See-Spot Technology Demonstrator

N. Cohen[a,b], G. Mizrahi[a], G. Sarusi[b] and, A. Sa'ar[a]

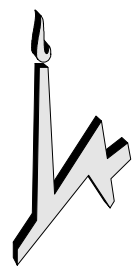
[a]Racah Institute of Physics, The Hebrew University of Jerusalem, Jerusalem 91904, Israel
[b]ELOP Electrooptic Industries LTD, Rehovot 76111, Israel

LWIR/SWIR Switchable Two Color Imager based on InP/InGaAs Integrated HBT/QWIP

N. Cohen[a,b], R. Gardi[a], G. Sarusi[b] and, A. Sa'ar[a]
[a]Racah Institute of Physics, The Hebrew University of Jerusalem, Jerusalem 91904, Israel
[b]ELOP Electrooptic Industries LTD, Rehovot 76111, Israel

H.C. Liu, M. Byloos, A. Bezinger, A. J. SpringThorpe
Institute for Microstructural Sciences, National Research Council ,Ottawa K1A 0R6 ,Canada

QWIP 2006 KANDY SRI-LANKA



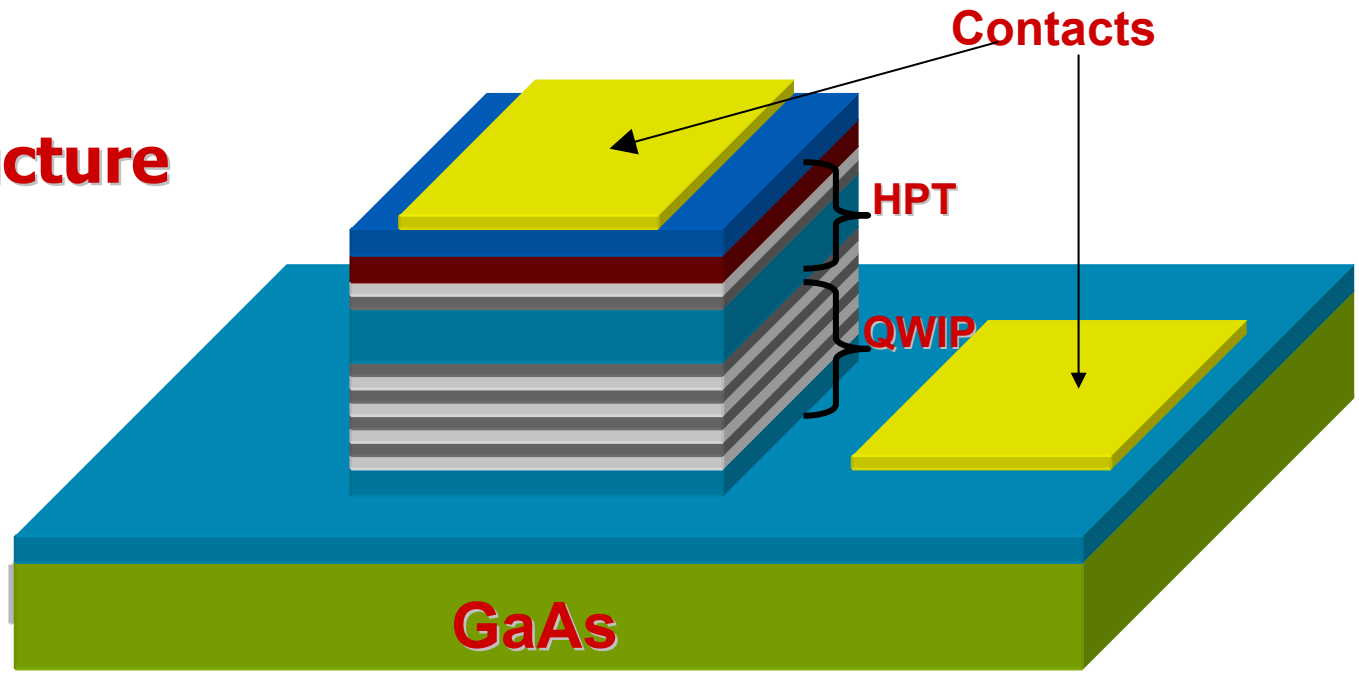
See-Spot Objectives

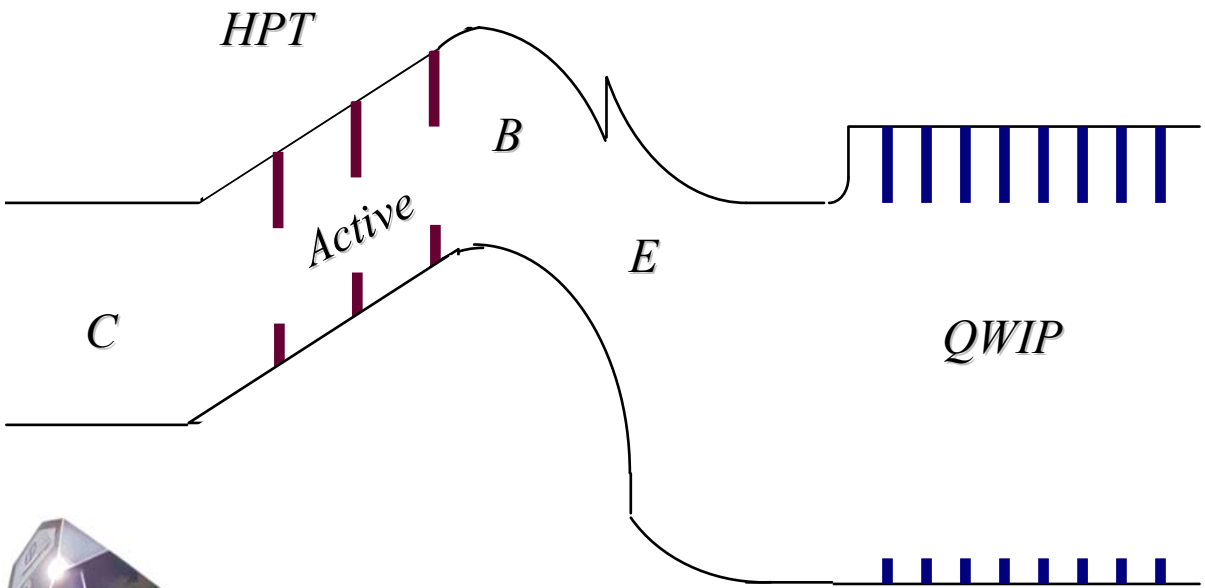
- Imaging of Nd:YAG laser spot and thermal scene at the LWIR spectral regime

- Operated and switched by a commercial 2 terminal ROIC (with one bias polarity)

- Allow long integration time for laser detection to increase the detection probability of short laser pulse

Pixel Structure

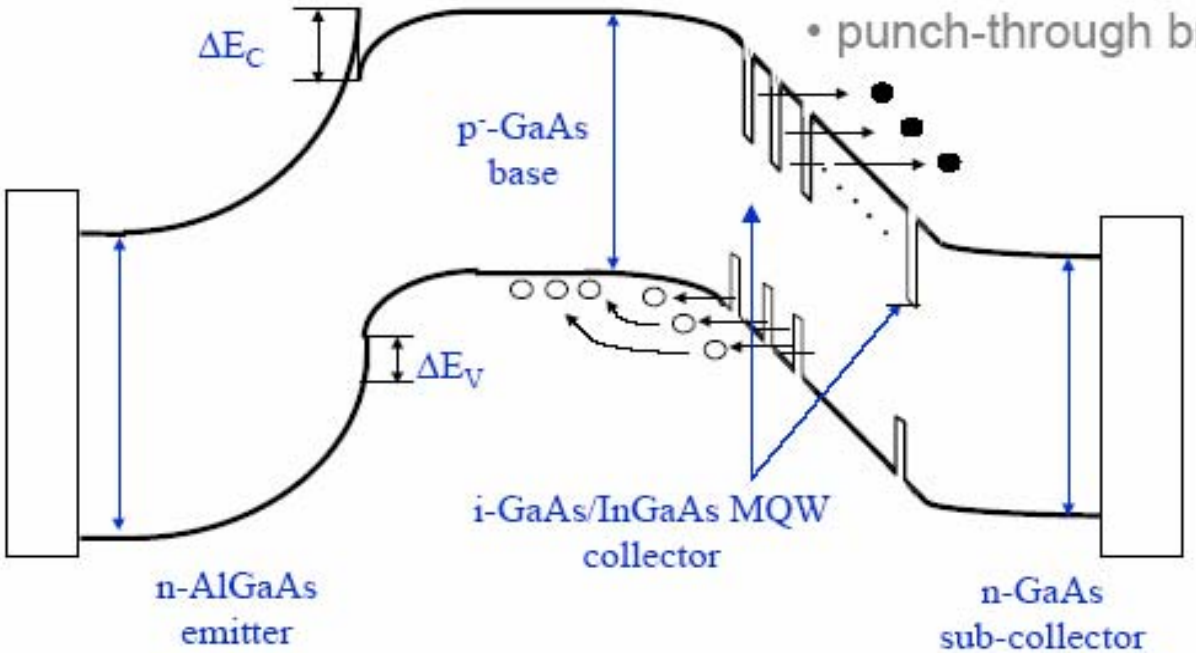




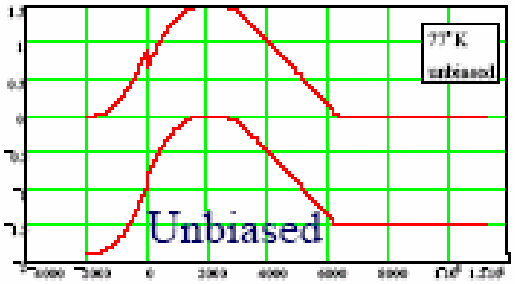
- LWIR – GaAs/AlGaAs QWIP
- NIR - n AlGaAs (Emitter)
  p GaAs (Base)
  i $In_{0.35}GaAs$ (Active)
  n GaAs (Collector)

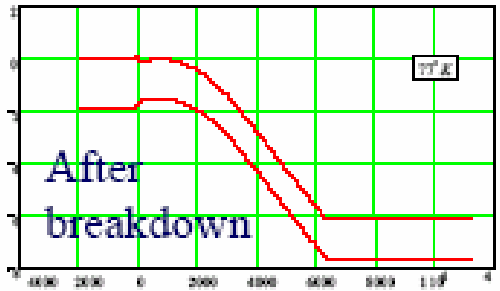
HBT Mode of Operation

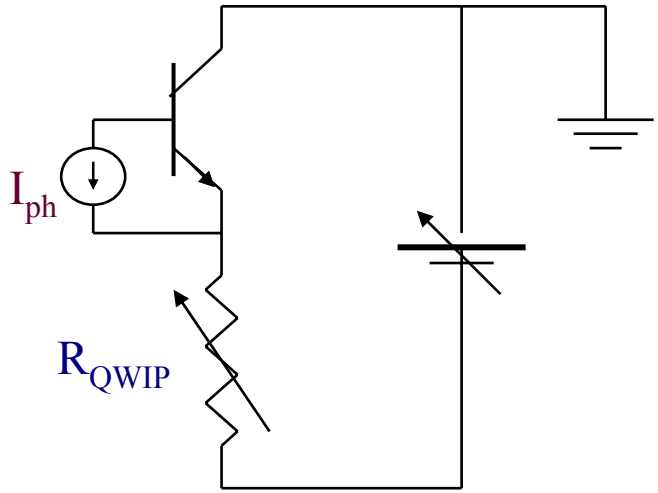
- Floating base HBT (no base contact)
- I_{ph} replaces the base current
- large pc gain = transistor β @ 77K
- high resistance in saturation >100 MΩ
- punch-through breakdown mode

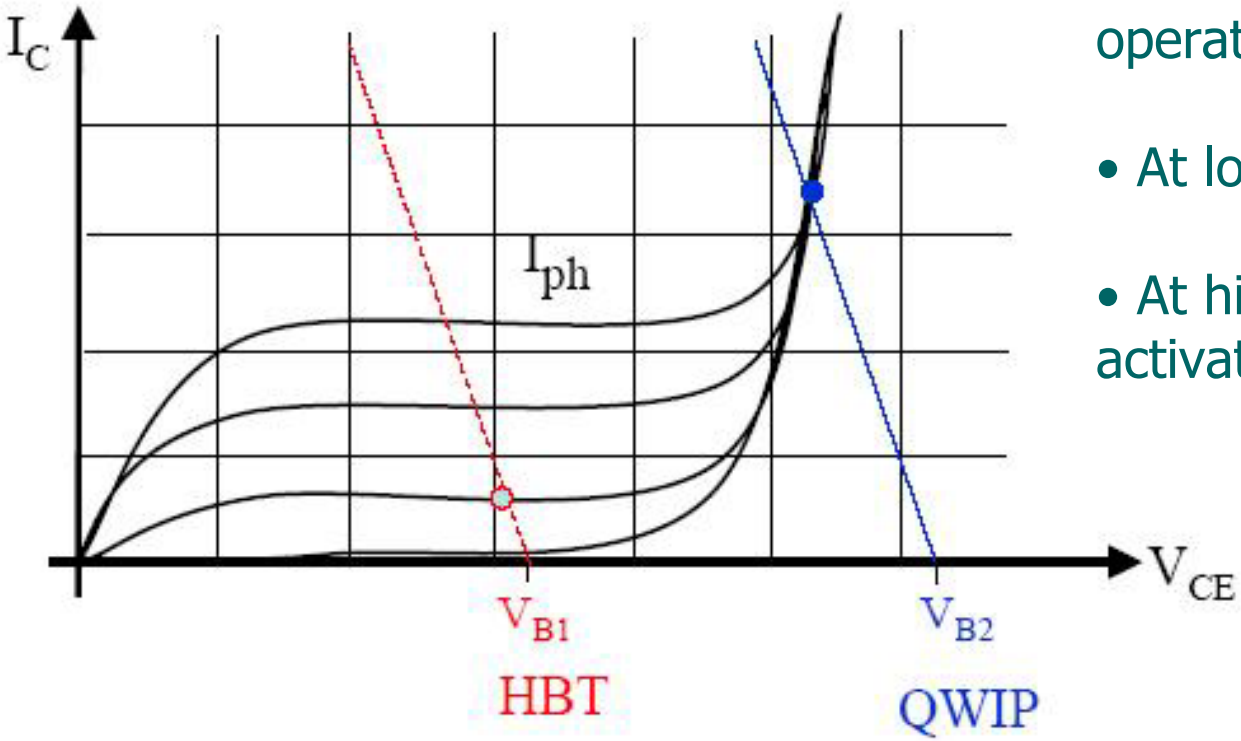


Device Concept
Switching By Punch Through Breakdown

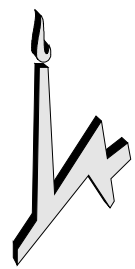


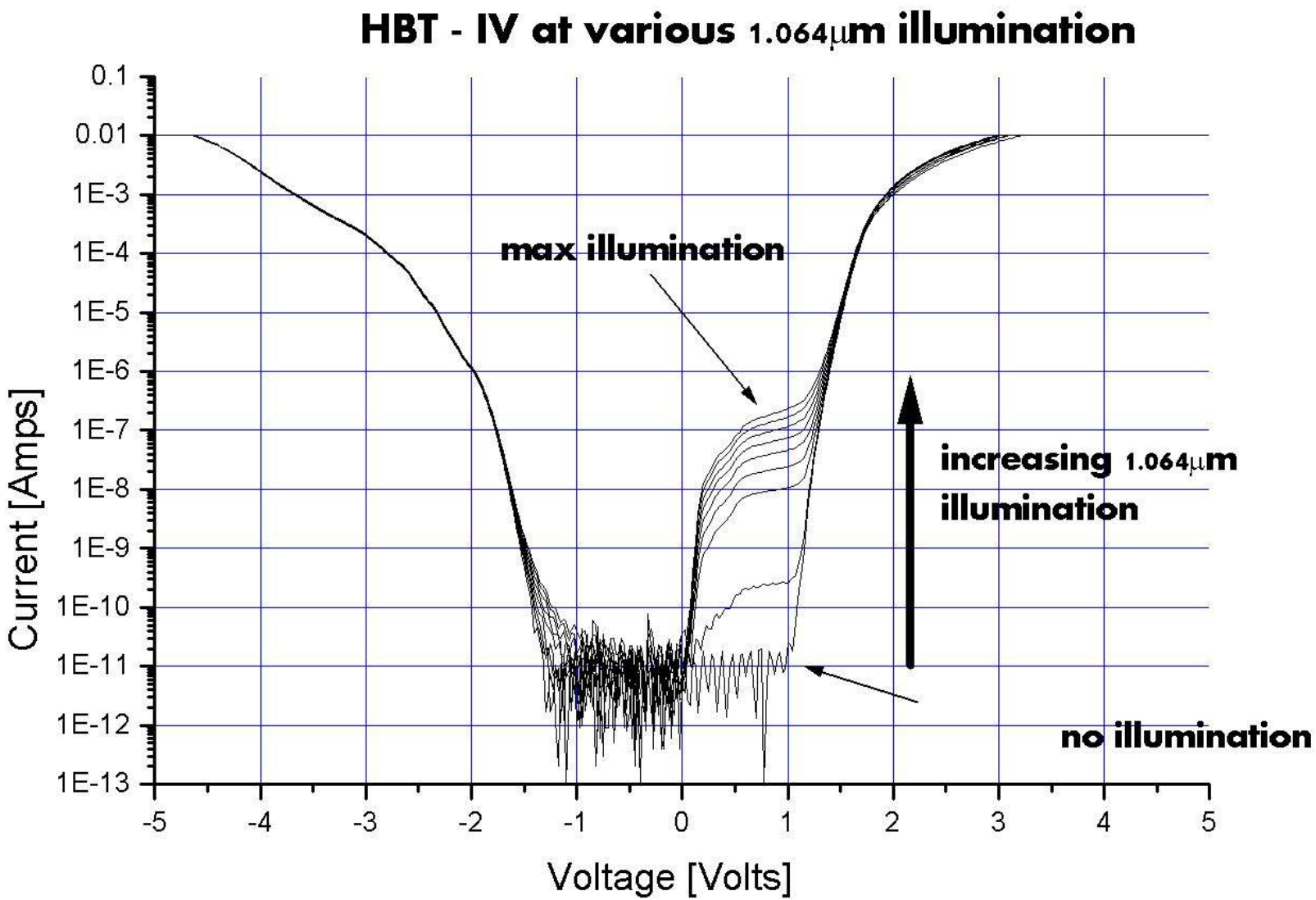






- One polarity bias voltage operates the device
- At low bias HBT is active only
- At high bias the QWIP is activated




HBT - IV at various 1.064μm illumination
0.1
0.01
1E-3
1E-4
1E-5
1E-6
1E-7
1E-8
1E-9
1E-10
1E-11
1E-12
1E-13
Current [Amps]
-5
-4
-3
-2
-1
0
1
2
3
4
5
Voltage [Volts]
max illumination
increasing 1.064μm illumination
no illumination

Last Slide Of QWIP 2004 Talk…

WHAT NEXT?

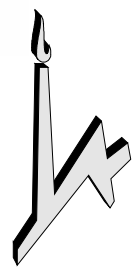
System

Fabrication of 320x256 Array.

Combined Optical (refractive) Channel.

Longer Wavelengths

InP Devices (based on the same concept) allows detection of eye safe laser radiation (1.54μm), but are less fabrication friendly.



What Was Done Since 2004?

- 320x256 Array was Fabricated

- Flip Chip Bonded to Indigo 9705 ROIC and integrated with Dewar and Cooler (Ricor K548) by SCD

- Supporting Electronics was Designed and manufactured for switching and signal processing

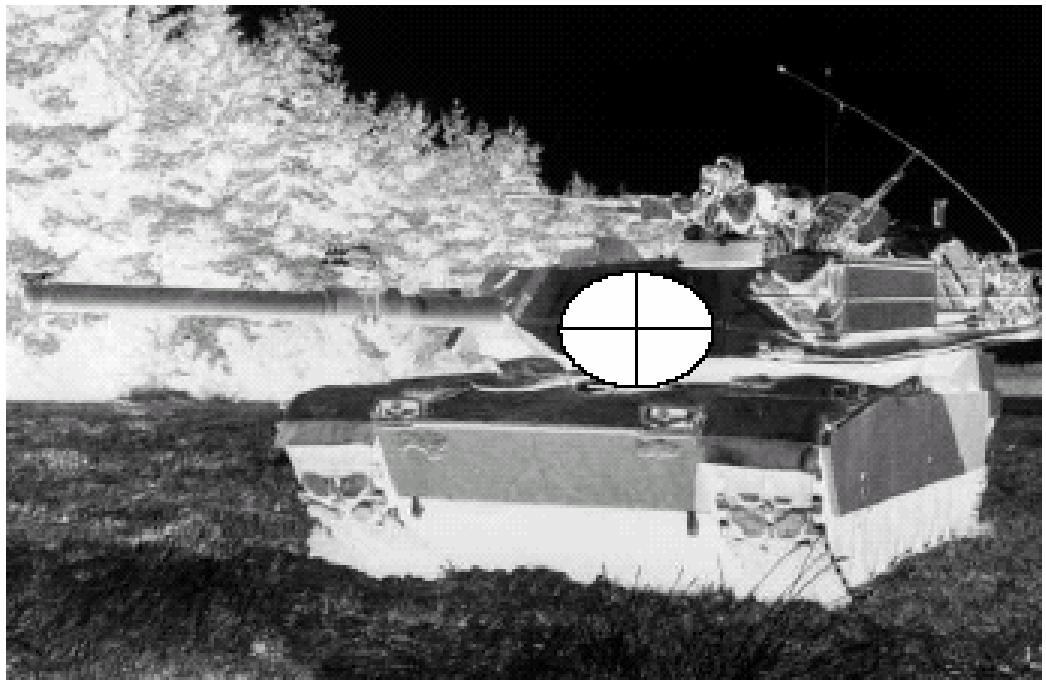
LWIR Image (bias @ high position)

LWIR NETD of 26mK (f/2)
Integration time ~ 5msec

- The movie was taken under low bias with Glass optics of a day camera

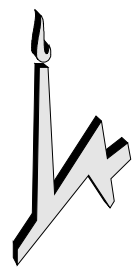
- No Non Uniformity Correction (NUC) was performed

- Source of signal – Sun reflections around 1064nm



InP/InGaAs Structure

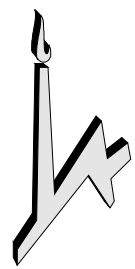
- Sensing longer wavelength up to 1600nm (covering the eye-safe laser at 1540nm)
- High sensitivity due to bound to free transition
- Fast temporal response for active imaging applications
- Unstrained structure

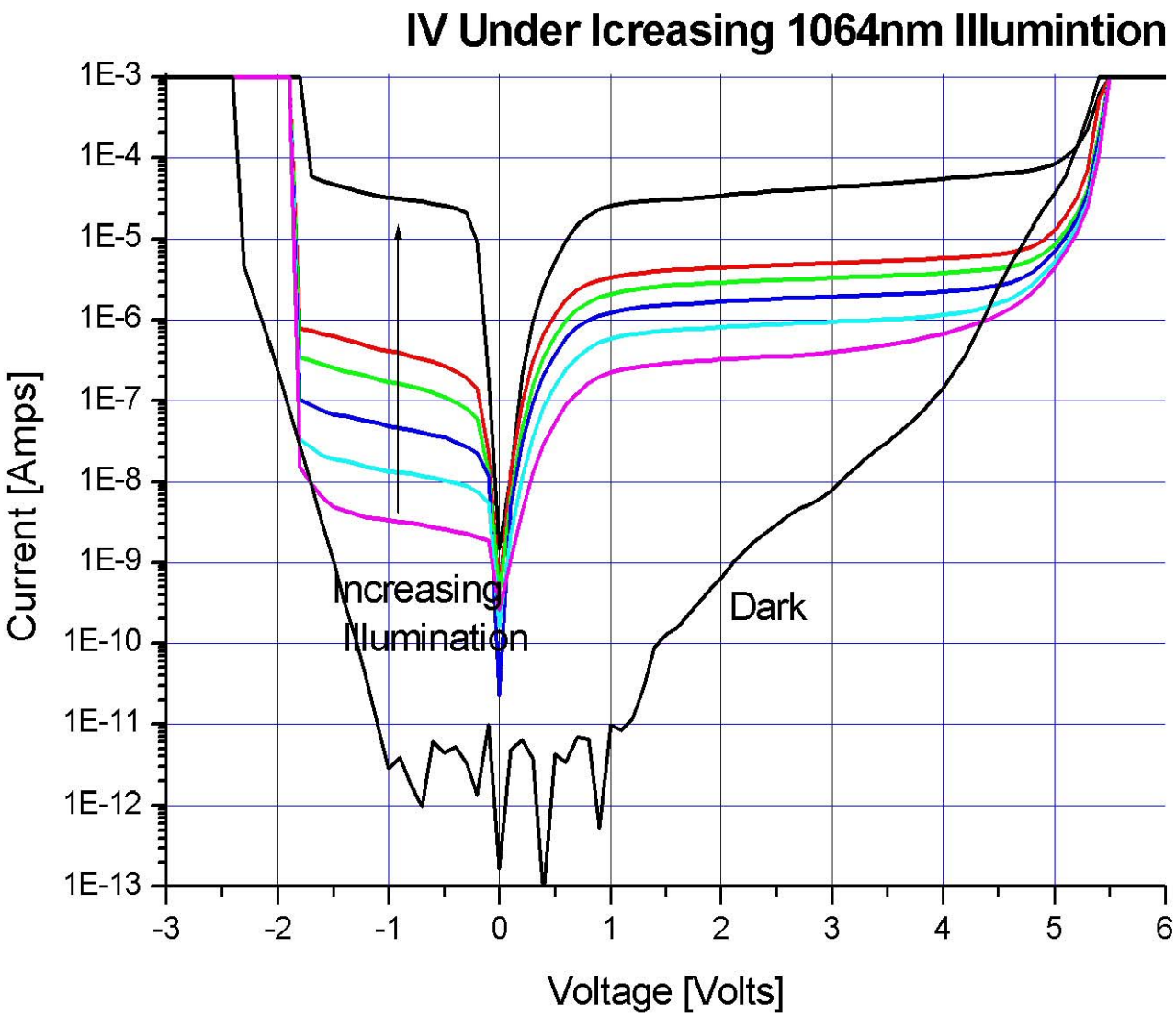


Device* Details

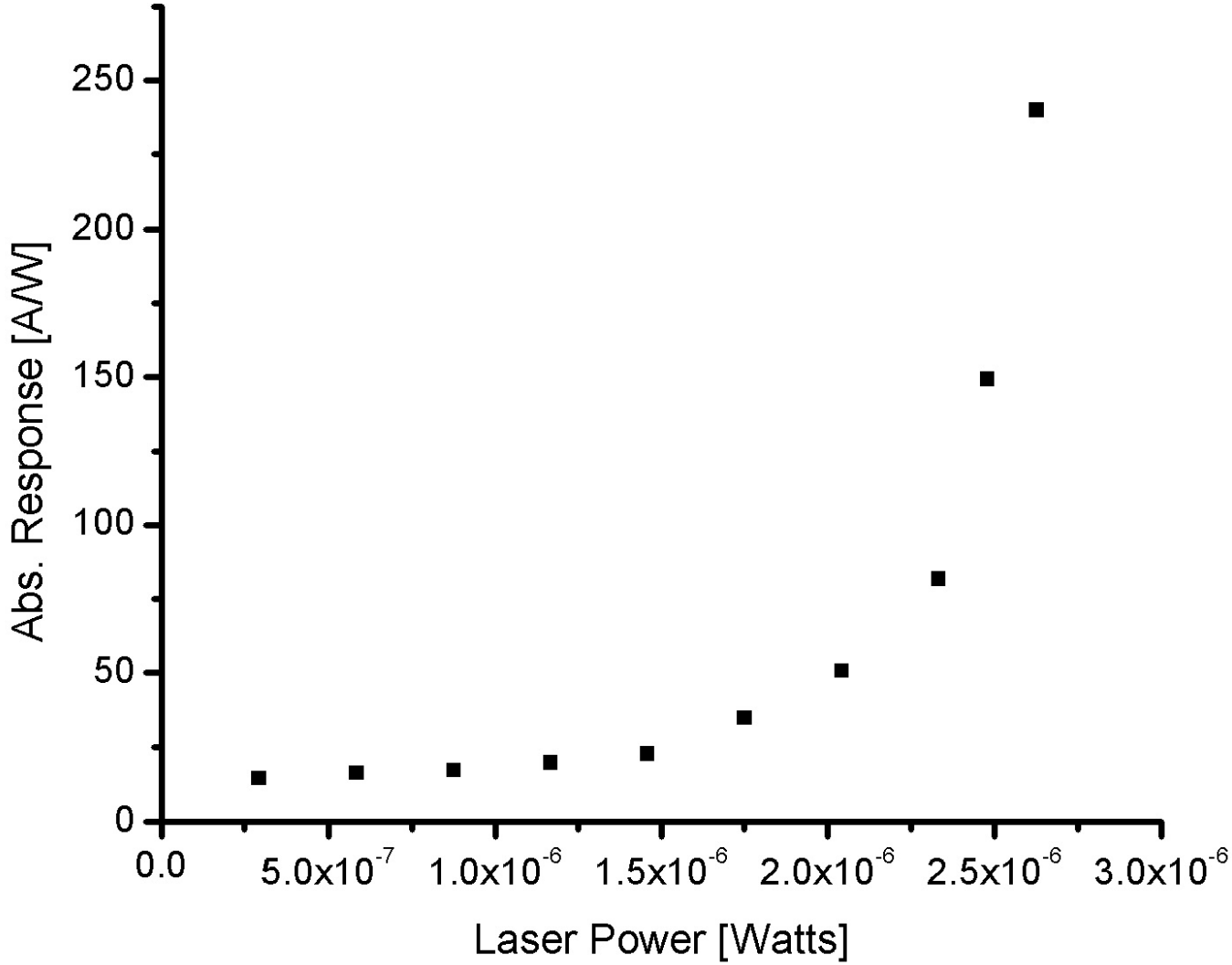
Layer	Width	Material	Doping
Emitter	200nm	InP	n (Si) $4x10^{16}$
Base	100nm	InGaAs (Lattice matched)	p (Zn) $5x10^{17}$
Active	100nm	InGaAs (Lattice matched)	i (Zn) $5x10^{16}$
Collector	500nm	InGaAs (Lattice matched)	n (Si) $5x10^{17}$

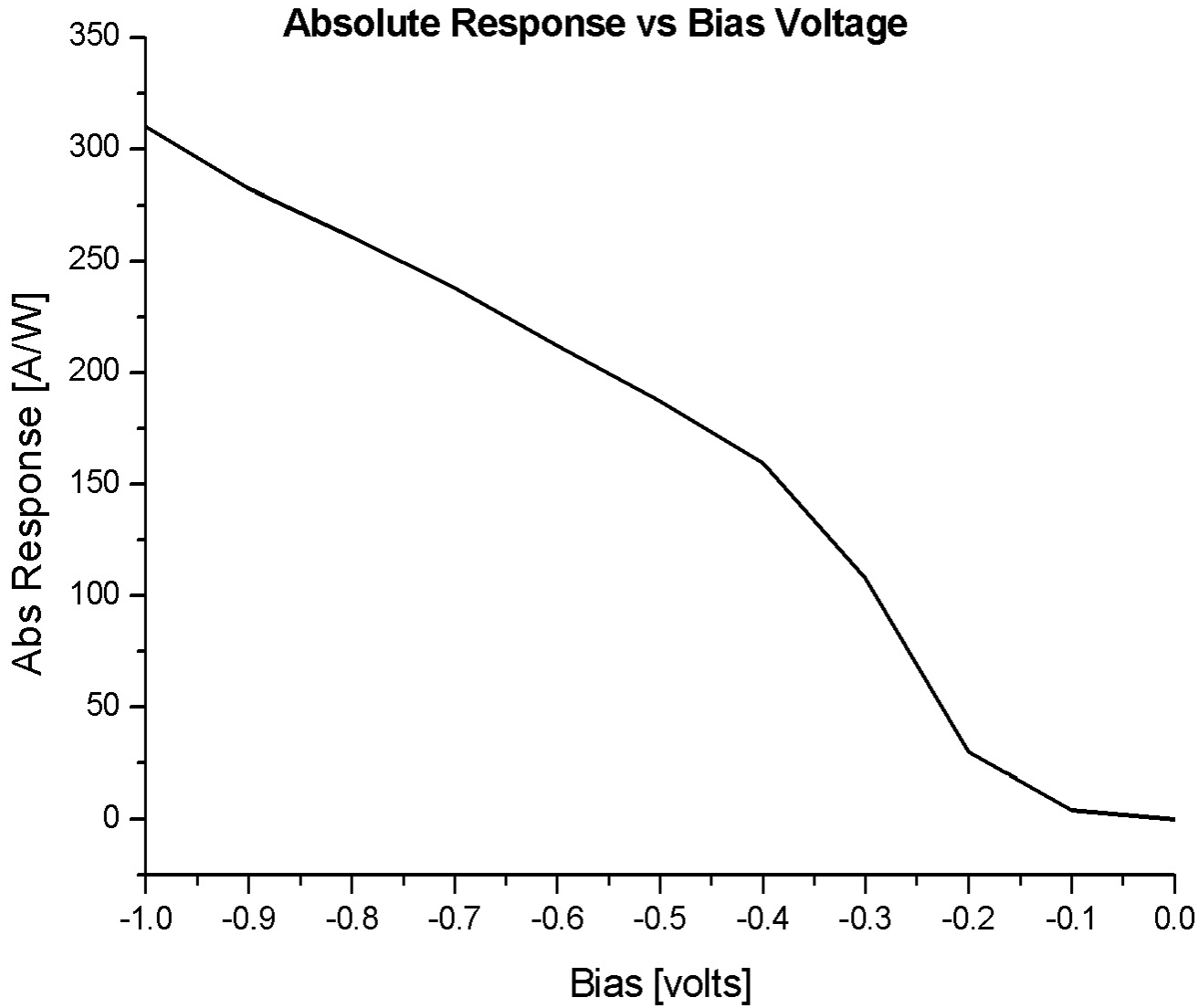
**The Device was grown and fabricated by H.C. Liu group NRC Canada*




IV Under Icreasing 1064nm Illumintion
Current [Amps]
1E-3
1E-4
1E-5
1E-6
1E-7
1E-8
1E-9
1E-10
1E-11
1E-12
1E-13
-3
-2
-1
0
1
2
3
4
5
6
Voltage [Volts]
Increasing
Illumination
Dark

Absolute Response @ 1064nm



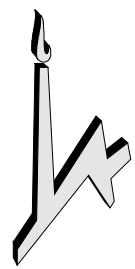

Absolute Response vs Bias Voltage
Abs Response [A/W]
350
300
250
200
150
100
50
0
-1.0
-0.9
-0.8
-0.7
-0.6
-0.5
-0.4
-0.3
-0.2
-0.1
0.0
Bias [volts]

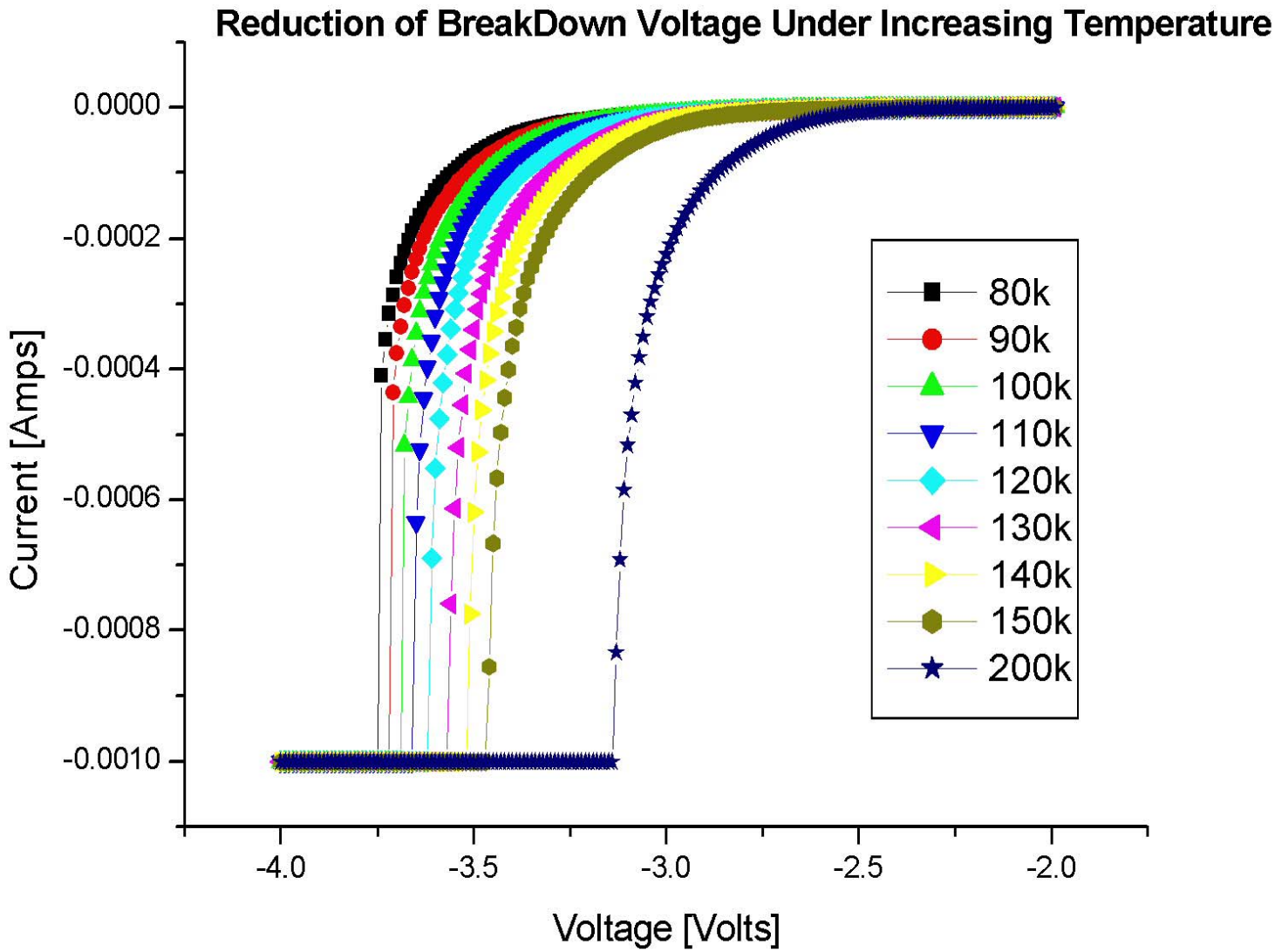
Is it Punch Through or Avalanche?

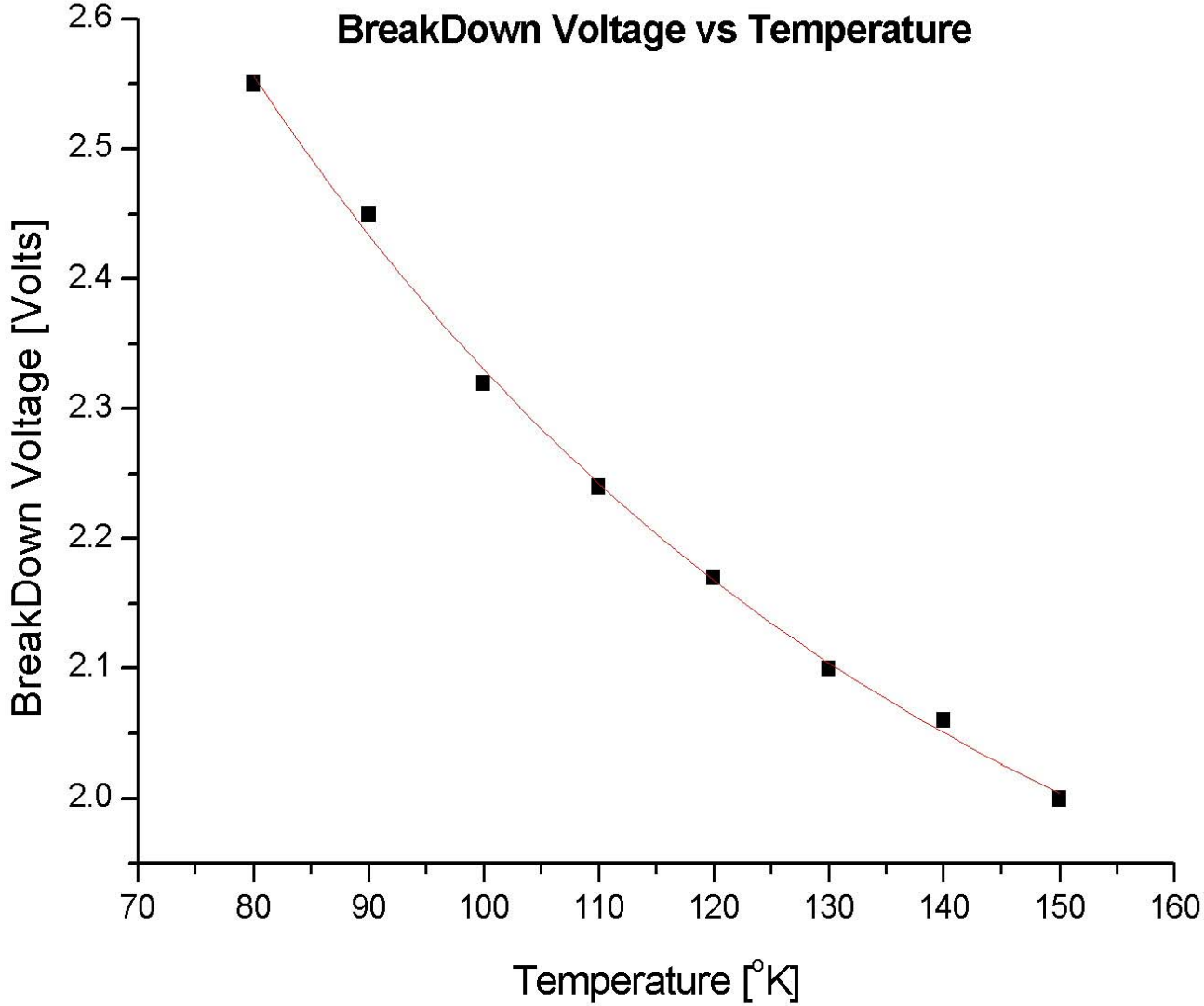
"… Avalanche mechanism has a positive temperature coefficient, i.e., the breakdown voltage **increases** with **increasing** temperature…

A simple explanation for this increase is that hot carriers passing through the depletion layer under high field lose part of their energy to optical phonons after traveling each electron-phonon mean free path λ. The value of λ decreases with increasing temperature. Therefore the carriers lose more energy to the crystal lattice along a given distance at constant field. Hence carriers must pass through a greater potential difference before they can acquire sufficient energy to generate electron-hole pair".

After Sze Physics of Semiconductor Devices

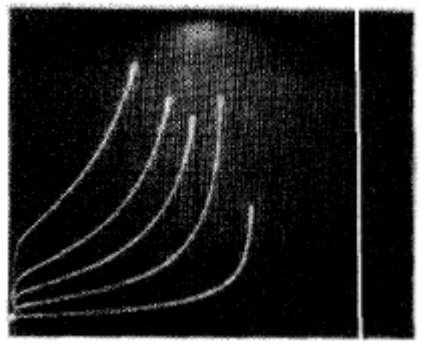



Reduction of BreakDown Voltage Under Increasing Temperature
0.0000
-0.0002
-0.0004
-0.0006
-0.0008
-0.0010
Current [Amps]
-4.0
-3.5
-3.0
-2.5
-2.0
Voltage [Volts]
80k
90k
100k
110k
120k
130k
140k
150k
200k


BreakDown Voltage vs Temperature
BreakDown Voltage [Volts]
2.6
2.5
2.4
2.3
2.2
2.1
2.0
70
80
90
100
110
120
130
140
150
160
Temperature [°K]

Another Avalanche Characteristic

"… The apparent breakdown moves to **lower voltages** as the incident optical power level **increases**".

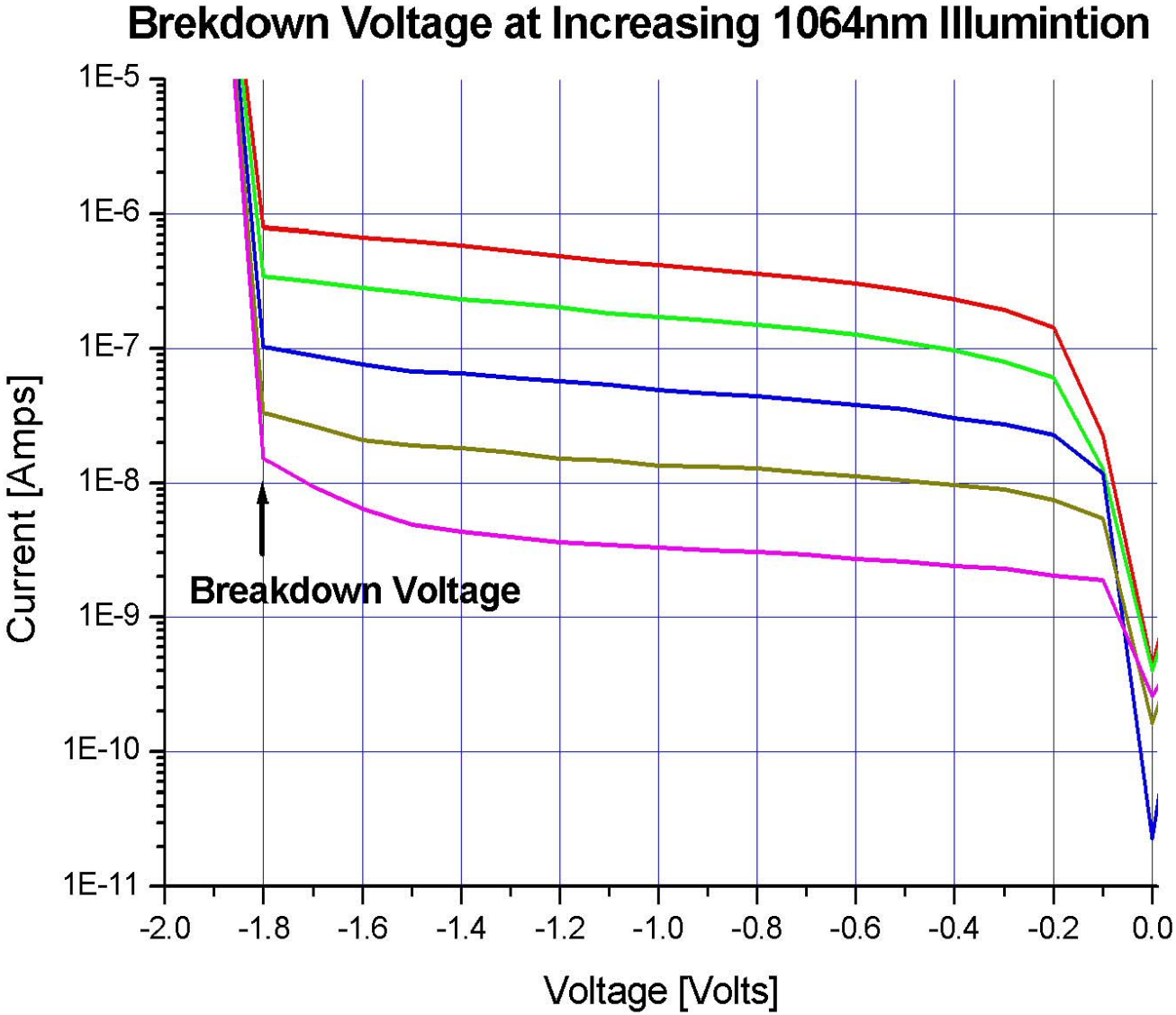


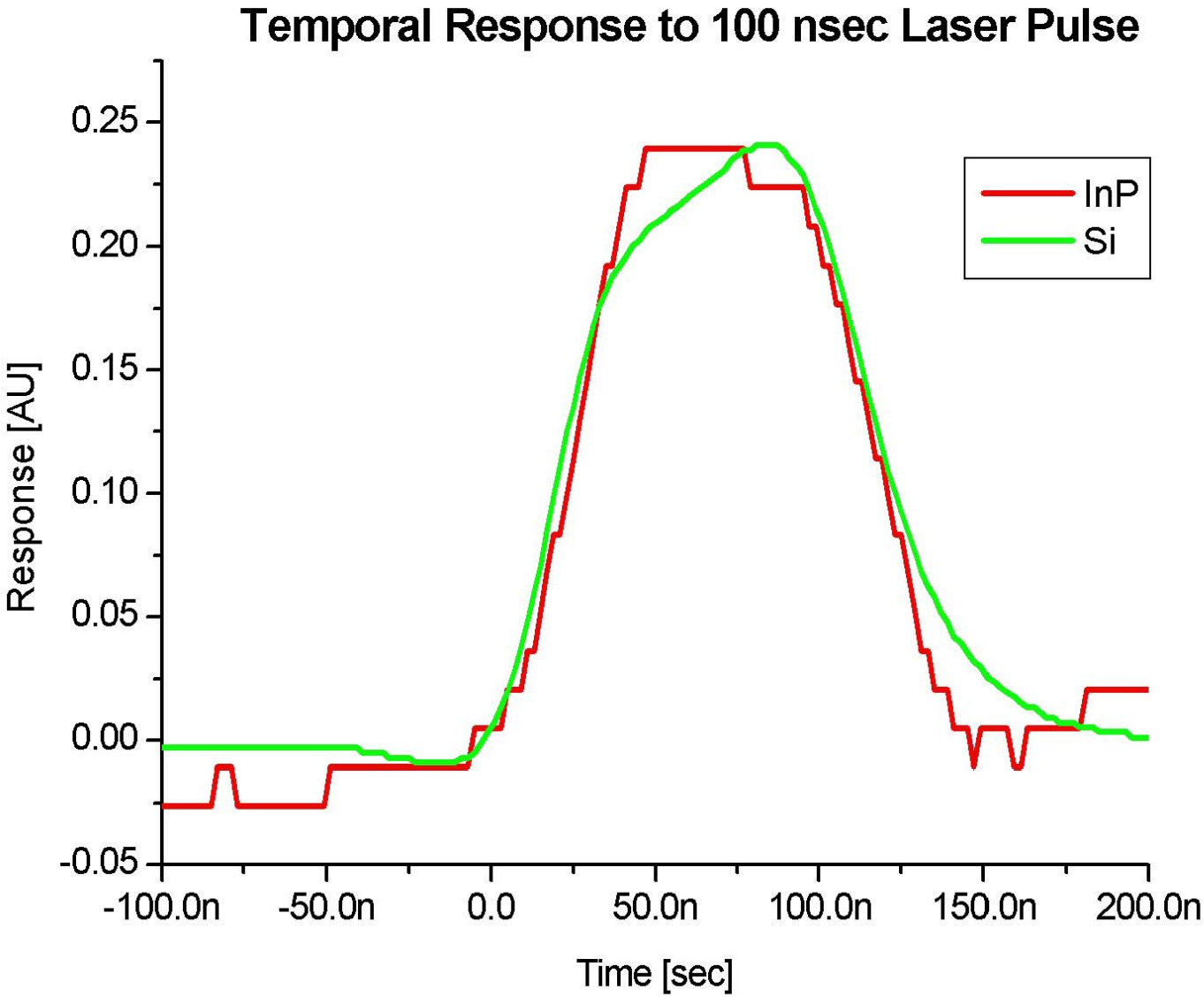
The DC current gain h_{FE} is an increasing function of the signal level. Hence, the breakdown avalanche condition:

$$(M-1)h_{FE} = 1$$

Is satisfied for lower values of the multiplication factor M, or lower bias voltage.

After Campbel et. al. IEEE Journal of Quantum Electronics 19 pp. 1134, 1983


Brekdown Voltage at Increasing 1064nm Illumintion
1E-5
1E-6
1E-7
1E-8
1E-9
1E-10
1E-11
Current [Amps]
Breakdown Voltage
-2.0
-1.8
-1.6
-1.4
-1.2
-1.0
-0.8
-0.6
-0.4
-0.2
0.0
Voltage [Volts]


Temporal Response to 100 nsec Laser Pulse
Response [AU]
0.25
0.20
0.15
0.10
0.05
0.00
-0.05
-100.0n
-50.0n
0.0
50.0n
100.0n
150.0n
200.0n
Time [sec]
InP
Si

Summery

- YAG/LWIR See-Spot imager was presented
- Proved switching concept
- Same concept can be utilized for eye safe laser based on InP/InGaAs structure