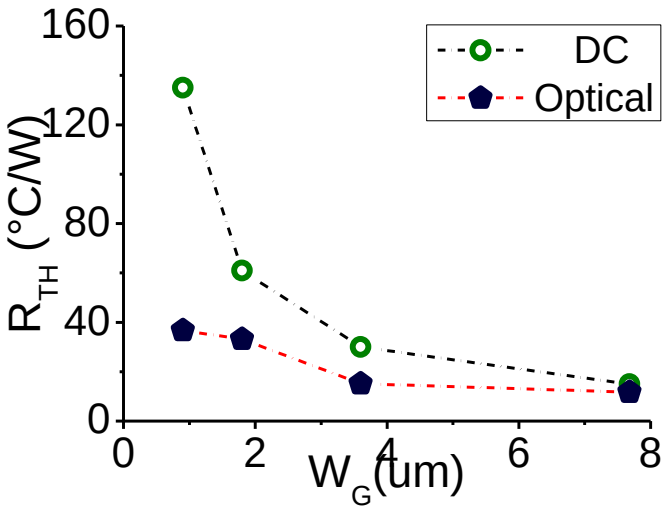
Analysis on power amplifier

- Device: four stage power amplifier

- Drawbacks: IR thermal camera and DC evaluation.
  - Board cannot be heated with temperature higher than 105°C.
  - Chip capacitors and SMD capacitors have been mounted to avoid oscillations. No Pulsed measurements

- Results: IR measurements strongly understimation confirmed.

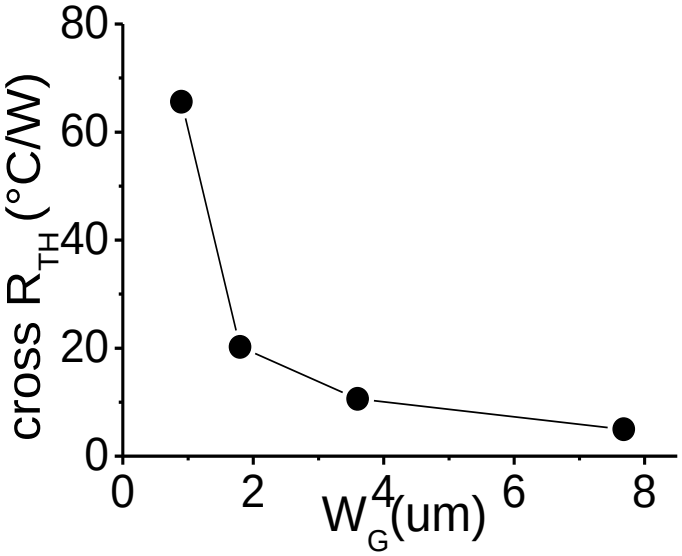


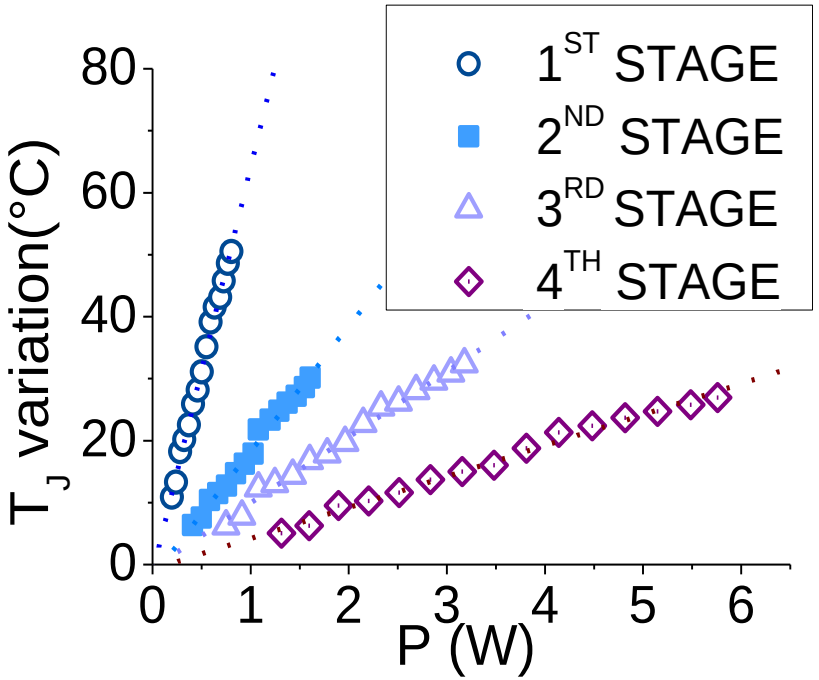


Cross thermal resistance

• Multistages devices are strongly influenced by mutual interaction among stages.

• Interaction evaluated from the difference of junction temperature evaluated in two conditions: (i) all stages biased, (ii) only one stage is biased





• Cross thermal resistance decreases with the increase of the periphery

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Conclusion

- Results extrapolated with pulsed method are consistent with the ones obtained with DC technique. IR thermal camera strongly underestimates.
- Results are confirmed by the measurements on a power amplifier.
  - DC method → influence of self-heating, dissipated power
  - Pulsed method → influence of trapping
  - IR method → resolution, metallization, emissivity calculation

- IR method provide a simple and possible way to estimate mutual interaction among stages.

Cross thermal resistance increases with the decrease of stage periphery

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Thanks for your attention

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