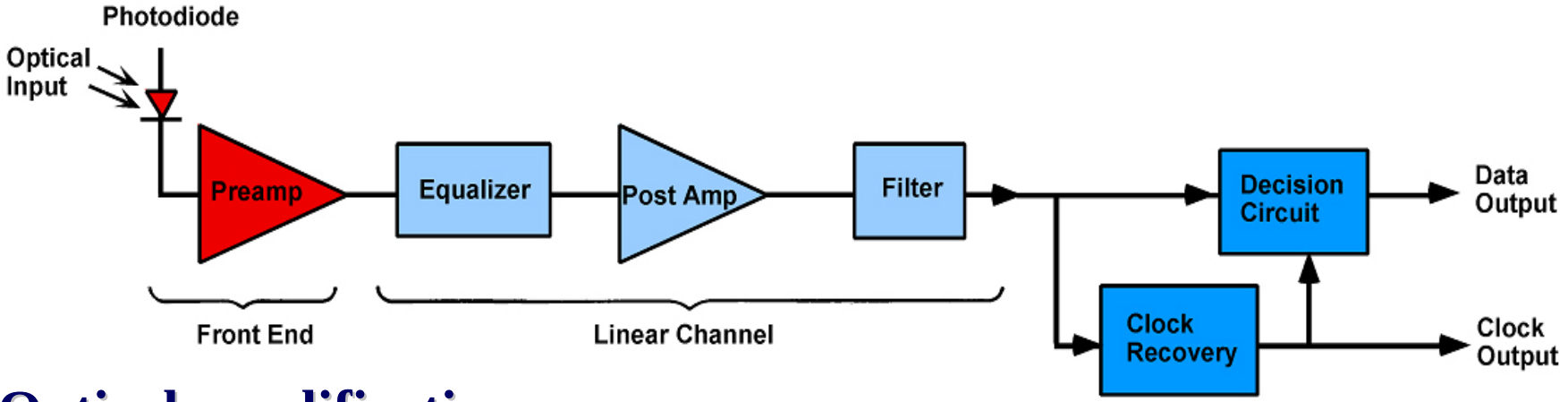
Amplifierless Receivers

Joe C. Campbell
Microelectronics Research Center
The University of Texas at Austin
Austin, TX, 78758

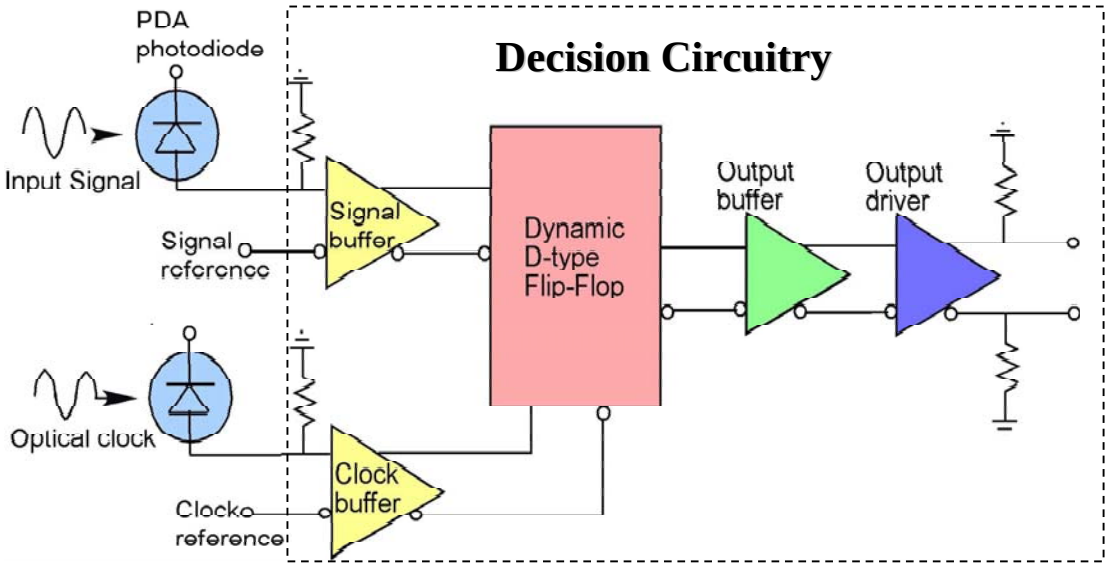
Larry A. Coldren
University of California
Santa Barbara, CA 93106

Receiver Architectures

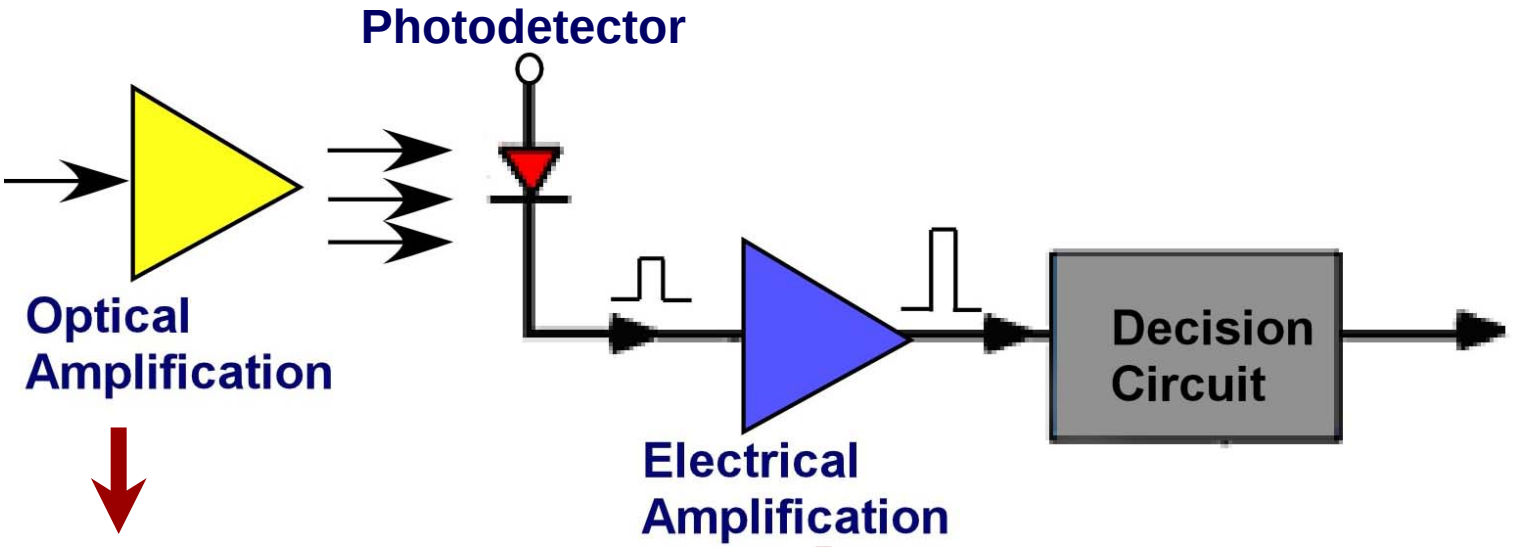
Electrical amplification



Optical amplification



High-Performance Optical Receivers



Lower noise
Higher speed

PIN Photodiode
- **High saturation power**
- **High speed**
- **(High linearity)**

Lower cost
Automatic gain control
Integrable with circuitry

Avalanche Photodiode
- **Low multiplication noise**
- **High speed + gain**

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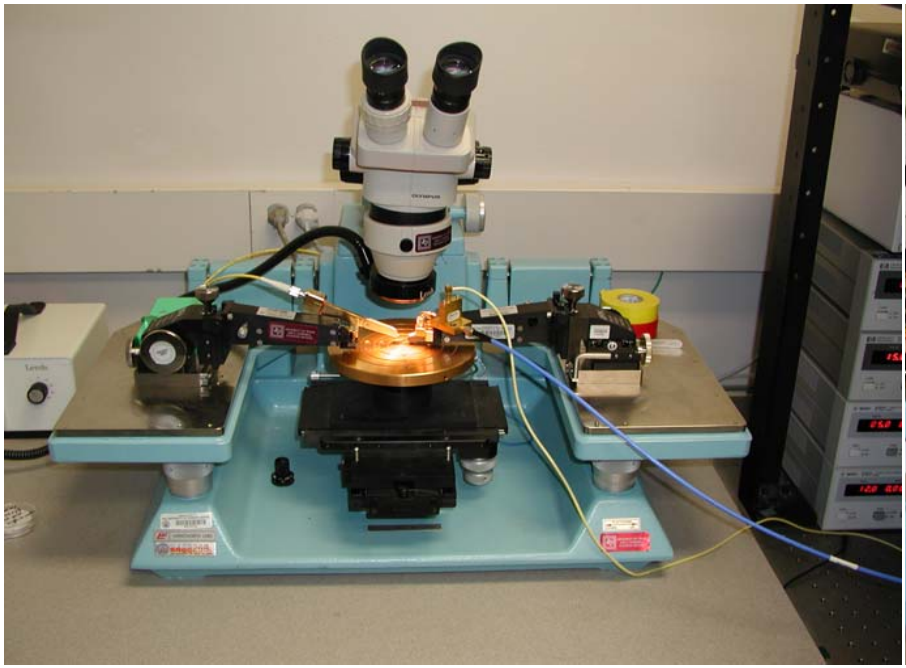
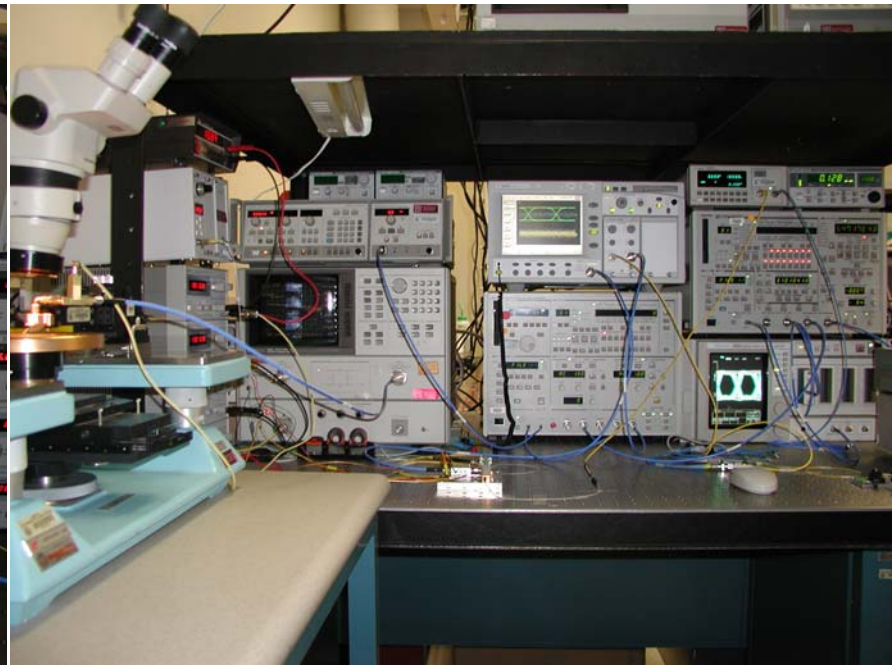
Receiver Characterization Apparatus





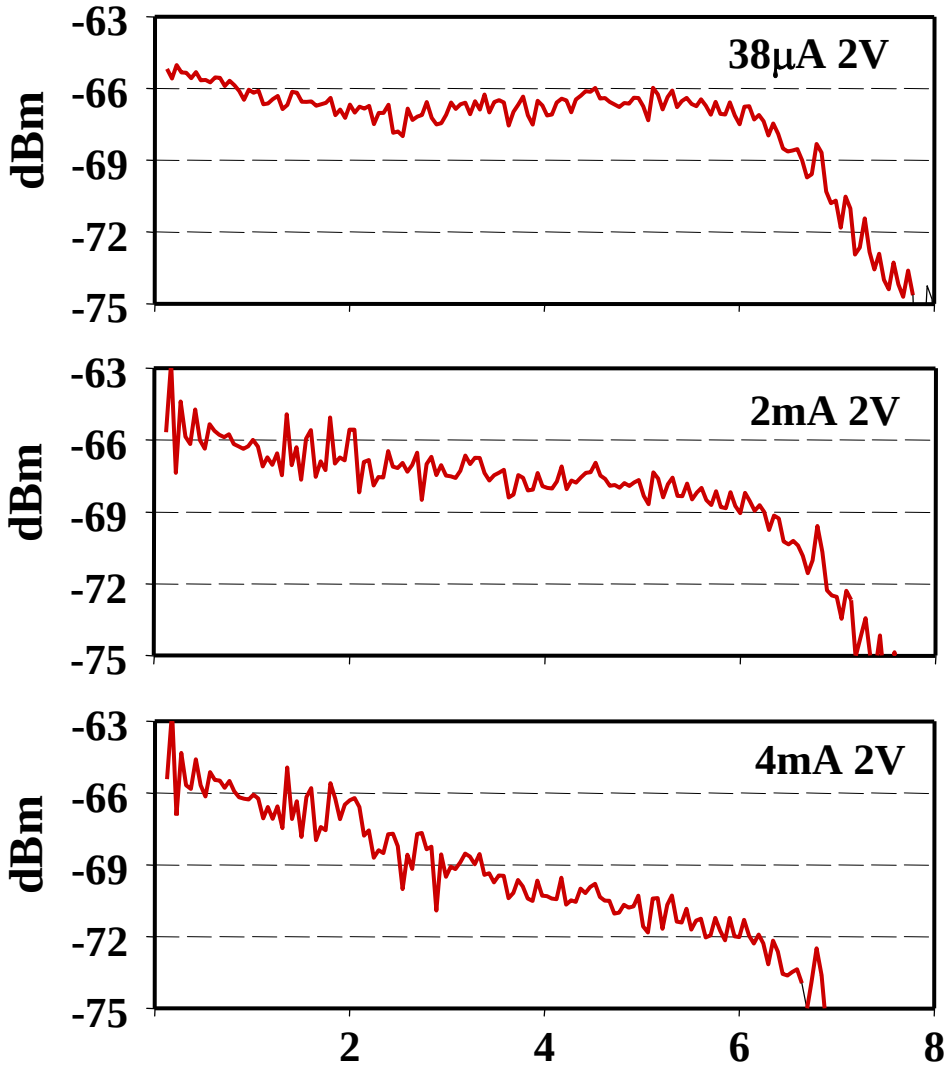
10 GB/s Bit error rate text set

50 GHz oscilloscope with electrical and optical inputs

50 GHz network analyzer with electrical and optical inputs

Low-noise, high-speed probe station

Current Saturation



High-Saturation-Current Photodiodes

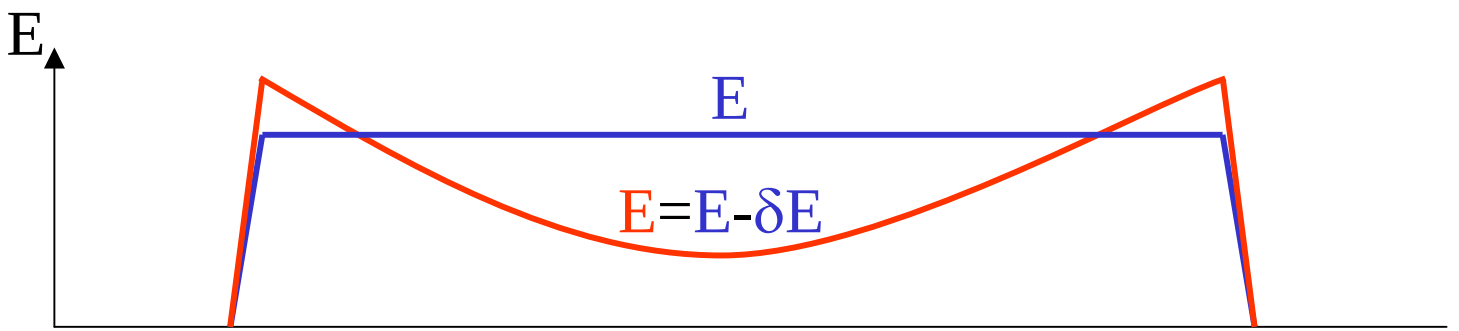
Space Charge

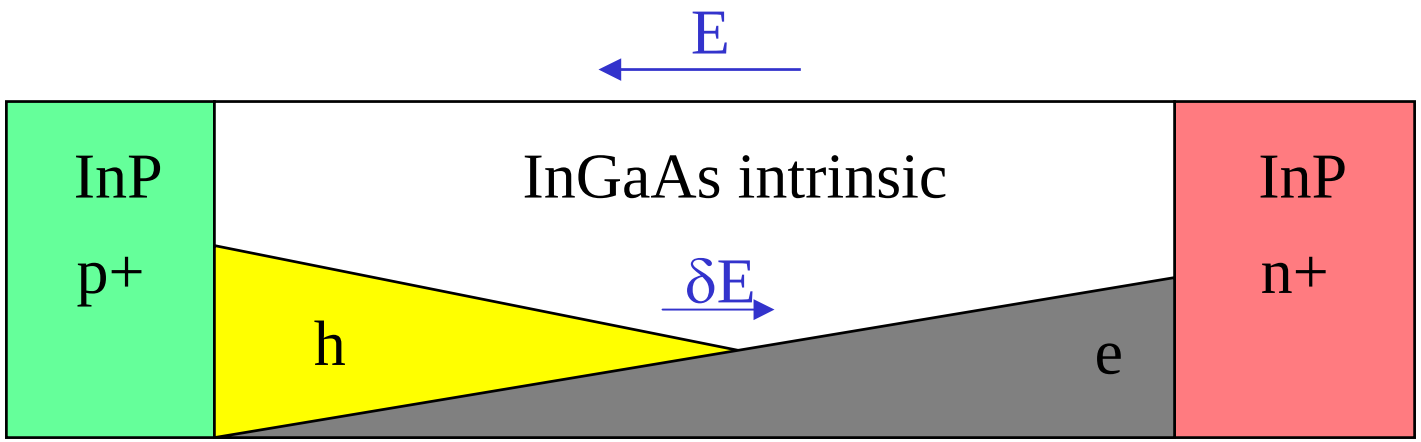
- Device Structure
  - Structure design
  - Layer parameters
    - Thickness
    - Doping
    - Composition
- Illumination conditions
- Bias Voltage
- Electric field profile

Thermal

- Heat sinking
- Layer parameters
  - Thickness
  - Composition
- Bias Voltage
- Device geometry

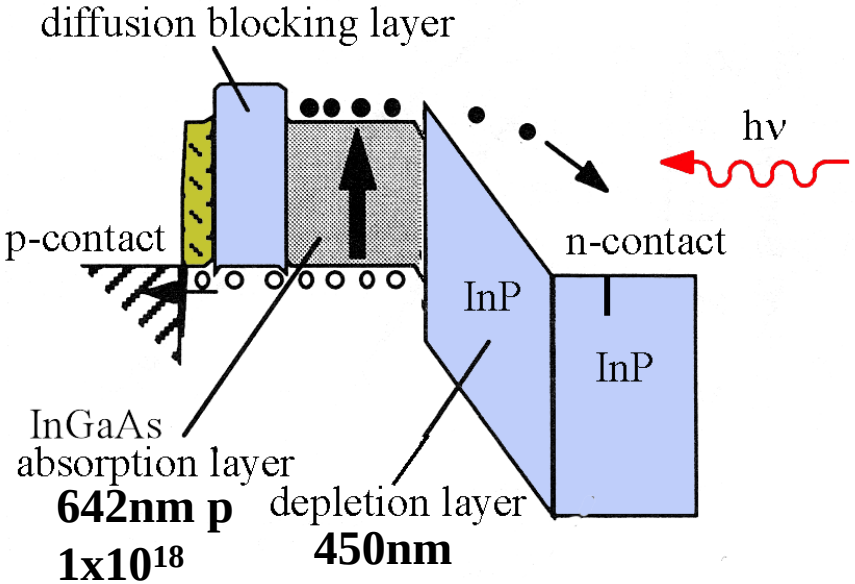
Space Charge Effect in PIN photodiode





Uni-Traveling-Carrier Photodiodes (UTC)

[H. Ito, et al., Proc. 2001 LEOS Annual Mtg, p. 386]



Receivers:

Input: Optical amplifier for low noise and high signal

Output: Drive decision circuit without post amplifiers

80 GB/s receiver has been demonstrated

- **Absorption in undepleted p-type InGaAs**
- **Electrons injected into InP drift region**

↓

- **High electron velocity**
- **Single carrier in drift region**

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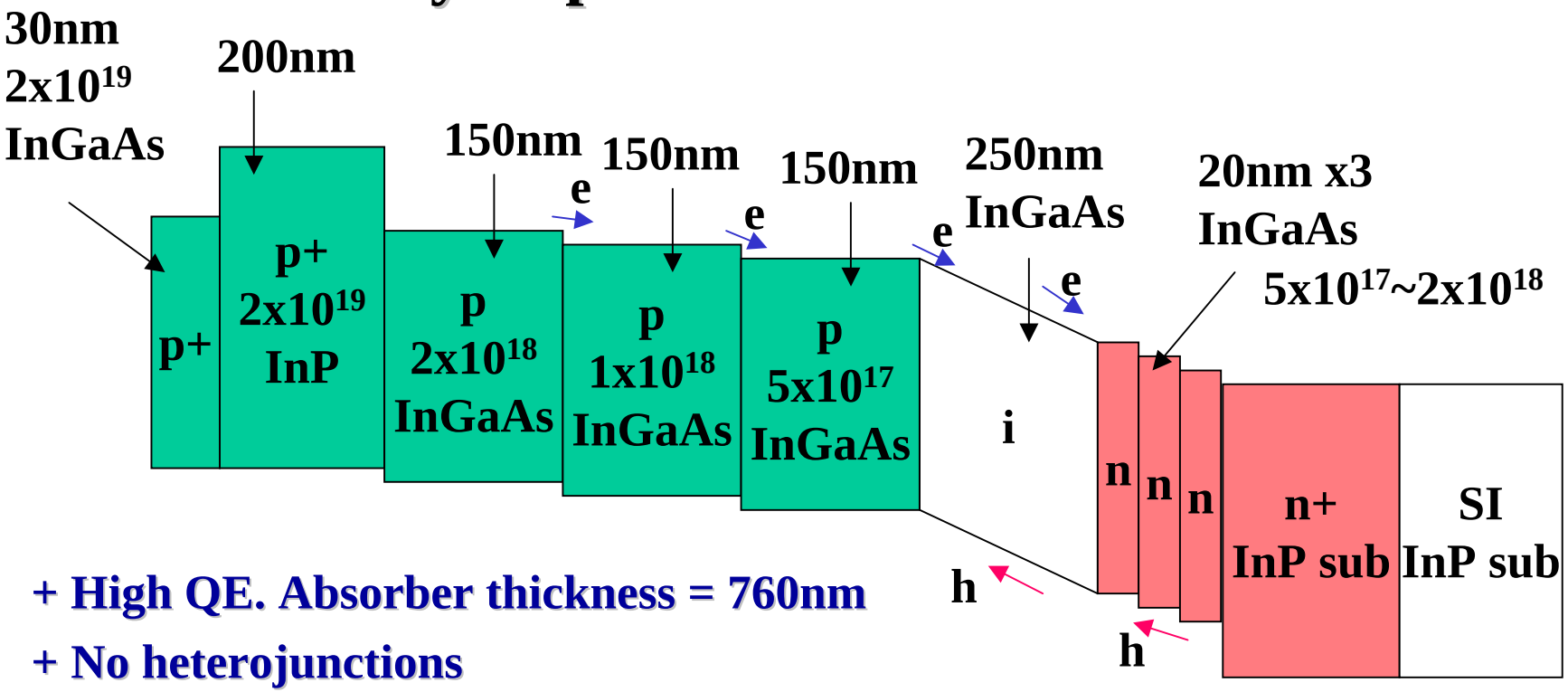
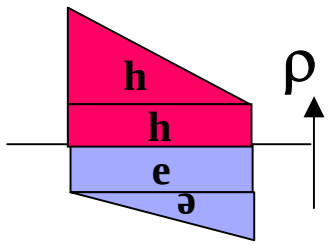
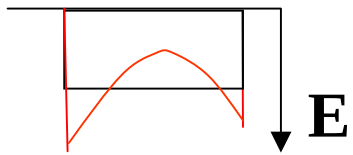
- **Very high speed – 220 GHz (limited by electron diffusion in absorber layer)**
- **Very high operating current (reduced space charge effects)**

Partially-Depleted-Absorber Photodiode



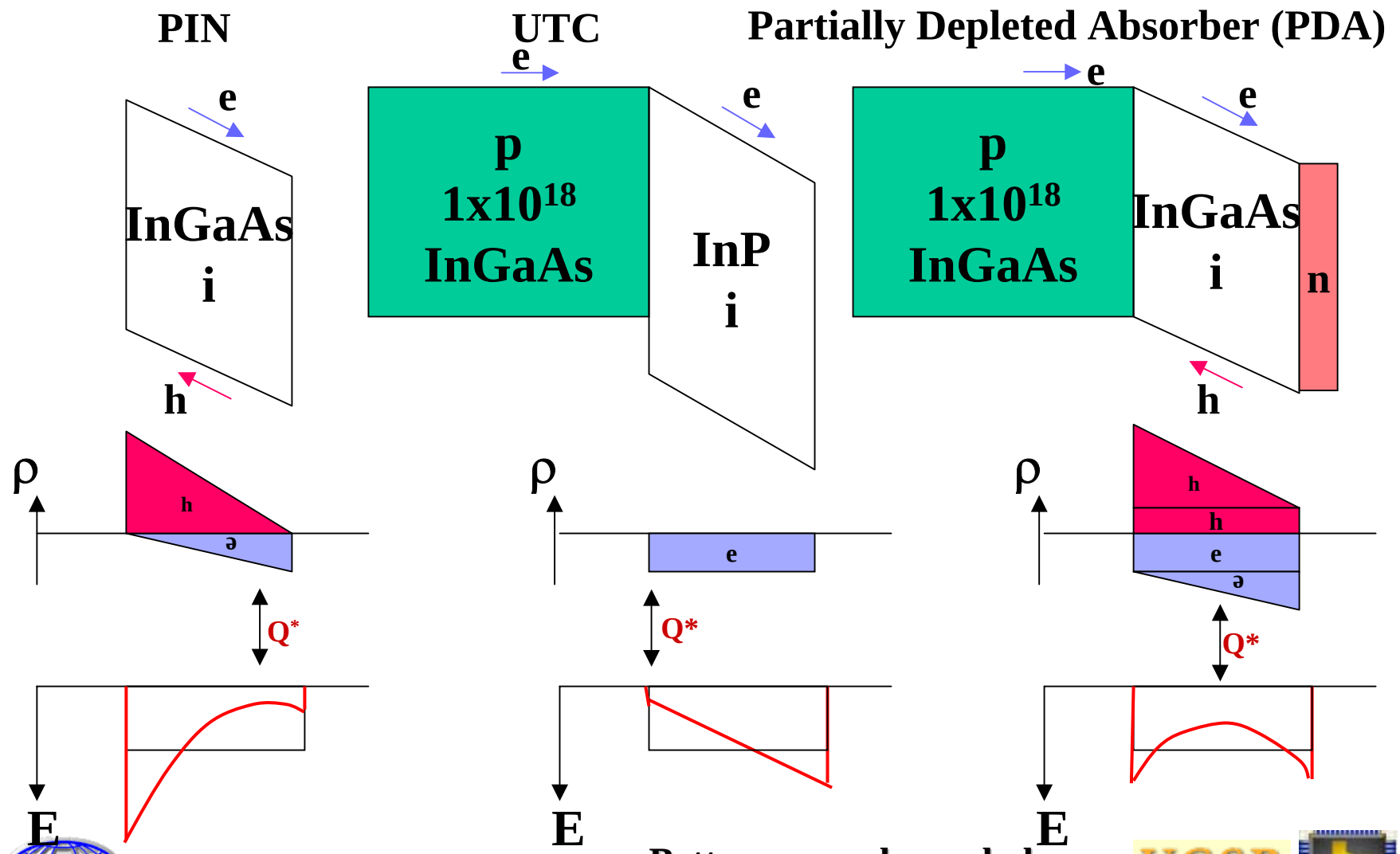
+ High QE. Absorber thickness = 760nm
+ No heterojunctions
+ Graded doping to accelerate diffusion
+ Transit time balancing
- Poor thermal conductivity (InGaAs)





- Can achieve better charge balance
- Greater control of position of field minimum

Schematic Representations of Charge Distribution

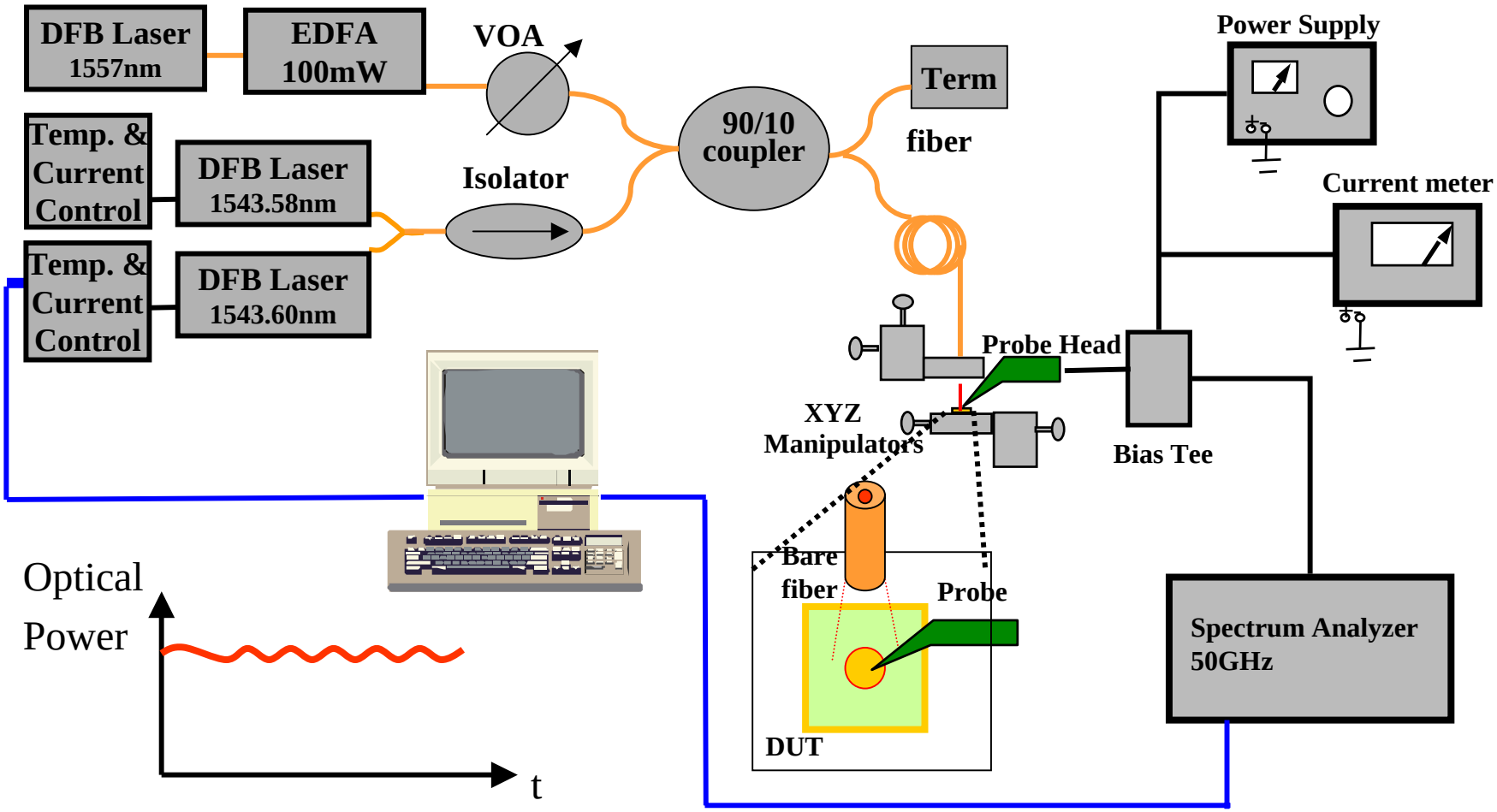


*Q: where the E-field collapses first.

- Better space-charge balance
- Greater control of field minimum

Saturation Current Measurement

Small Signal Modulation (SSM)

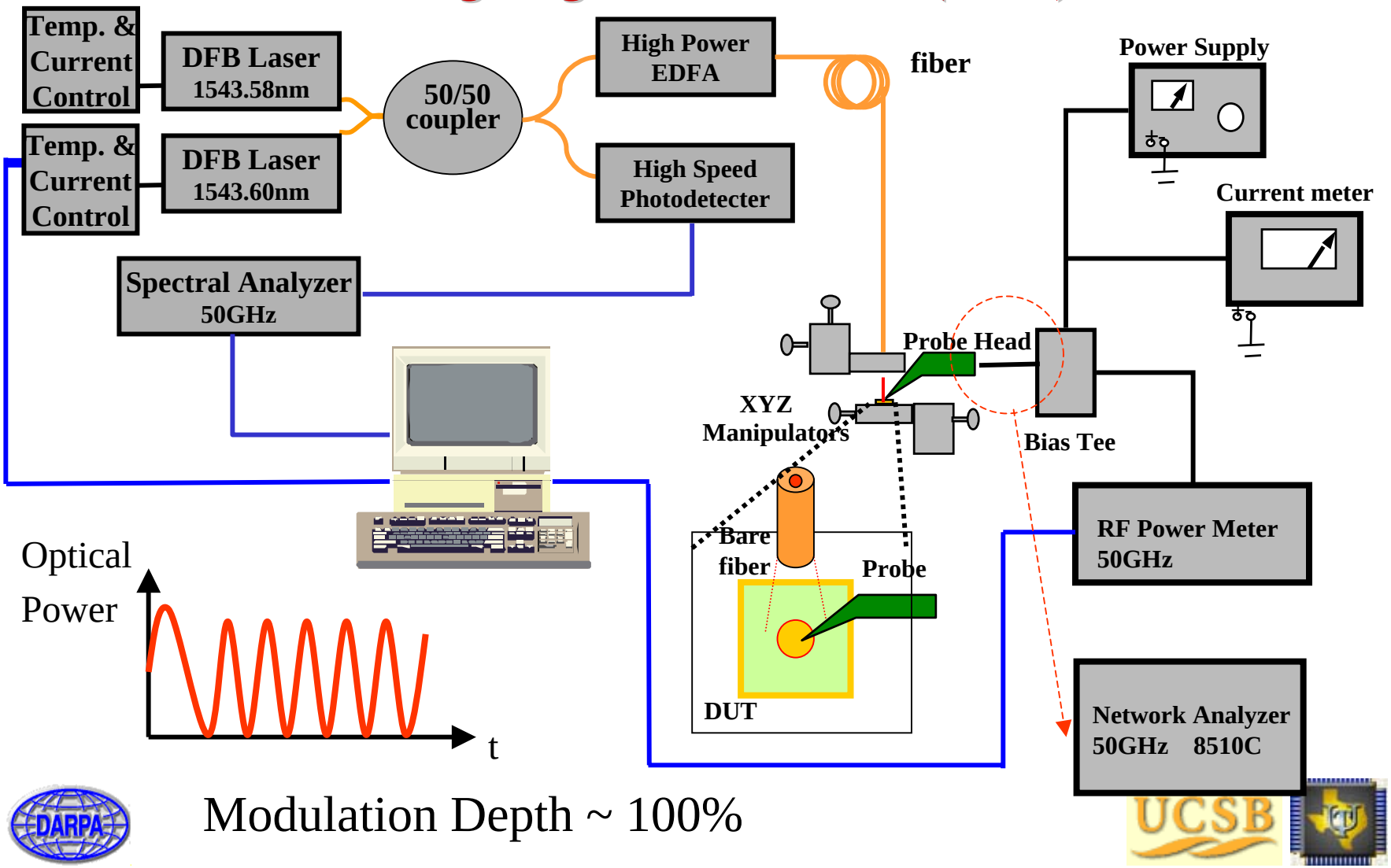


Modulation Depth < 5%

1dB compression current

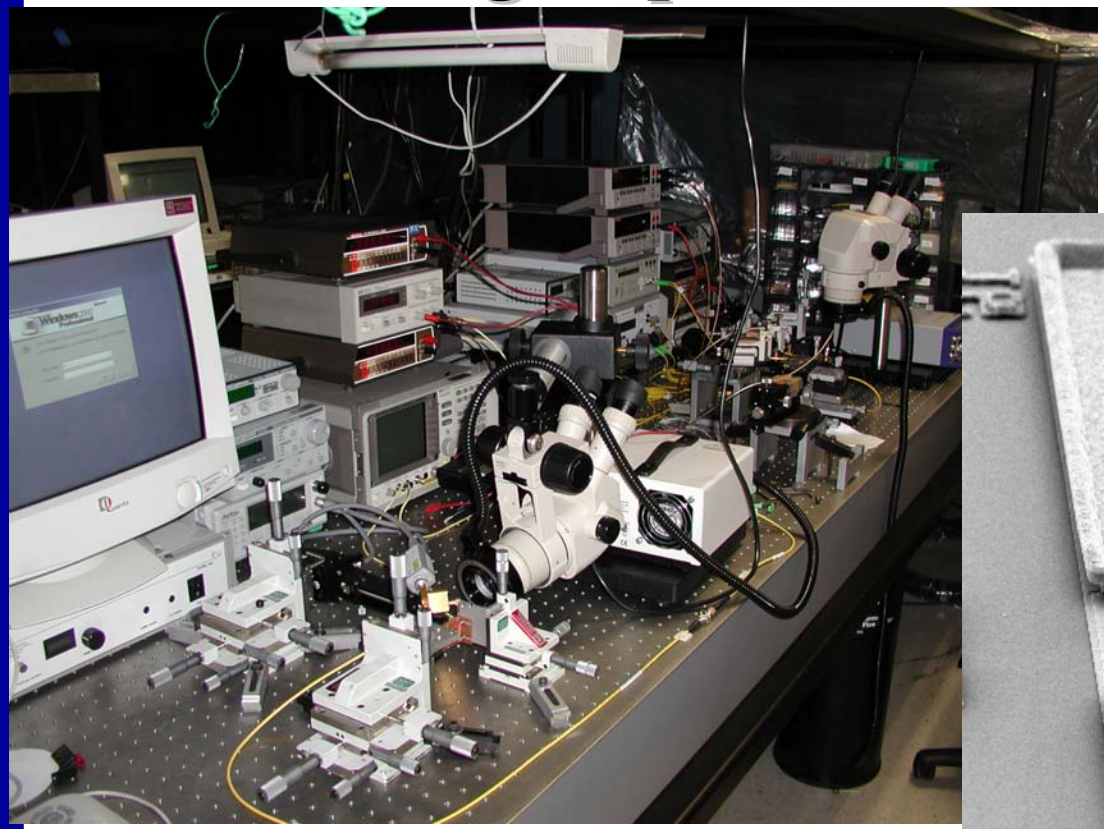
Saturation Current Measurement

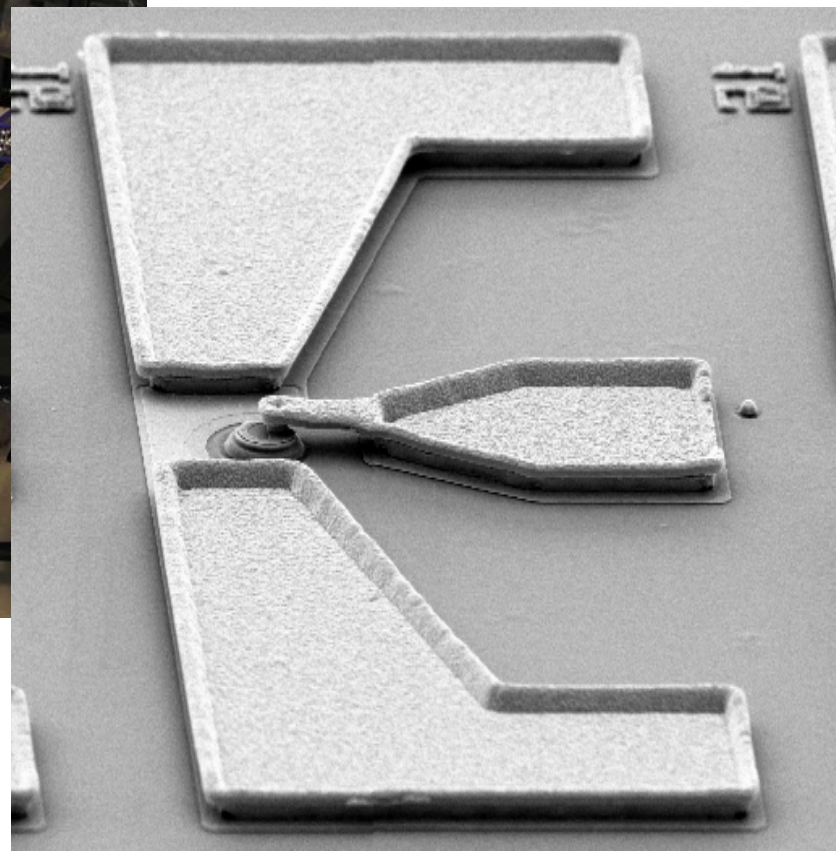
Large Signal Modulation (LSM)



Modulation Depth ~ 100%

High-Speed PIN Photodiodes





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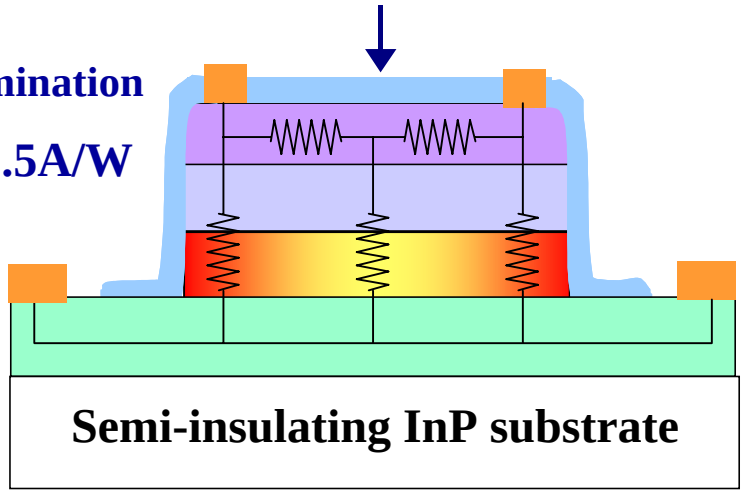
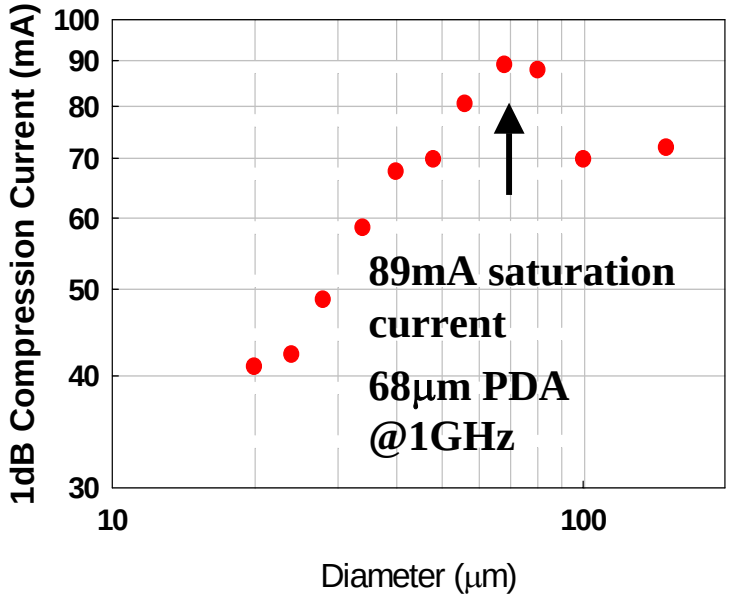
PDA top and backside illumination @1GHz SSM

Top Illumination

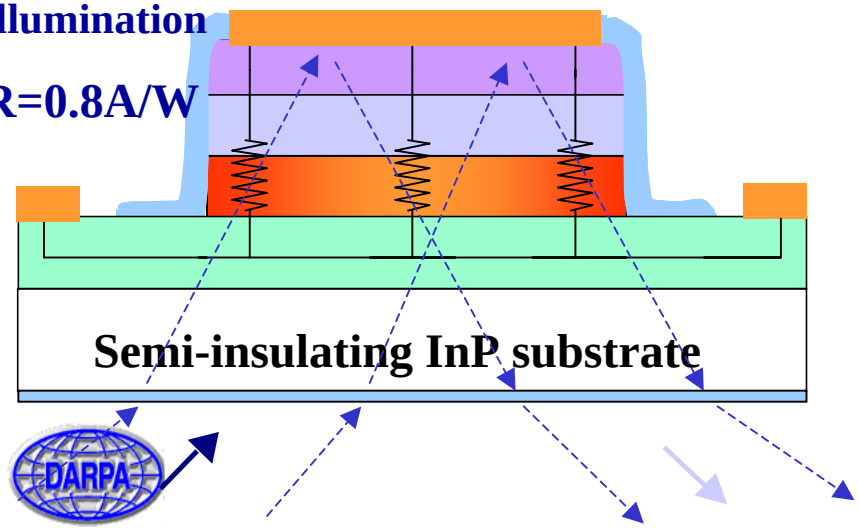
R=0.5A/W

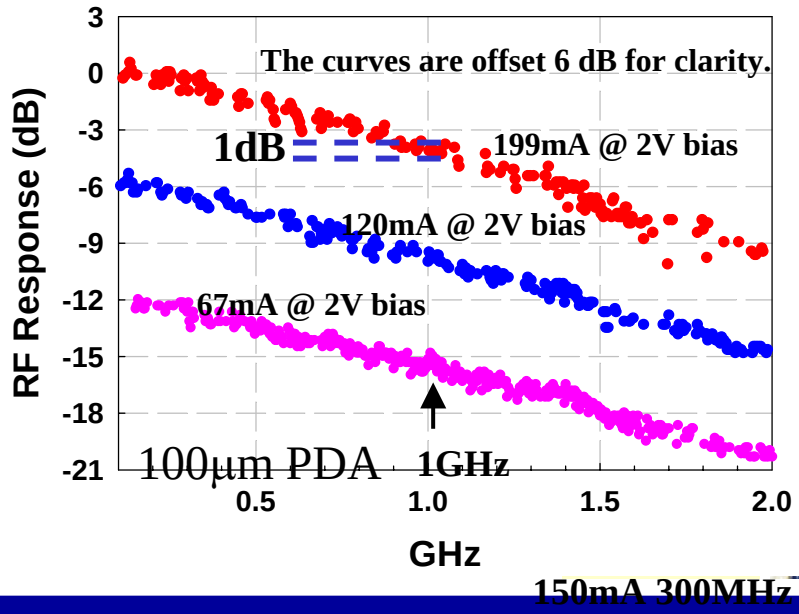




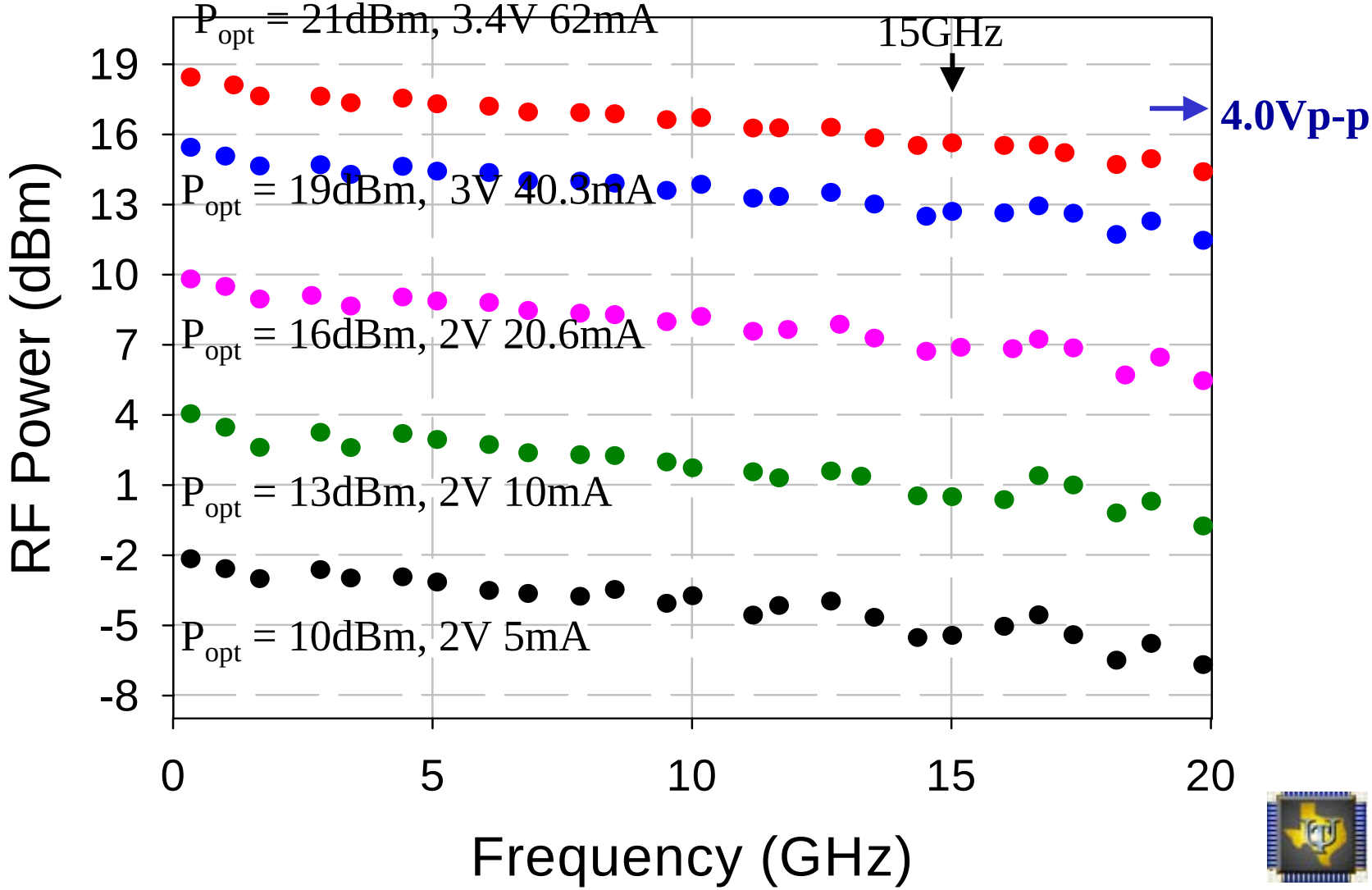
Backside Illumination

R=0.8A/W

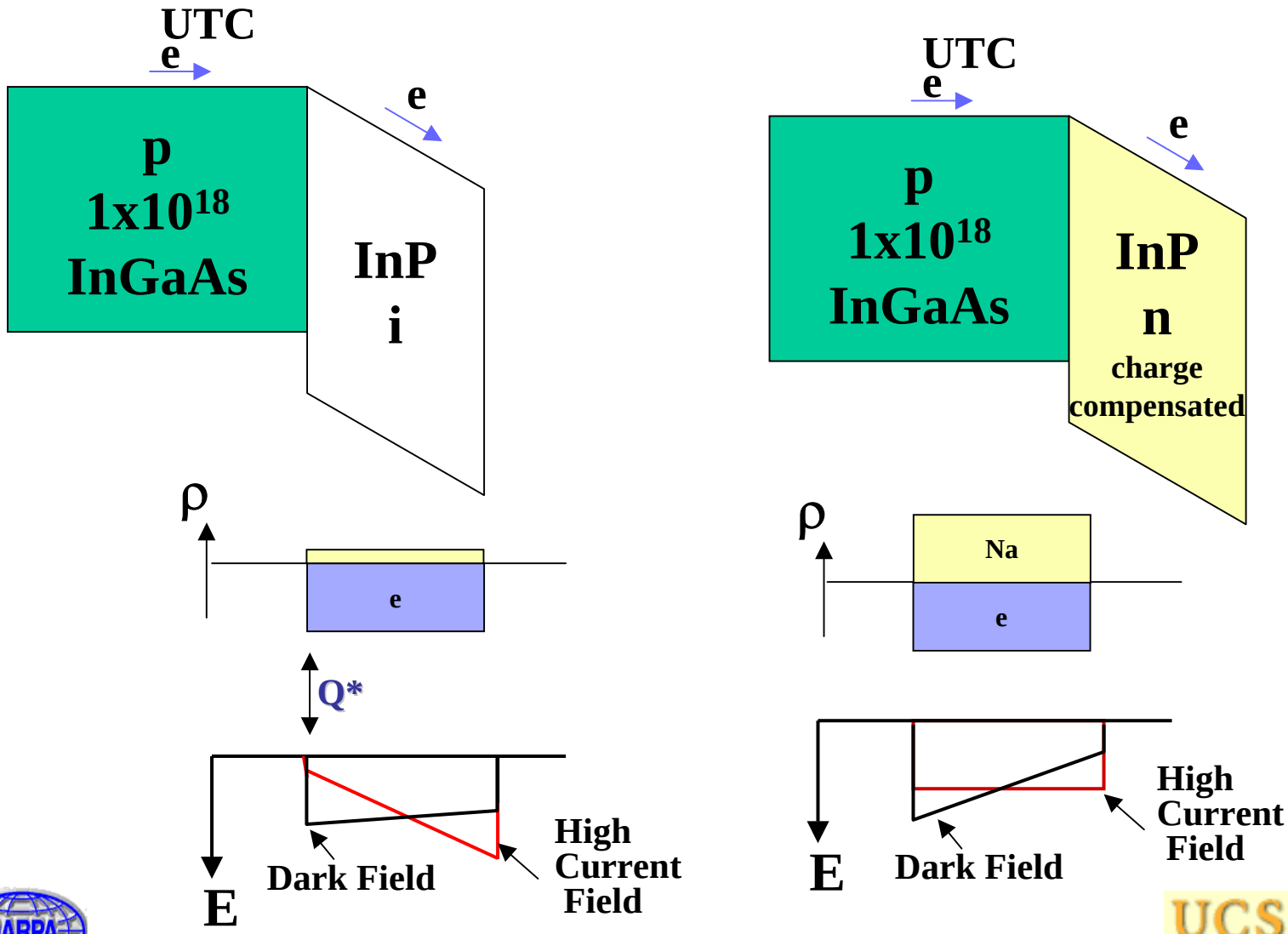




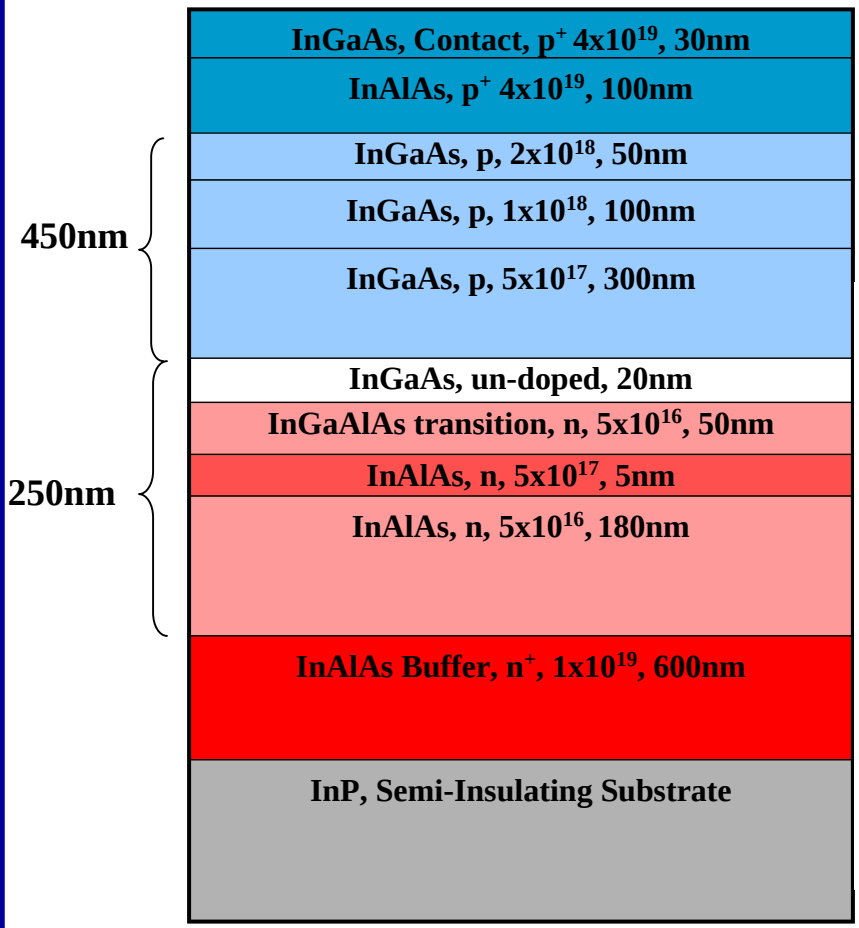
16μm-diameter PDA RF response under Large Signal Modulation

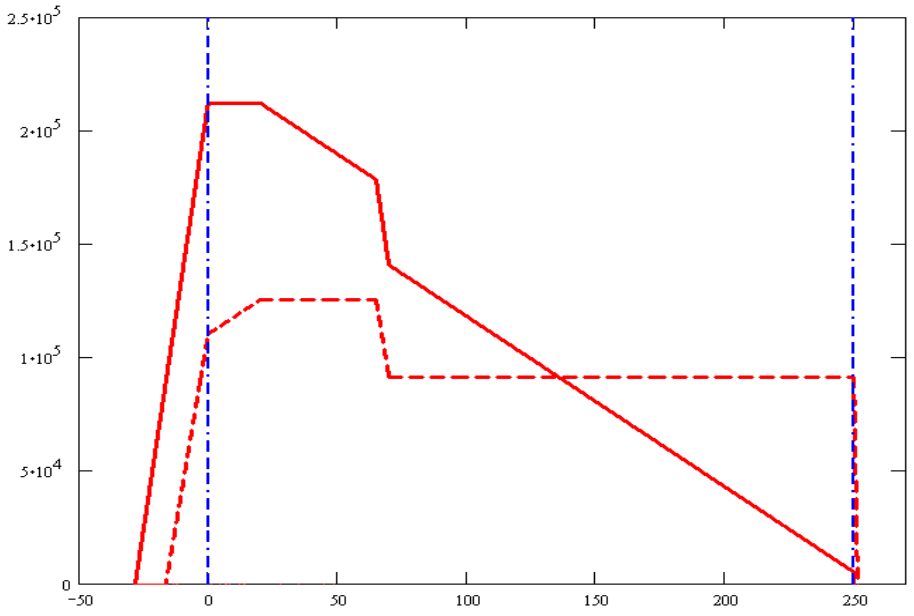


Charge-Compensated UTC



Charge-Compensated InGaAs/InAlAs UTC



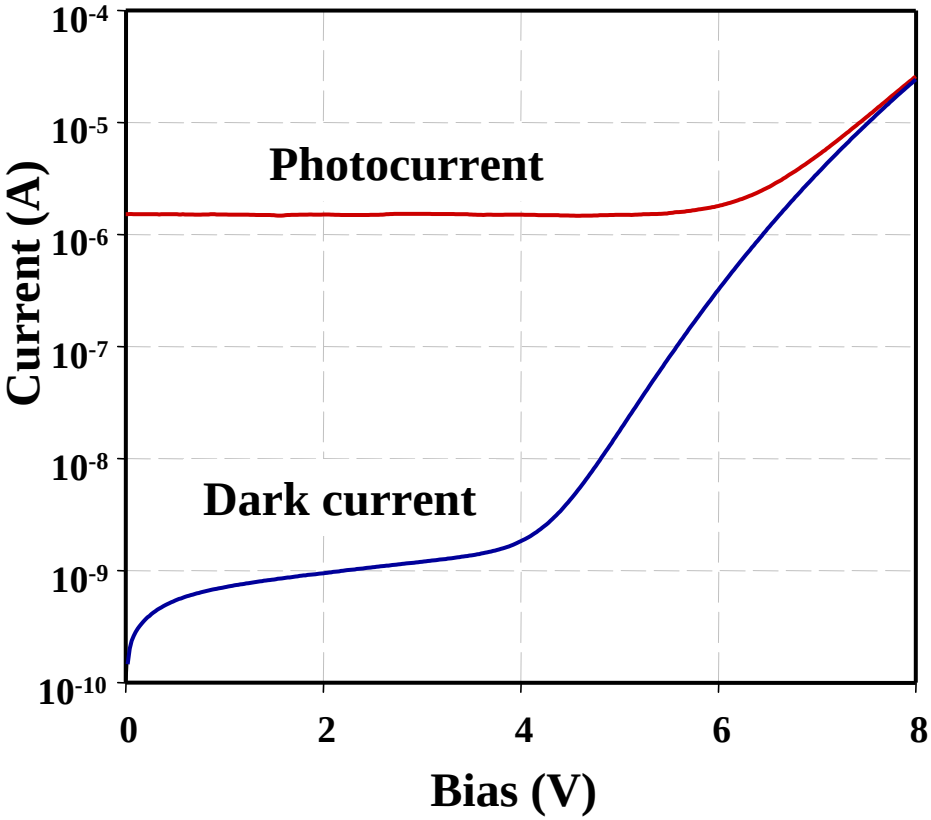


Dark

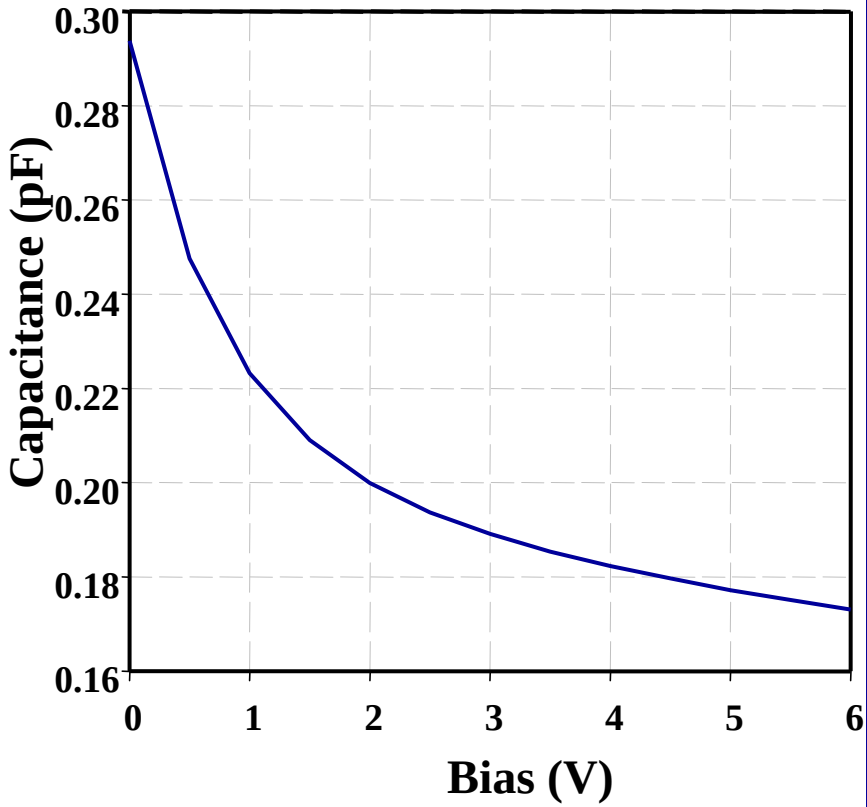
Space charge density = 5×10^{16} cm^{-3}

Current-Voltage and Capacitance-Voltage Characteristics

I-V curve of a 60 μm device



C-V profile of a 20 μm device



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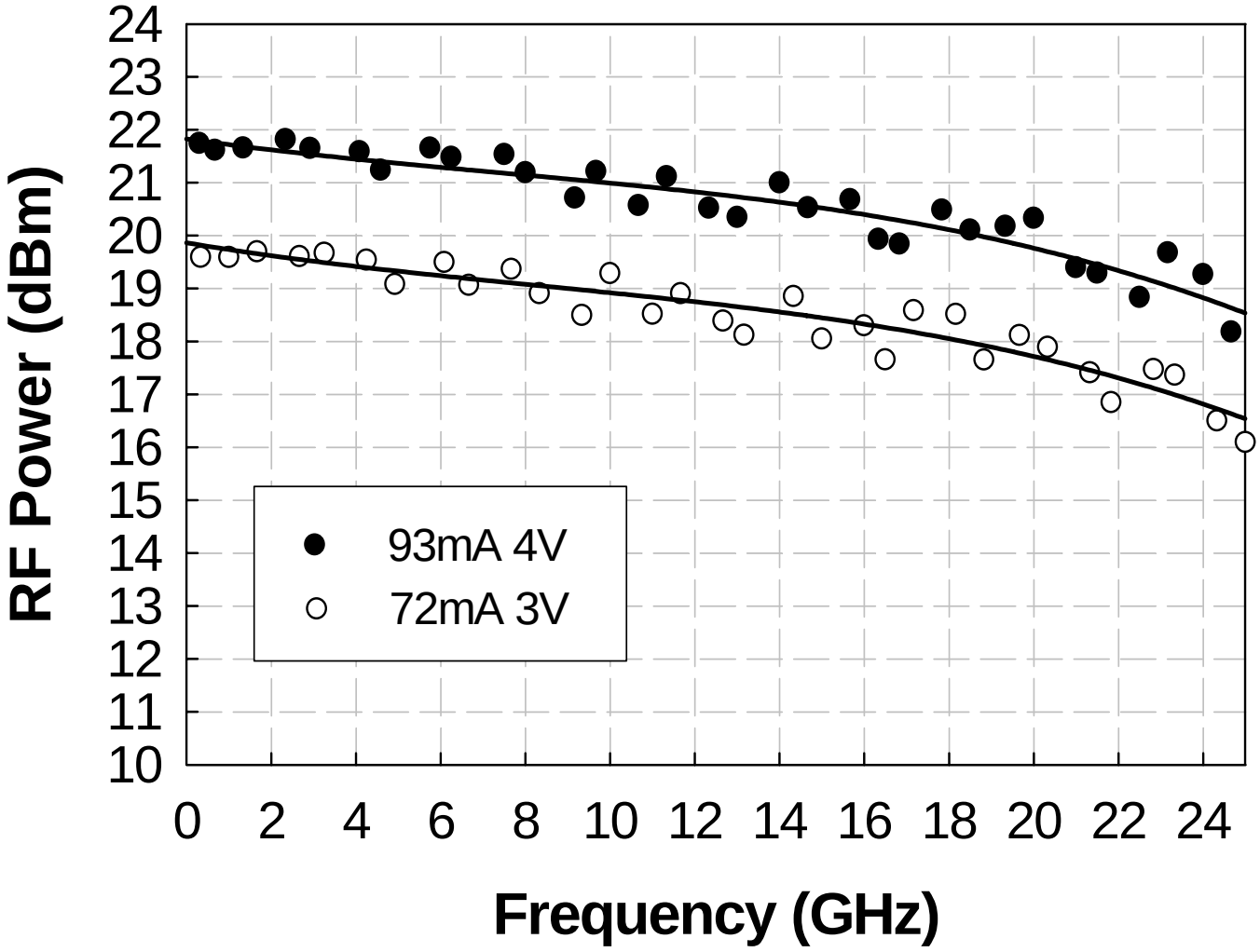
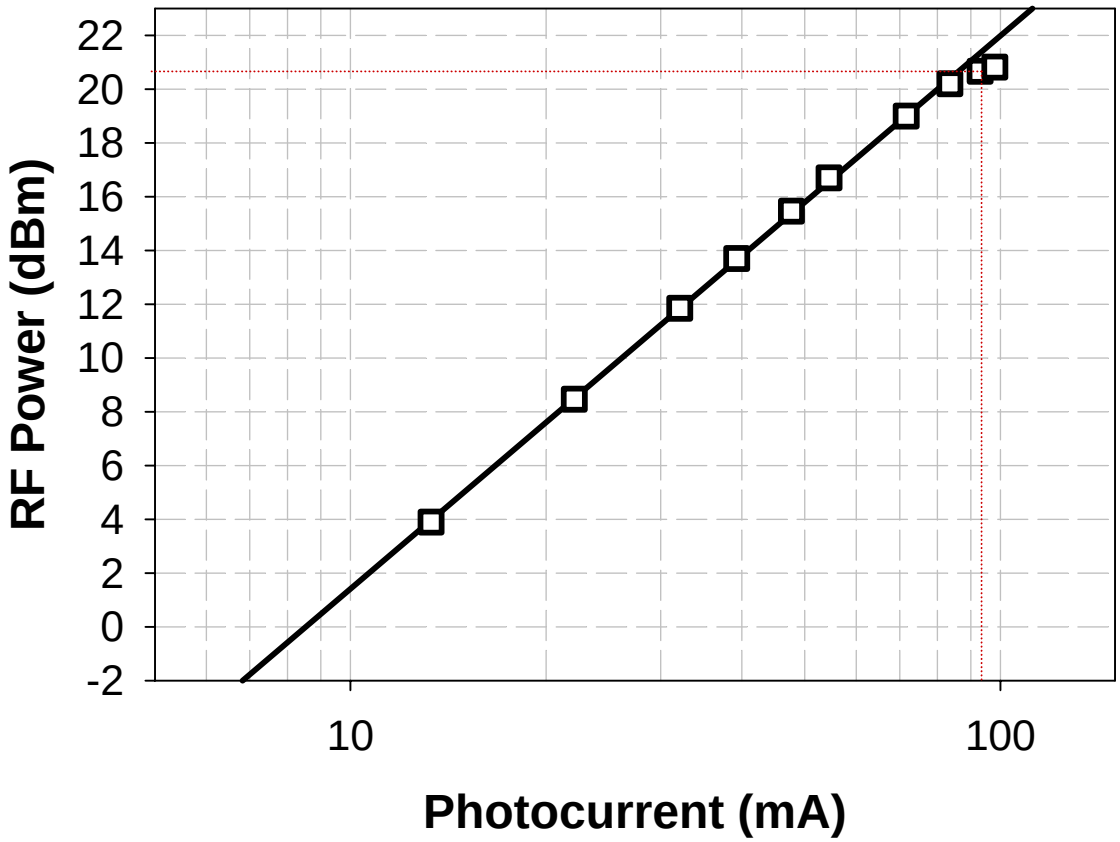
InGaAs/InP Charge-Compensated UTC - 20μm Diameter



Corrected for measurement parasitics

InGaAs/InP Charge-Compensated UTC - 20μm Diameter
RF Power at 20 GHz



Corrected for measurement parasitics

Saturation Current Progress