InP HBT Technology for Extreme Temperature

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May 14, 2003

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"The present overwhelming dominance of the compound semiconductor device field by FET's is likely to come to an end, with bipolar devices assuming an at least equal role, and very likely a leading one."

Herbert Kroemer, Proc. IEEE, Jan. 1982.

Nobel Prize Winner, 2000

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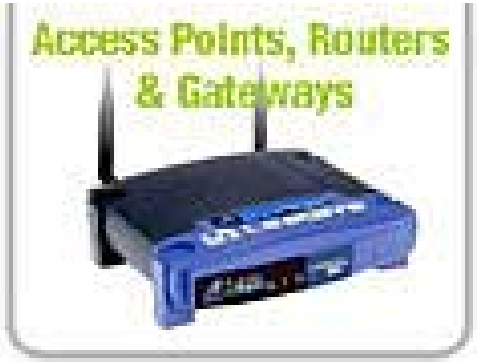
The “Killer Apps” for GaAs HBT



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InP HBT: The Need for Speed

SFP & SFF Transceivers for Metro Area Networks

- High speed digital and analog ICs for defense
- 10 – 40 Gb/s low power ICs for optical networks
- Digital and analog ICs for wireless infrastructures

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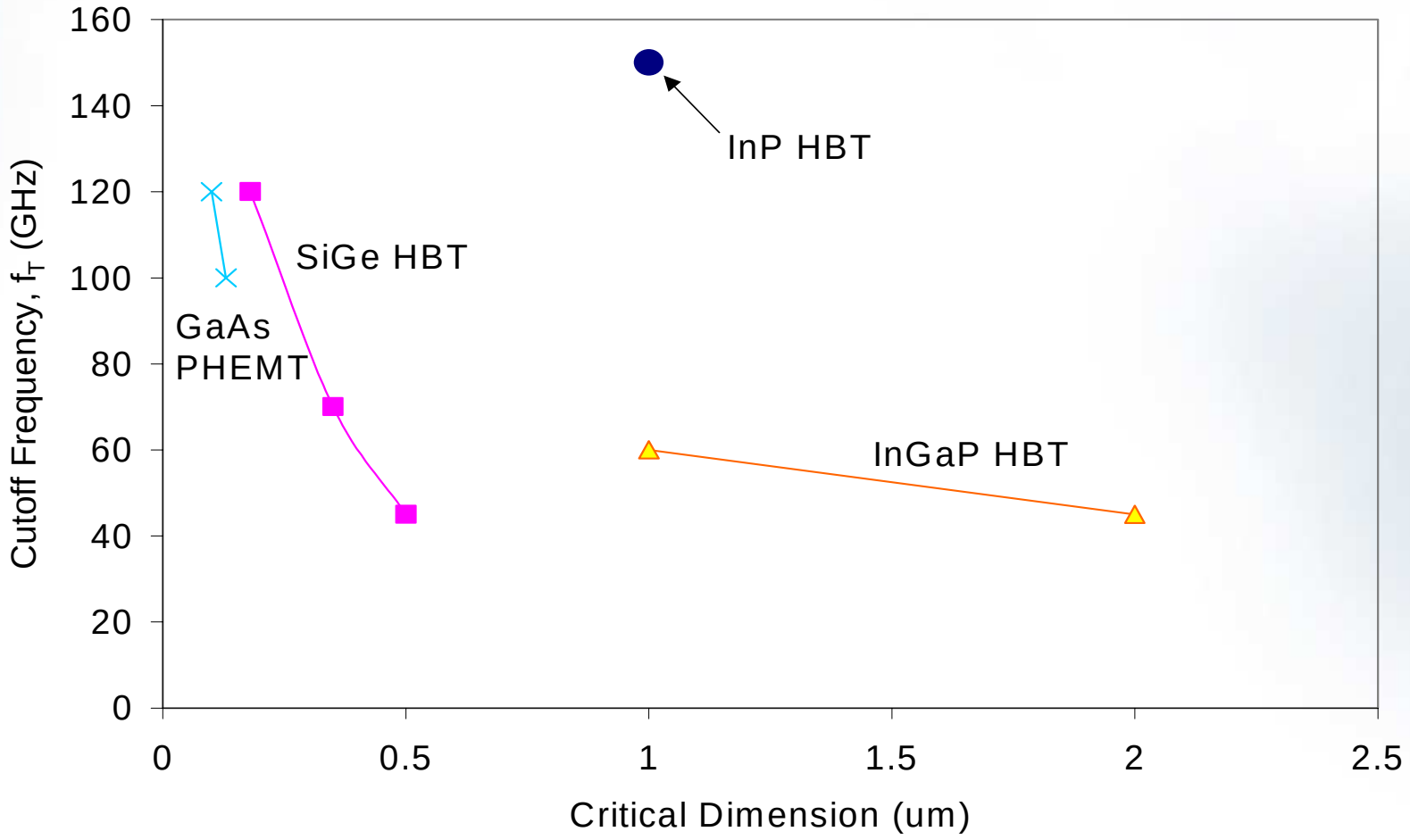
Speed vs. Feature Size



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Technology Comparison

	InGaP HBT	GaAs PHEMT	SiGe HBT	InP HBT
Cutoff Frequency (GHz)	45 - 60	80 - 110	45 - 120	>150
Integration Level	2K	< 100	>10K	2K
Breakdown Voltage (V)	7 - 14	7 - 10	3	3 - 10
Radiation Hardness	Good	Good	?	Good
1/f Noise	Good	Poor	Good	Good
Cryogenic Operation	?	Yes	?	Yes

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InP HBT IC Products & Applications

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July 25, 2003

40 Gb/s Optical Transmission

InP HBT 4:1 MUX, 1.5W

GaAs PHEMT Driver, 3W

Lithium Niobate Modulator

4X10Gb/s Data In

40Gb/s Data Out

InP PIN Diode + InP HBT TIA (200 mW)

InP HBT 4:1 MUX, 1.1W

40Gb/s Data In

4X10Gb/s Data Out

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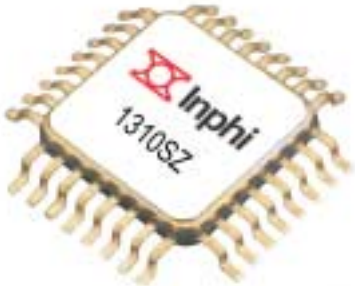
10 Gb/s Optical Transmission

16X622 Mb/s Data In → *16:1 MUX in CMOS or SiGe BiCMOS* →

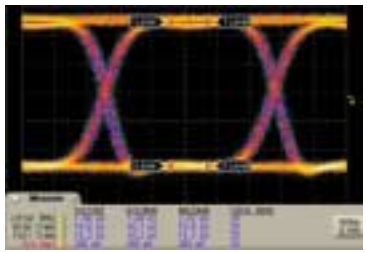
InP HBT Driver



→ **10 Gb/s Data Out**

10 Gb/s Data In (from PIN diode) →

InP HBT TIA



→ *1:16 DeMUX in CMOS or SiGe BiCMOS* → **16X622 Mb/s Data Out**

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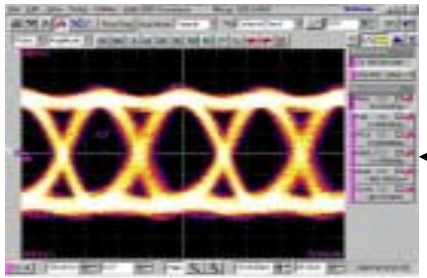
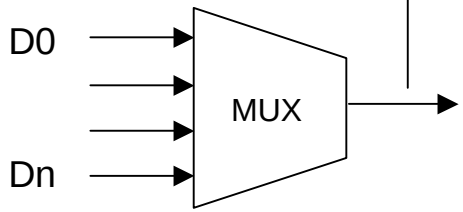
DC to 50 GHz Retiming

43 Gb/s D-FF Input

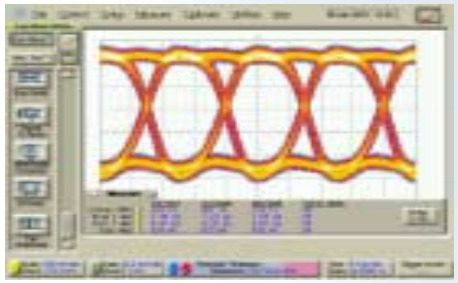


MUX output exhibits duty cycle distortion



50 Gb/s InP HBT D-Type Flip Flop

43 Gb/s D-FF Output



D Flip Flop retimes and cleans up duty cycle distortion

<u>Applications:</u>

- **Optical communications and lasercom**
- **Test instrument**
- **Satellite communications**

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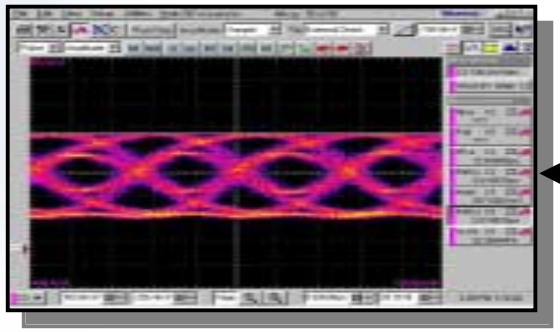
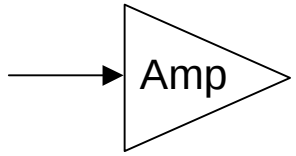
DC to 50 GHz Decision Circuit

50 Gb/s Data Input

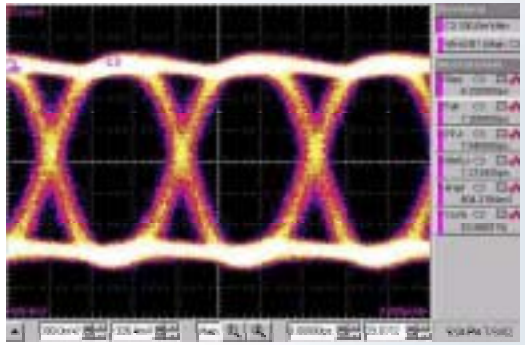


Noisy data from fiber or over the air



50 Gb/s InP HBT D-Type Flip Flop

50 Gb/s Data Output



D Flip Flop retimes and makes “1” or “0” decisions on noisy signal

<u>Applications:</u>

- **Optical communications and lasercom**
- **Test instrument**
- **Satellite communications**

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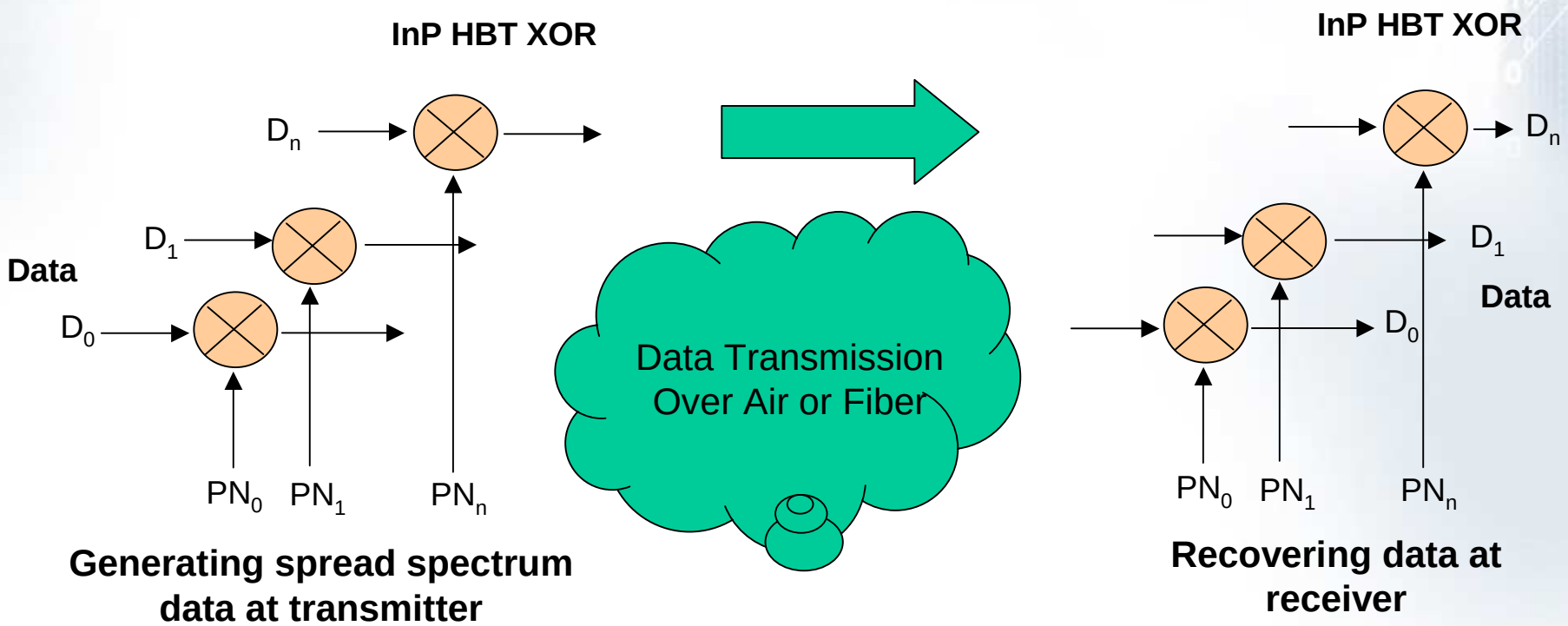
DC to 50 GHz Direct Sequence Spread Spectrum (DSSS)



Applications:

- **Milsatcom ground terminals**
- **Military radios**

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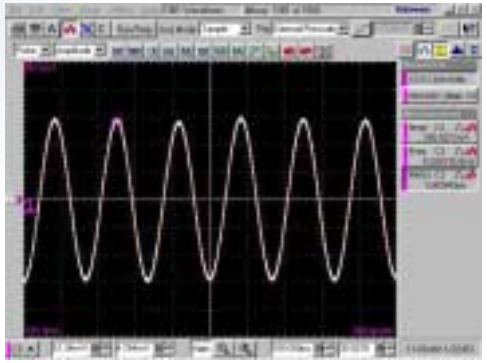
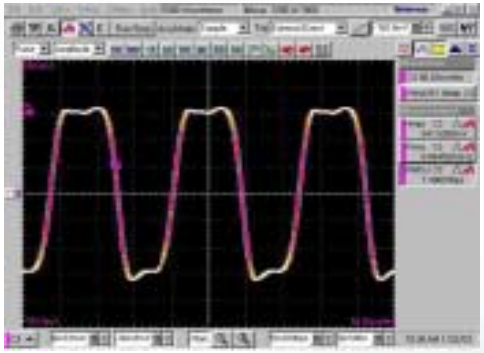
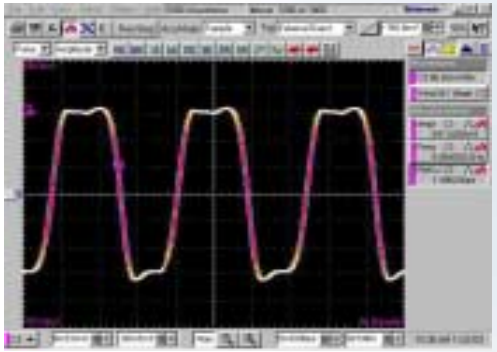
DC to 50 GHz Local Oscillator Distribution

Dc to 50 GHz LO







<u>Applications:</u>

- **Optical communications and lasercom**
- **Test instrument**
- **Satellite communications**

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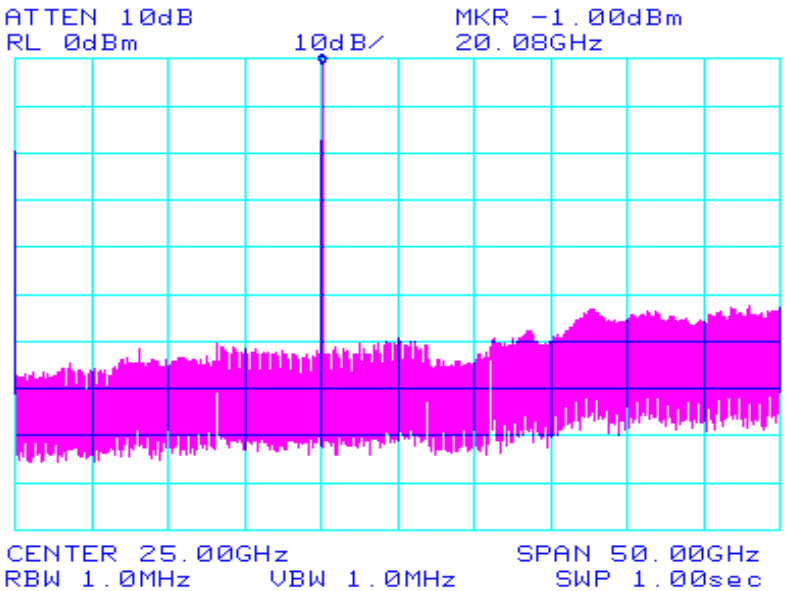
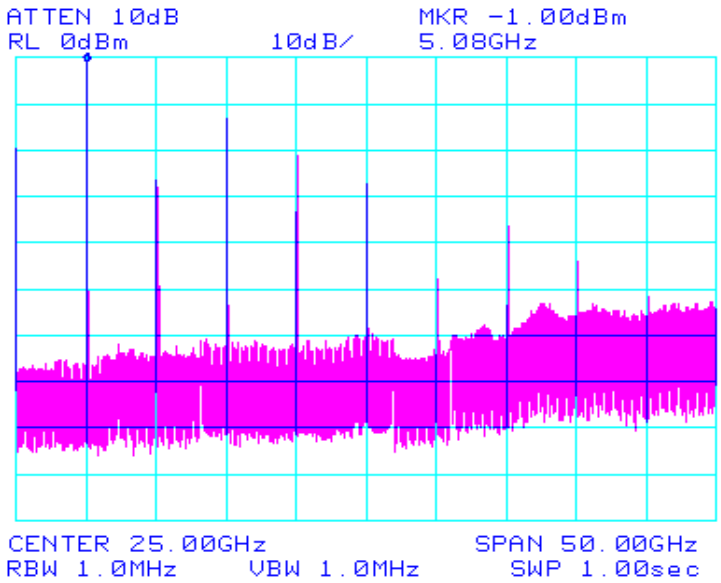
DC to 25 GHz Divide-by-4 Prescalers

- **High input sensitivity, -20dbm at 25 GHz**
- **Low phase noise, -130 dbc/Hz @ 100KHz offset at Fin = 20 GHz**
- **360 mW power consumption**

RF Input



RF Output



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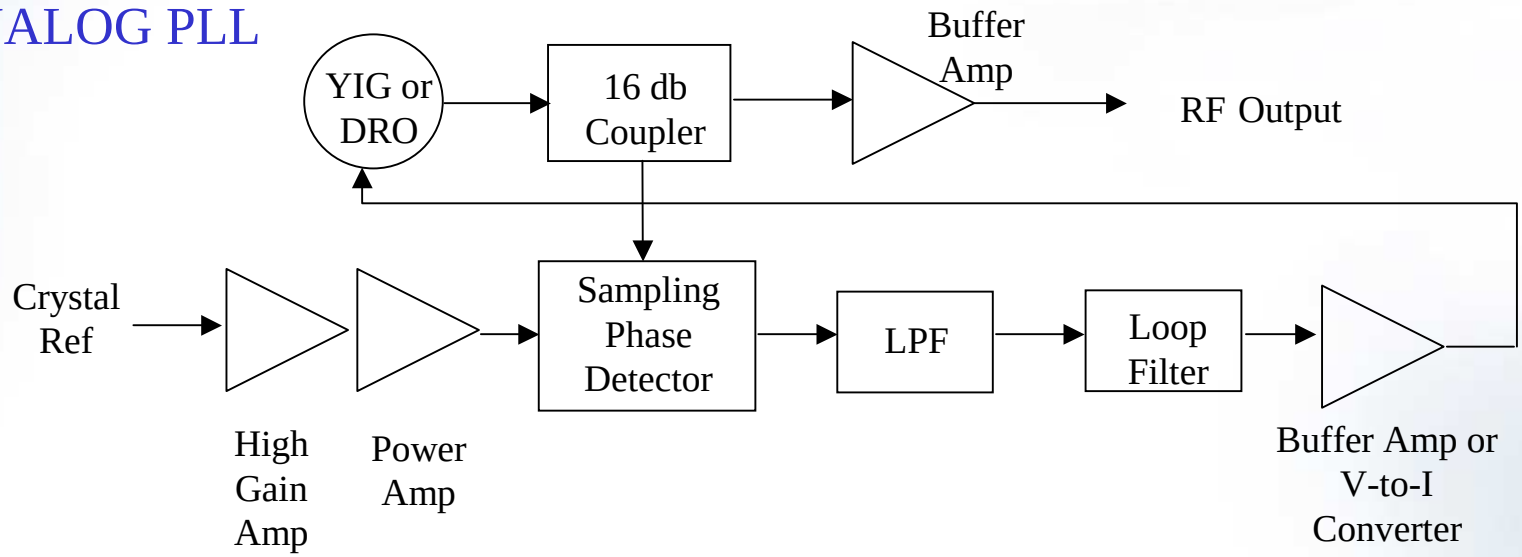
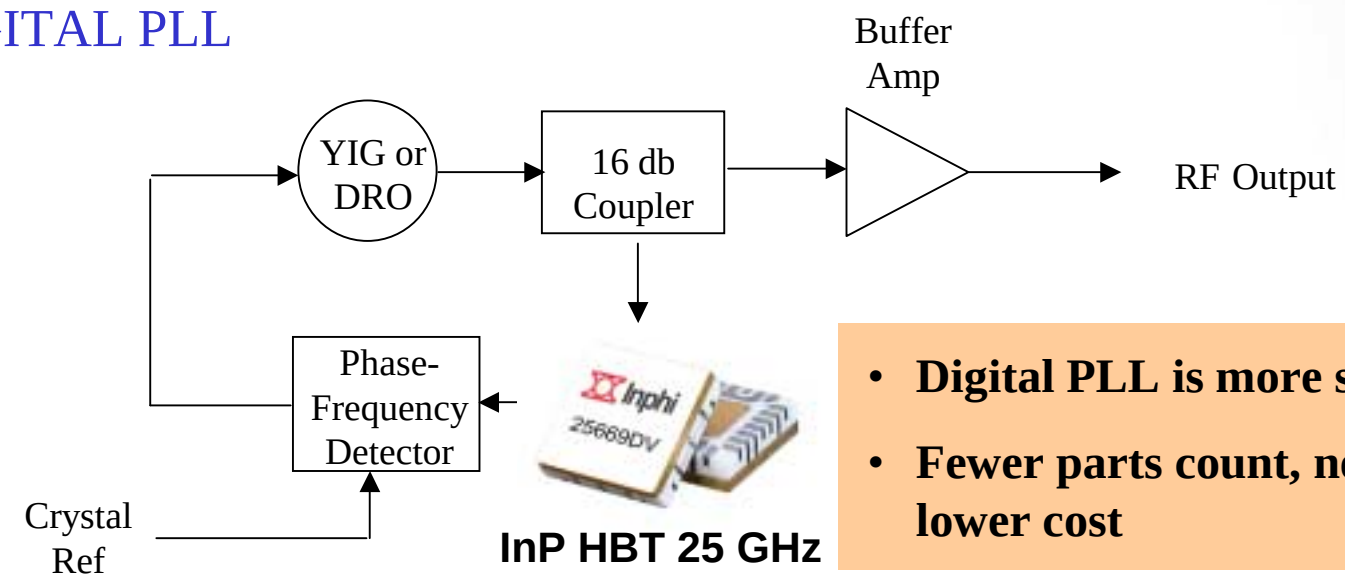
DC to 25 GHz Phase-Locked Oscillators

ANALOG PLL



DIGITAL PLL



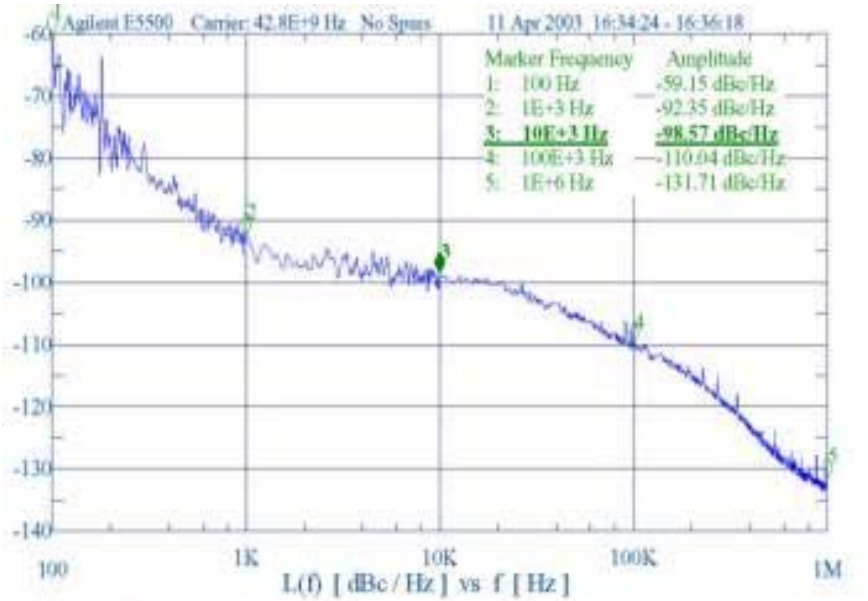
InP HBT 25 GHz Prescaler

- **Digital PLL is more stable over temp**
- **Fewer parts count, no manual tuning, lower cost**

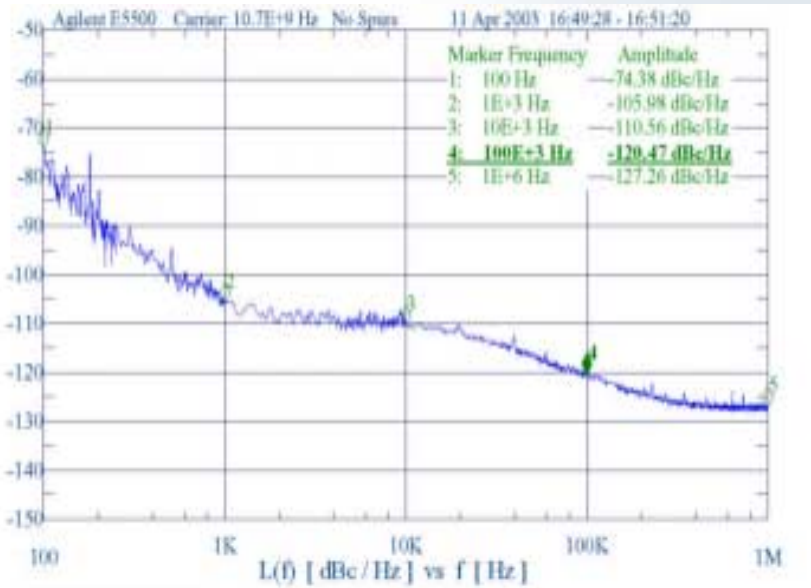
DC to 50 GHz Divide-by-4 Prescalers

- **High input sensitivity, -10dbm at 50 GHz**
- **Low phase noise, -120 dbc/Hz @ 100KHz offset at Fin = 40 GHz**
- **700 mW dc power consumption**

RF Input at 42.8 GHz (from DRO)



RF Output at 10.7 GHz



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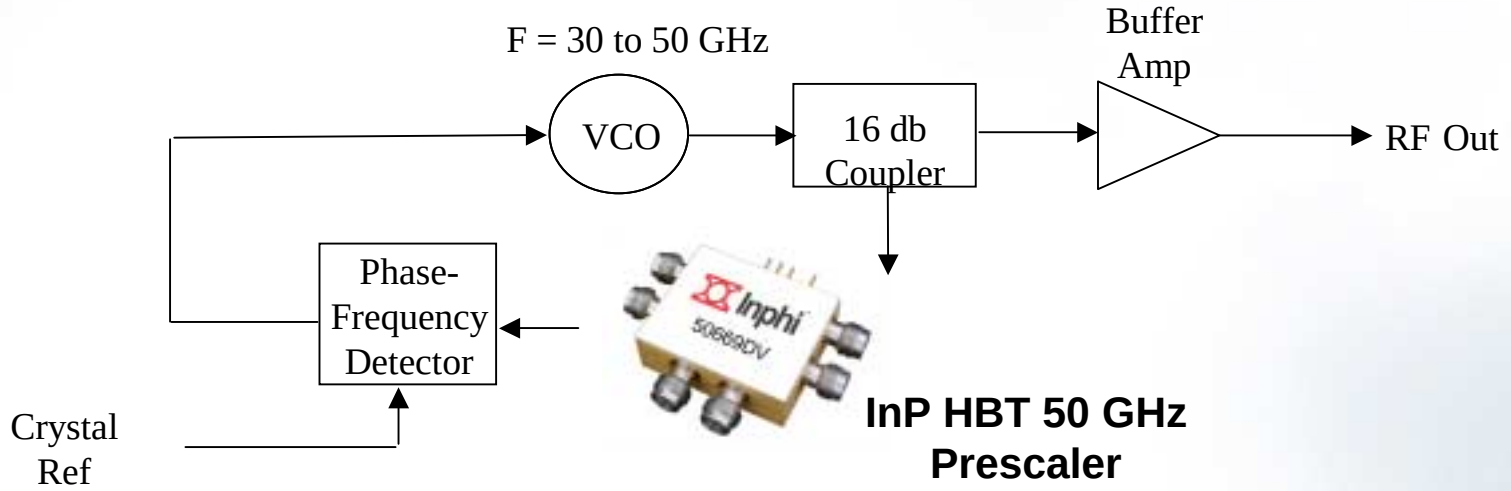
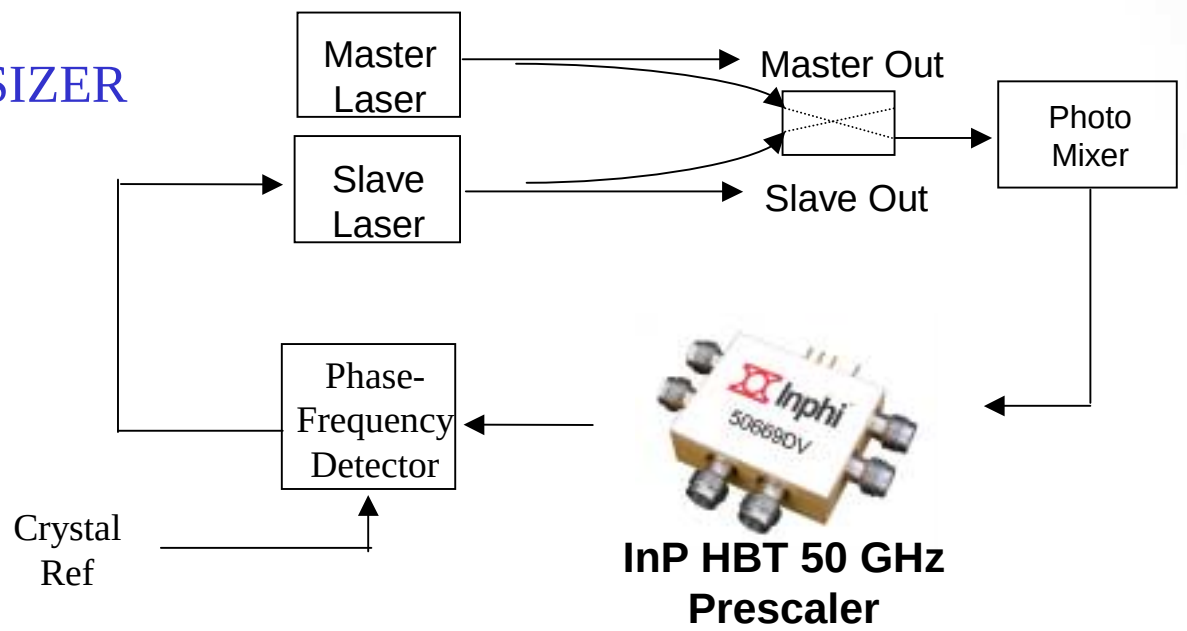
Ka/Q-Band Phase Locked Loop

Ka-Band RADAR



LASER SYNTHESIZER



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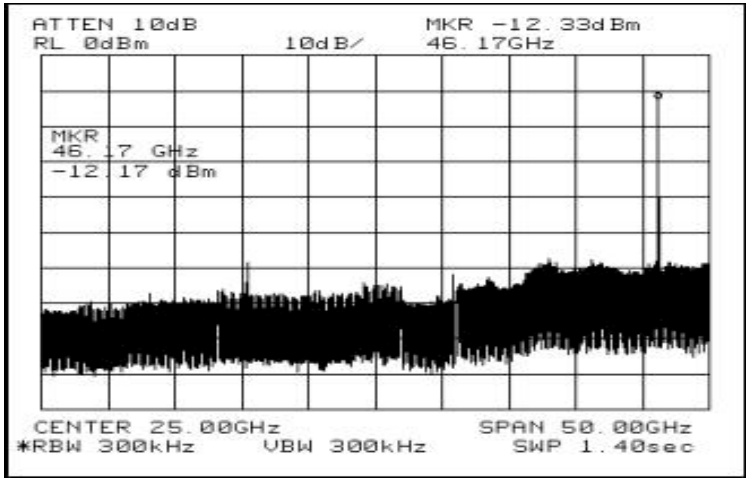
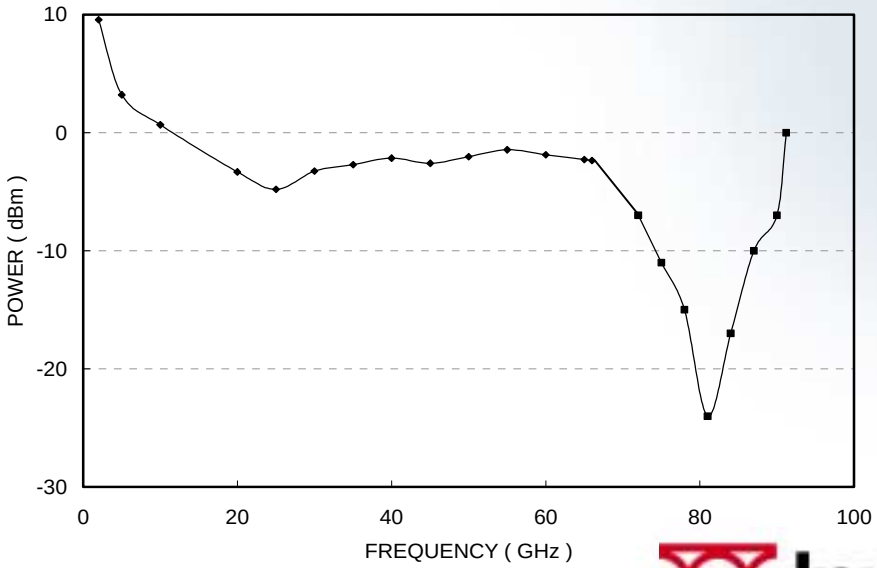
DC–92 GHz Divide-by-2 Prescaler

- **InP HBT technology with 150 GHz f_T**
- **Static divider operates from dc to 92 GHz**
  - 0 dbm input power, 650 mW dc power
- **Dynamic divider operates from 75 to 110 GHz**
  - 3 dbm input power, 700 mW dc power
- **100 GHz divider is in development**

RF Output at 46 GHz



Minimum Input Power Sensitivity



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77K Operations

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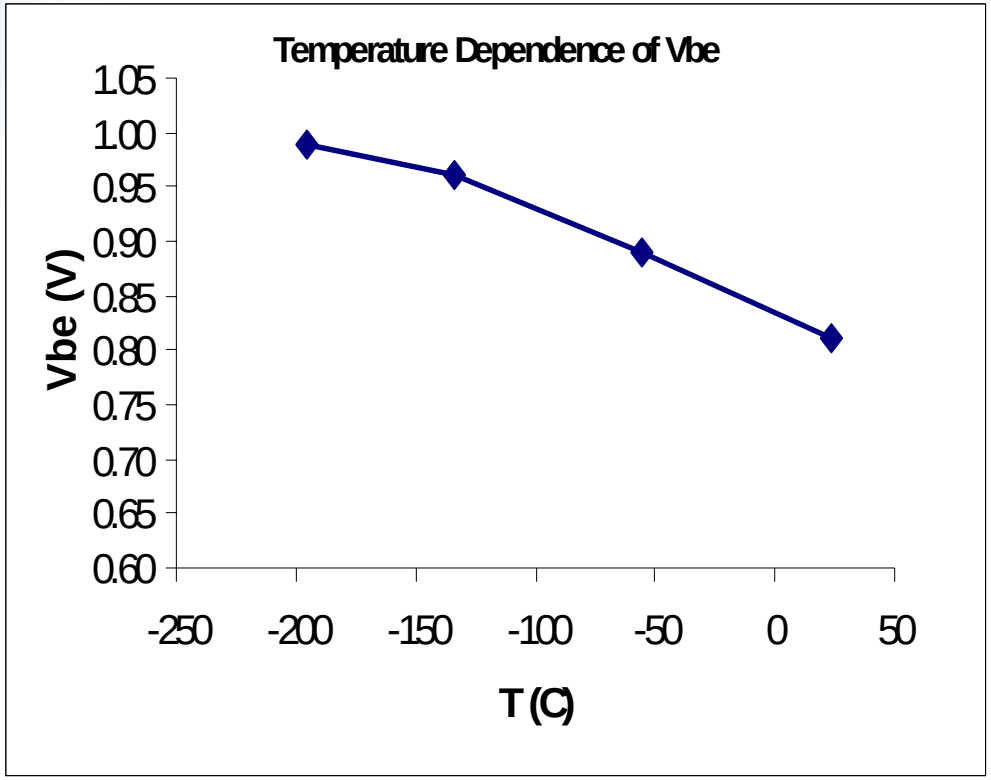
V_{be} Shift as Function of T



- **Turn on voltage shifts by 0.2 V from RT to –200°C**
- **No carrier "freeze out"**

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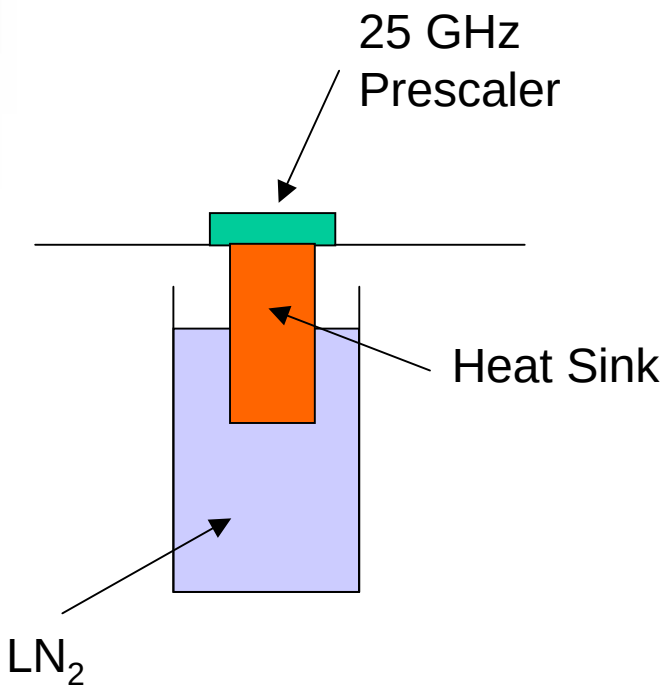
77K Prescaler Test Setup



- **Part mounted on FR-4 board and heat sink**
- **Heat sink was lowered into LN_2 with DC/RF on**
- **RF output was monitored with spectrum analyzer**
- **Data was taken when temperature was stable around –160^{0}C (113K)**

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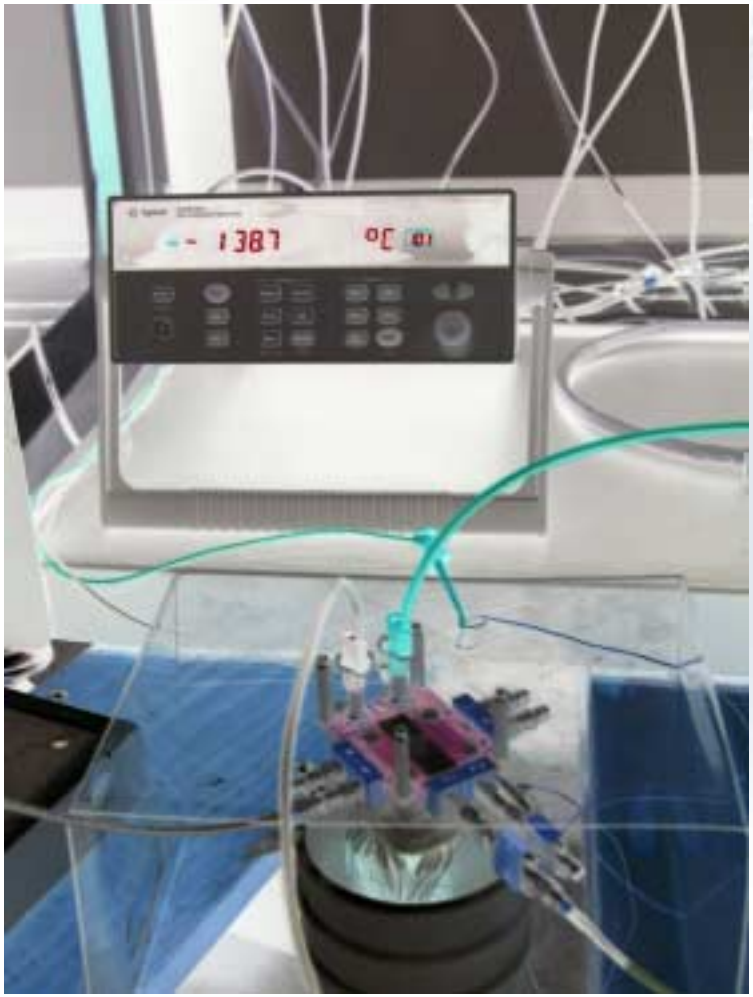
77K Prescaler Test Setup



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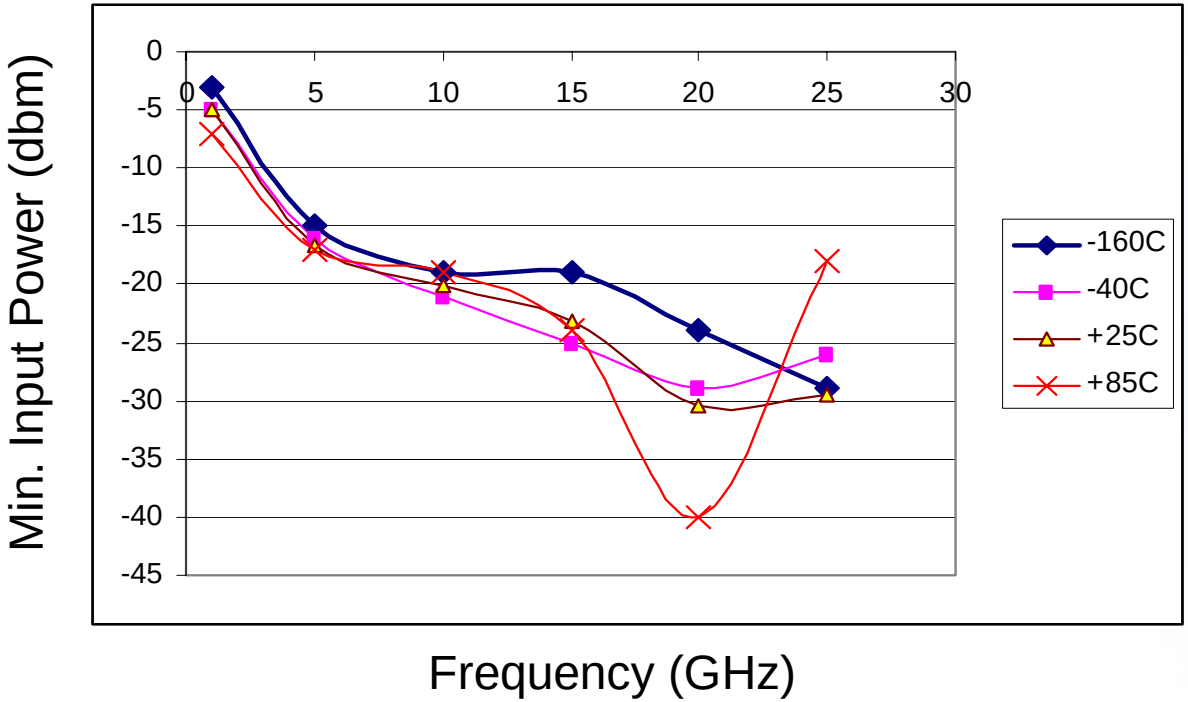
Minimum Input Power vs. Temp



- **Prescaler operated normally from dc to 25 GHz over a wide temperature range from –160°C (113K) to 85°C**

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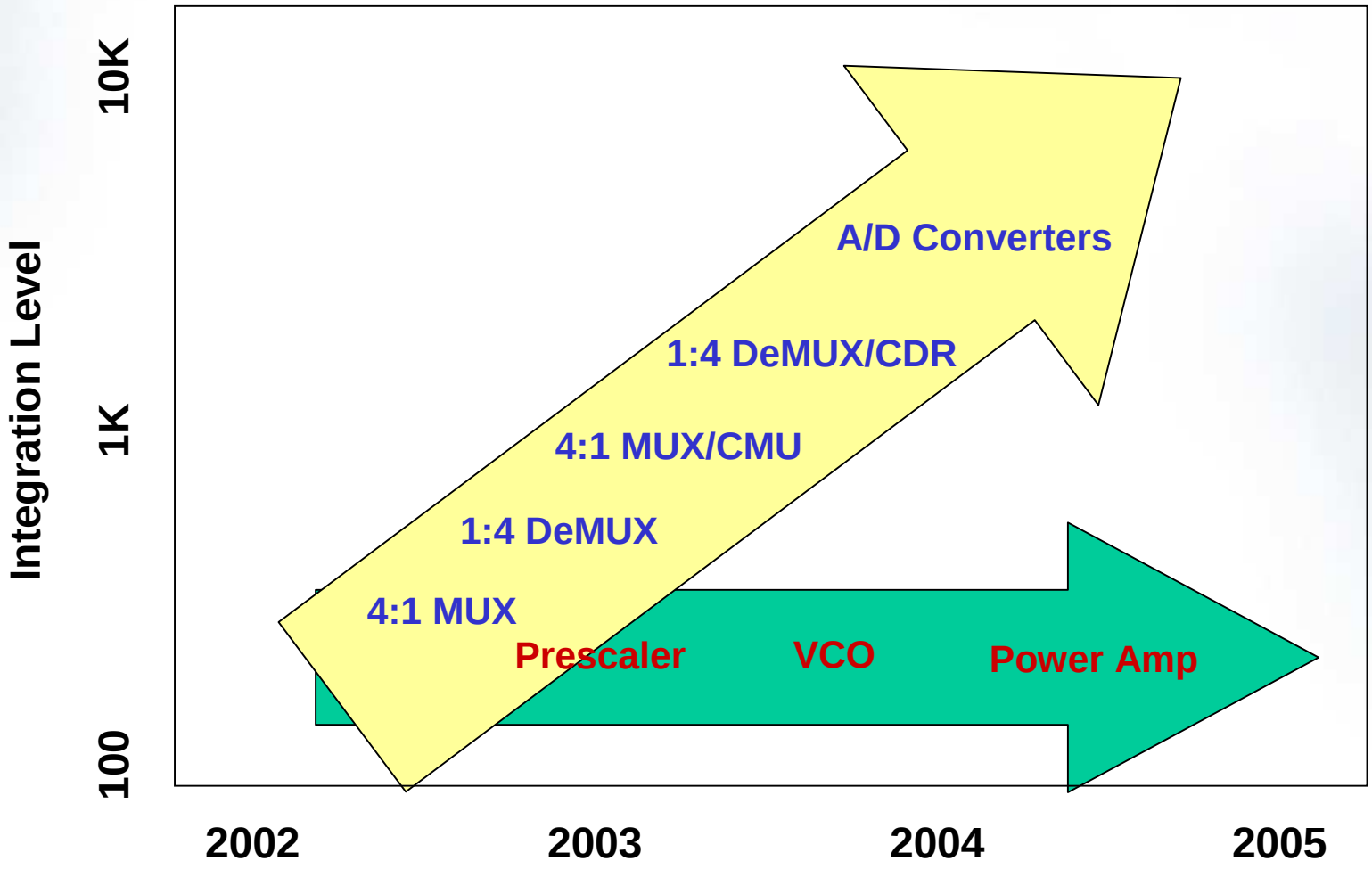
InP HBT Product Roadmap



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Summary

- InP HBT technology enables the development of digital and mixed-signal ICs up to 100 GHz
- Integration level is about 3K HBTs today going to >10K HBTs in a few years
- Technology is well suited for extremely cold temperature environment

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