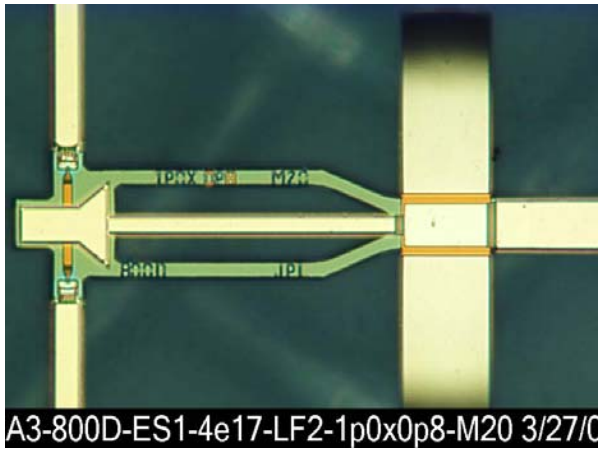
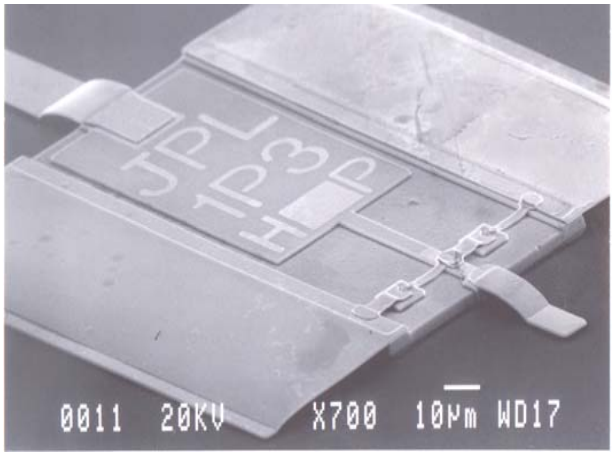
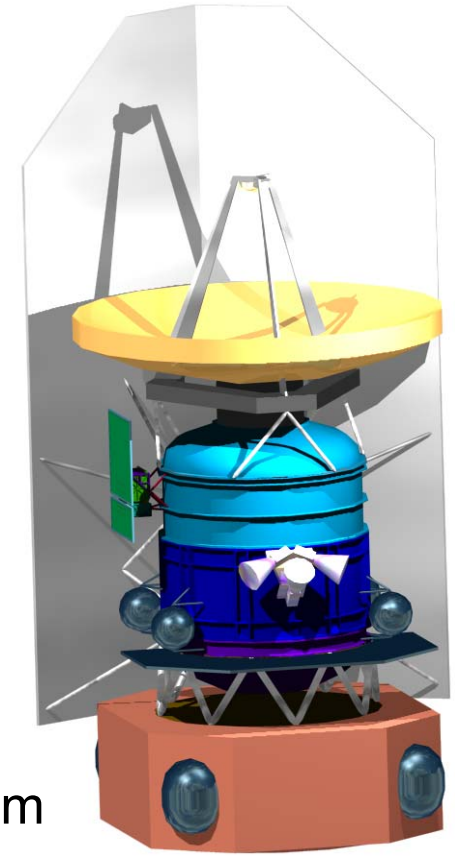
Terahertz Schottky Multiplier Sources







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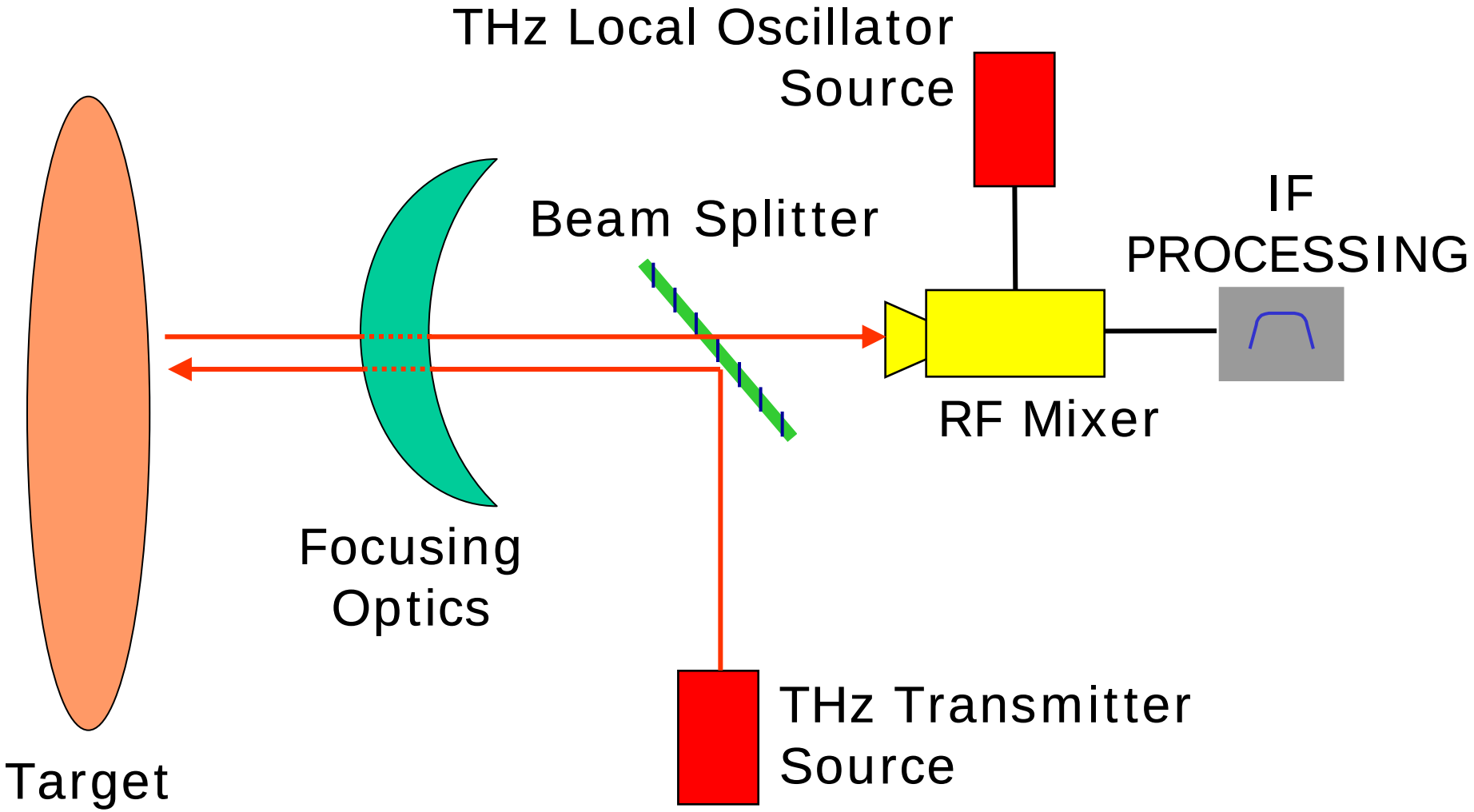
Outline

- Introduction, applications, requirements
- Multiplier source technologies
- Status/Performance of THz multiplier sources
- Challenges
- Roadmap
- Concluding remarks

One THz Application: Imaging Radar



Terahertz Sources

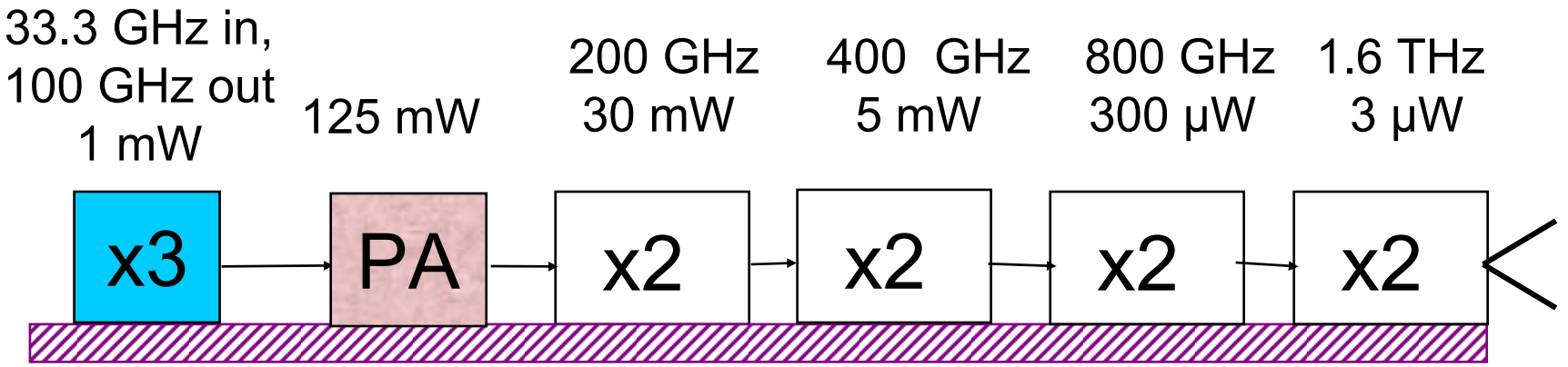
Requirements

- Figures of merit
  - Frequency – Terahertz for high resolution
  - Bandwidth – at least 15 GHz for high range resolution
  - Efficiency – minimize power supply requirements
- Output power:
  - Milliwatts below 800 GHz
  - 10s of microwatts above 1 THz,
  - 1-2 microwatts near 2 THz
- Mechanical--stability, compact, low mass
- Environmental--radiation, vibration, thermal

Sources for 0.3 — 2 THz

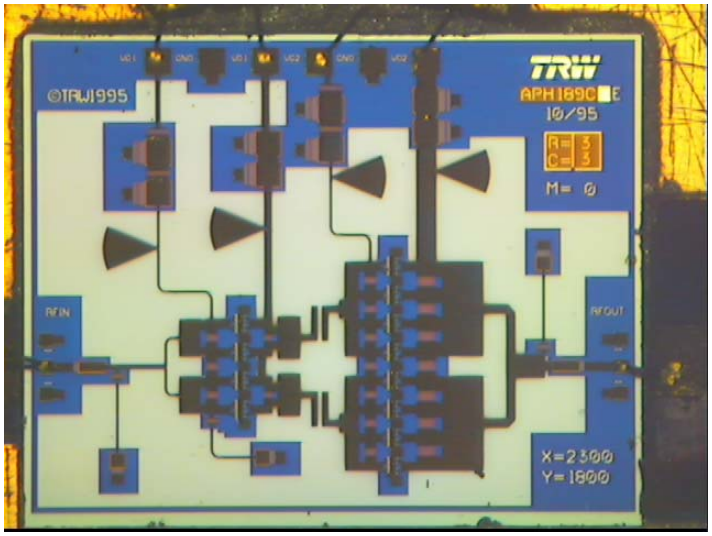
- FIR lasers: narrowband, large, expensive, and power hungry
- QCL: narrowband, low temperature (<80 K)
- BWOs: wide band, but: large, inefficient, heavy, fragile
- Multiplier sources: compact, wideband

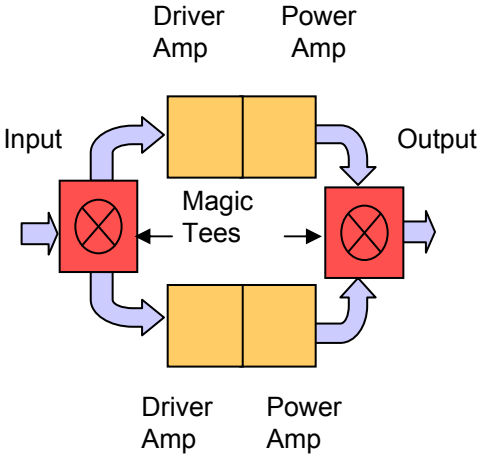
Multiplier Chain Source for 1.6 THz



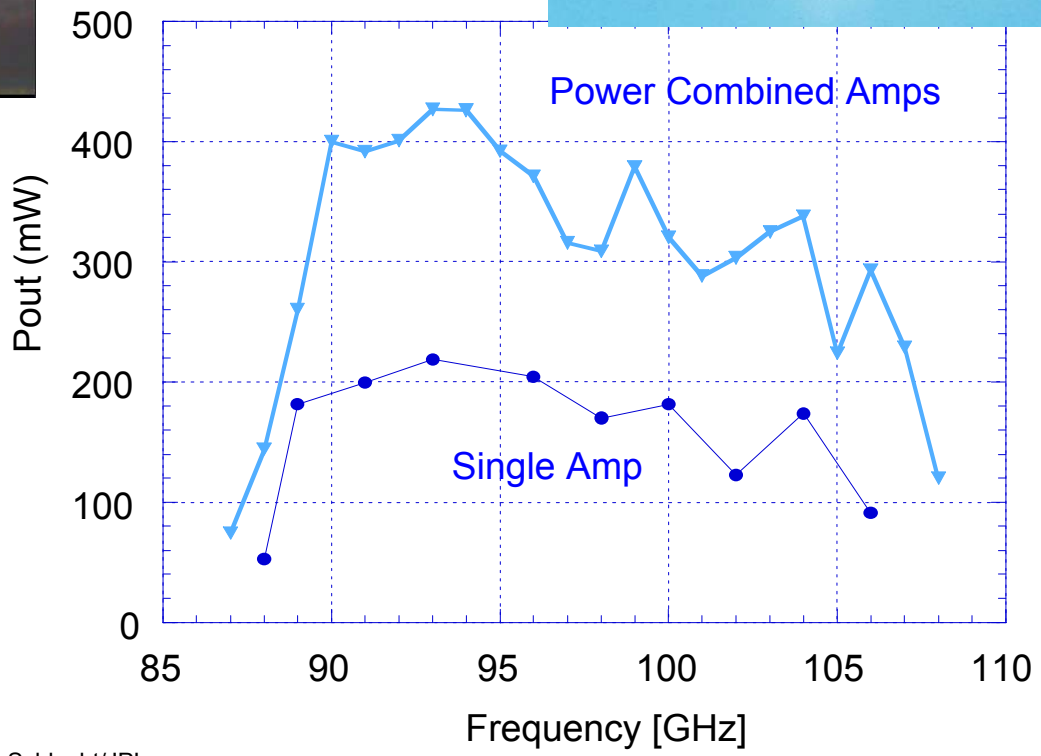
- Fundamental oscillator multiplied up to 100 GHz
- Power amplifier produces 100 to 230 mW
- Frequency multiplier chain
  - Planar GaAs Schottky diodes
  - Multi-diode, balanced configurations
  - Monolithic devices in low-loss waveguide circuits
  - No mechanical tuners
  - Fixed-tuned bandwidth ~ 8-15%

MMIC PA Chip/Modules



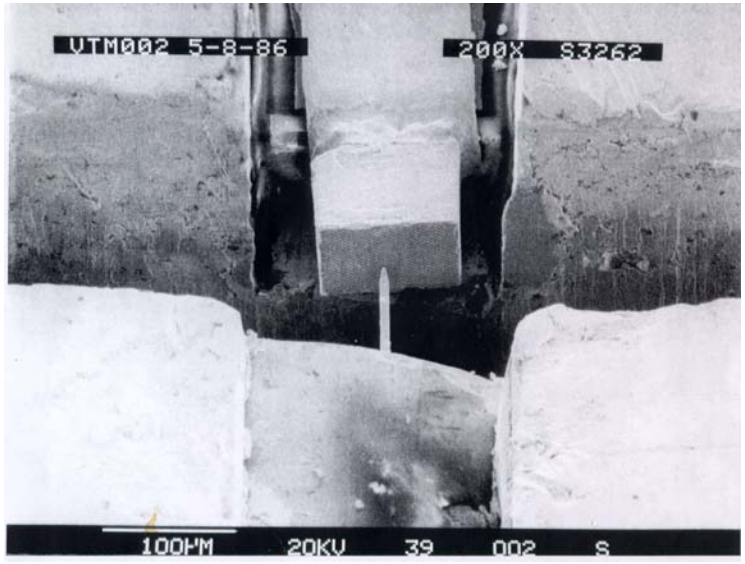


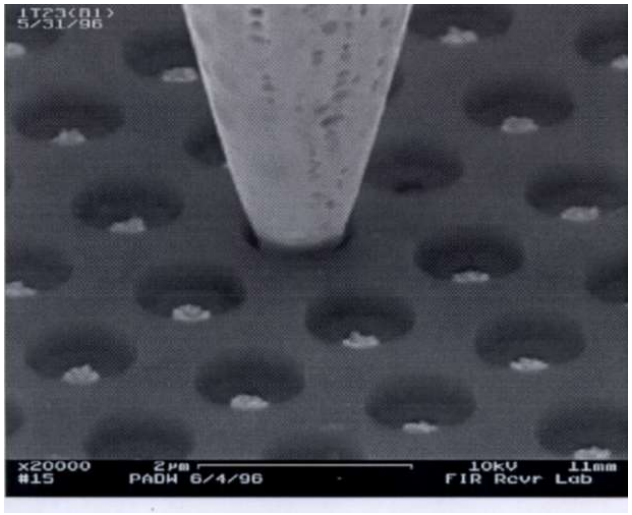
- 0.1 um PHEMT process
- 50 um thick substrate
- f_t = 200 GHz
- 64 finger device cell (output)
- on-chip bias network
- 50 ohm matching in/out
- 2.3 mm x 1.8 mm



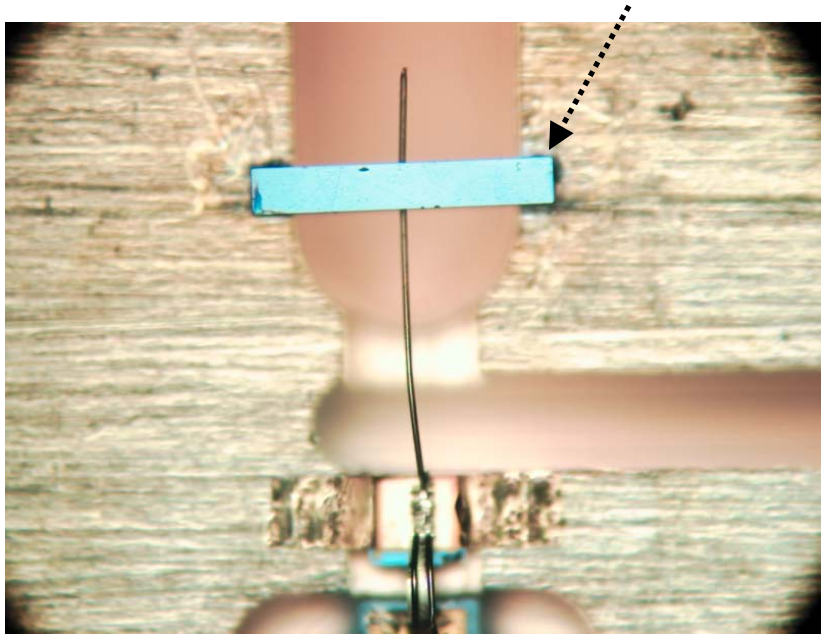
Prior Multiplier Devices

Whisker contact diode





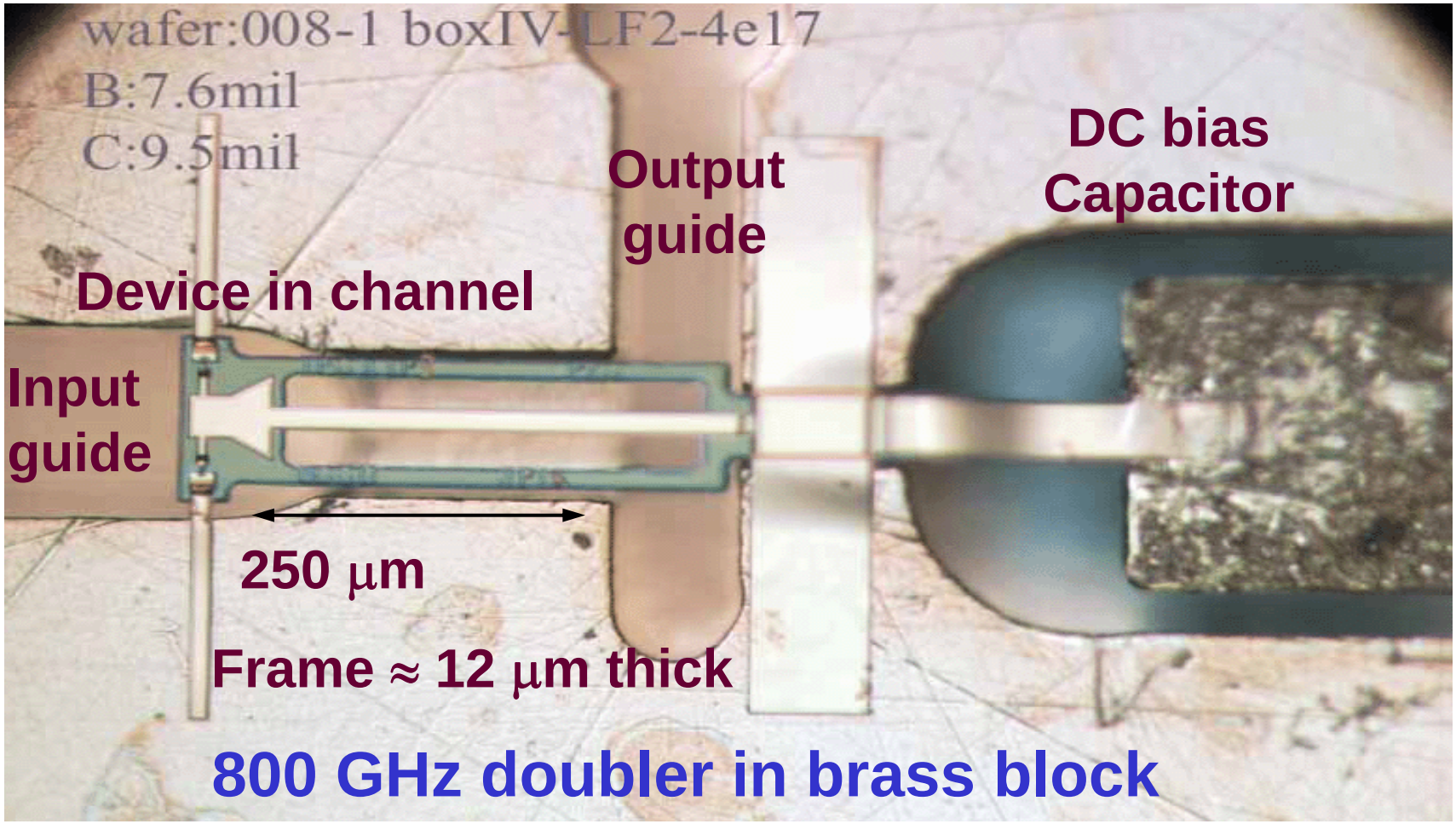
6-anode 170 GHz chip



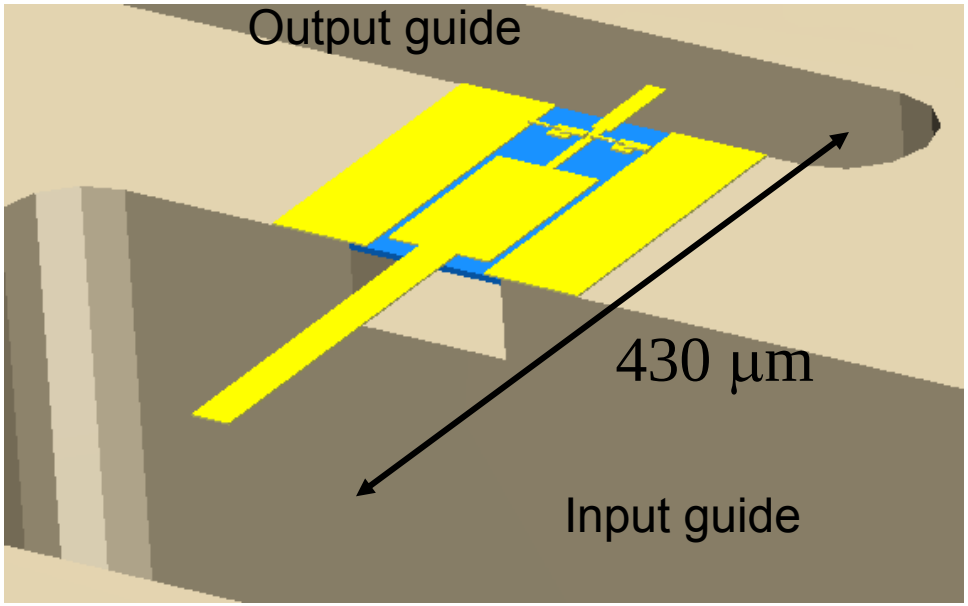
Performance at room temperature
(Erickson, STT 2000)
- Able to handle 220 mW of input power
- > 30% efficiency, 65 mW at 150 GHz

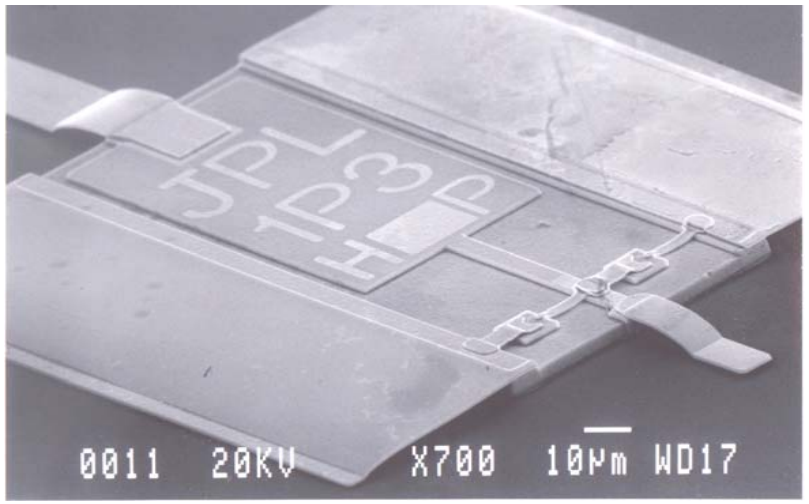
Current SoA: Substrateless Technology

200 to 800 GHz multipliers demonstrated



Current SoA: Devices beyond 1 THz



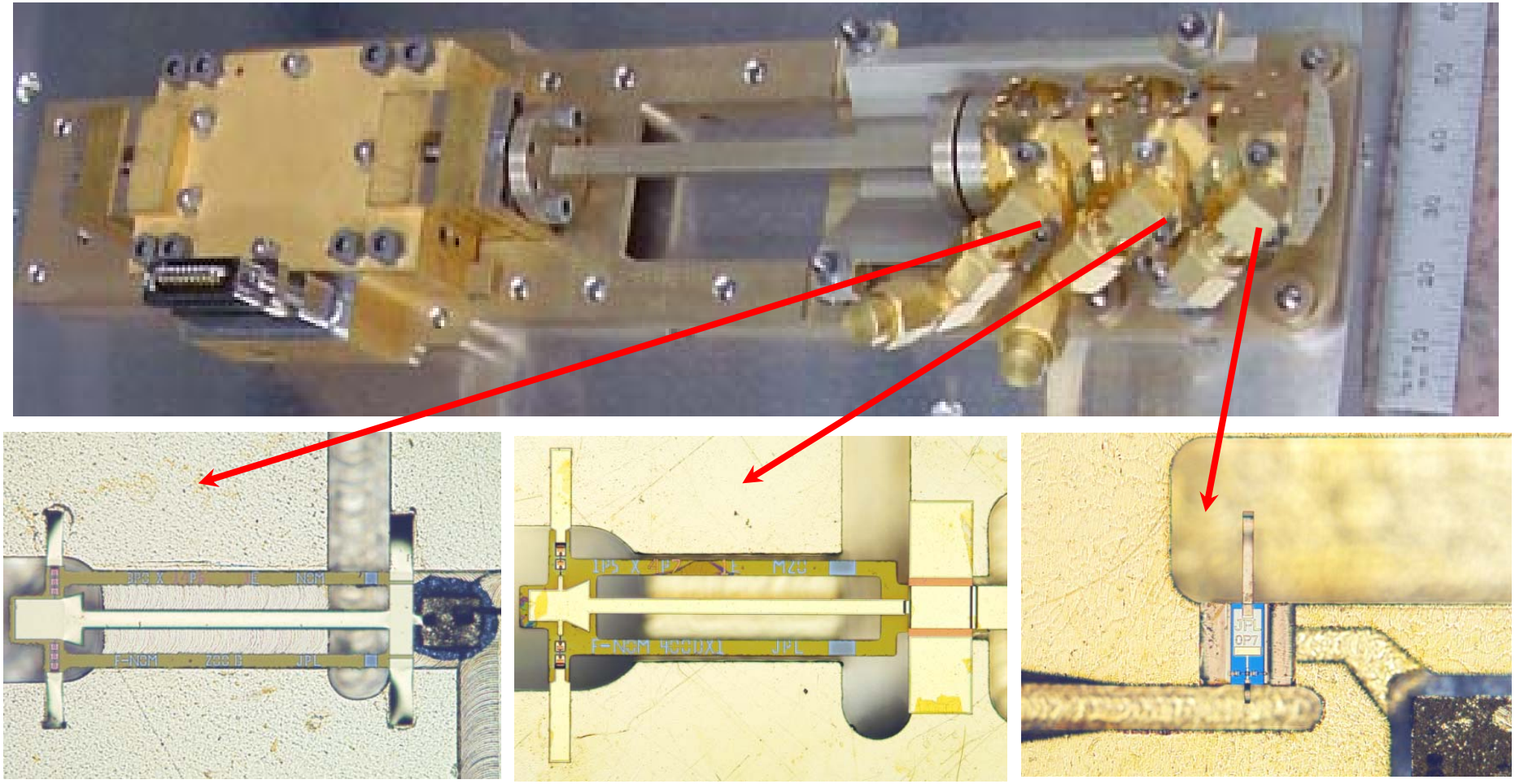


1200 GHz tripler chip

- Membrane is a few microns thick
- Extensive use of beam-leads
- Extremely simplified assembly

Demonstrated up to 2.7 THz!

x2x2x3 Frequency Chain

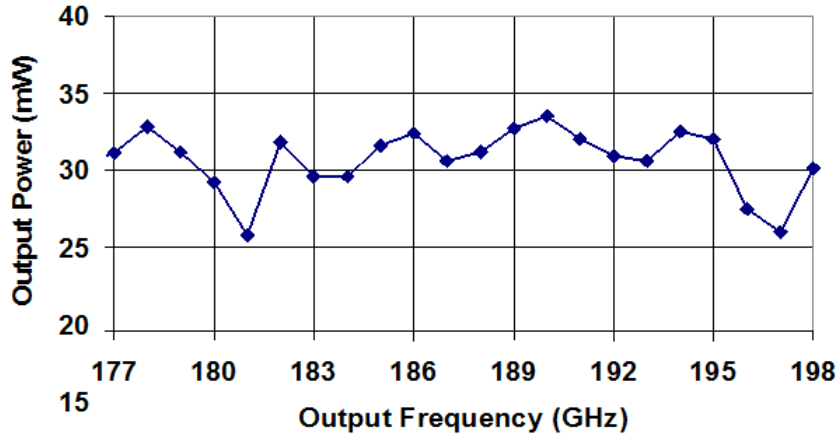


Circuits have 3-50um thick GaAs. Beam leads provide ground and thermal contact.

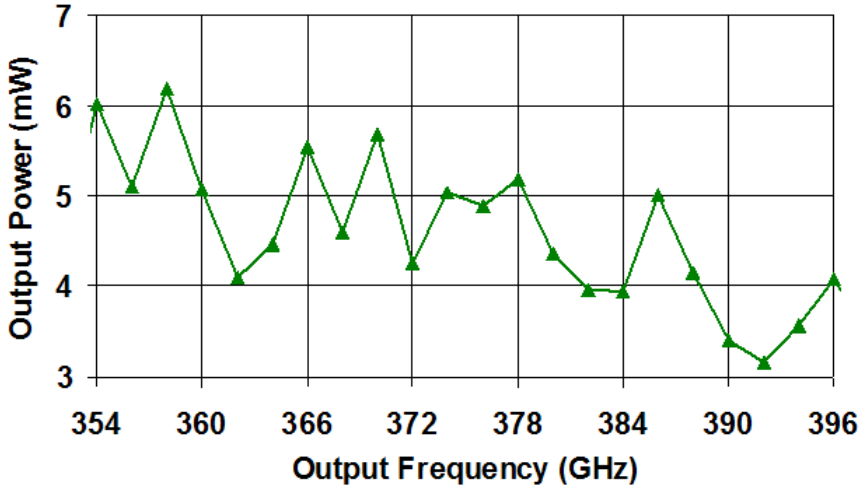
Reliability of these planar GaAs Schottky circuits is critical for mission success

PERFORMANCE

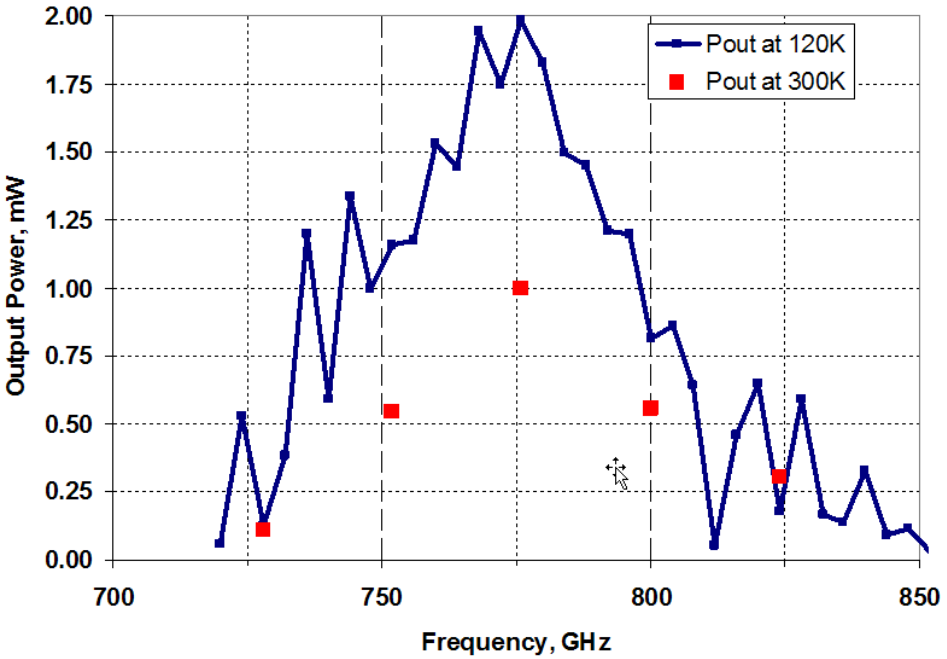
190 GHz Doubler (6 anodes)



375 GHz Doubler (4 anodes)

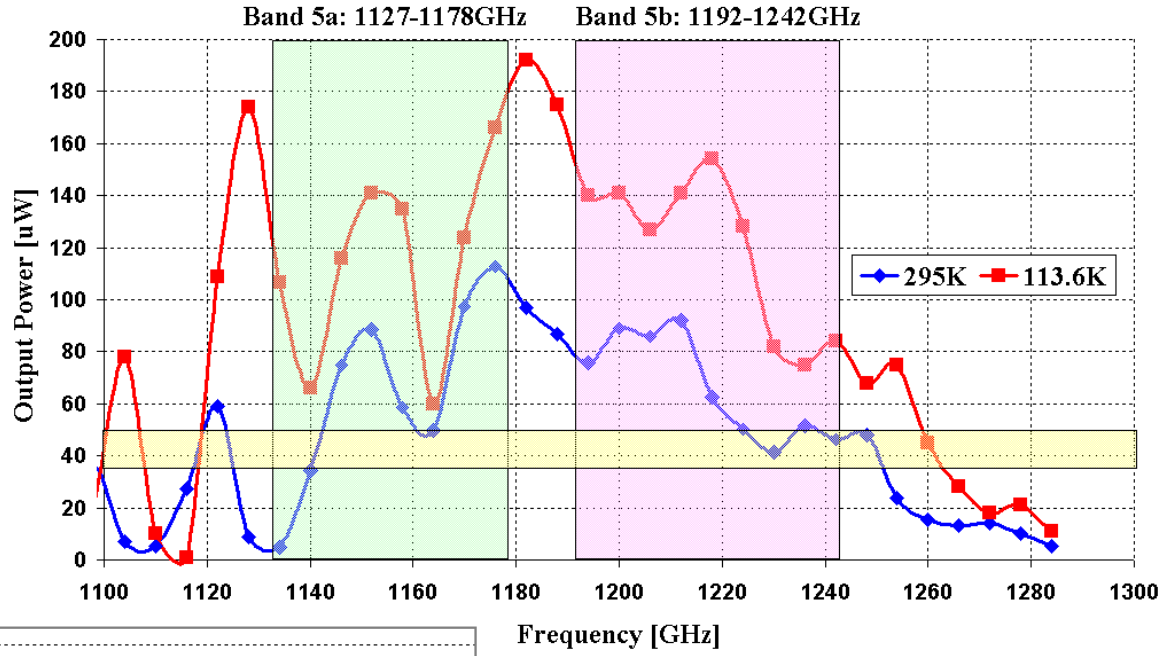


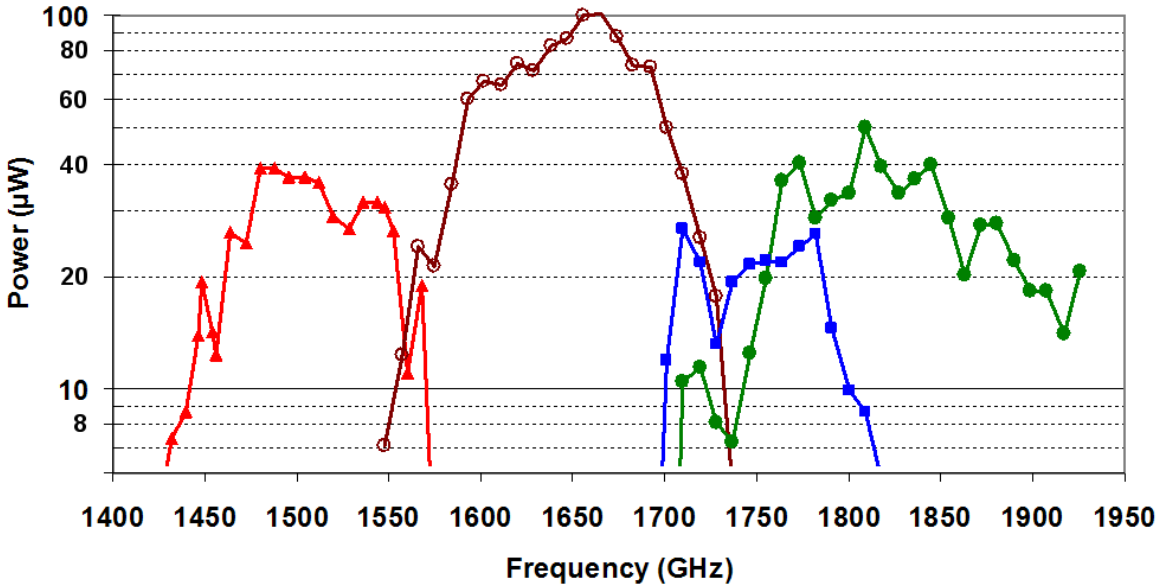
780 GHz Doubler (2 anodes)



Broad Band Chains above 1 THz

1.12 – 1.26 THz

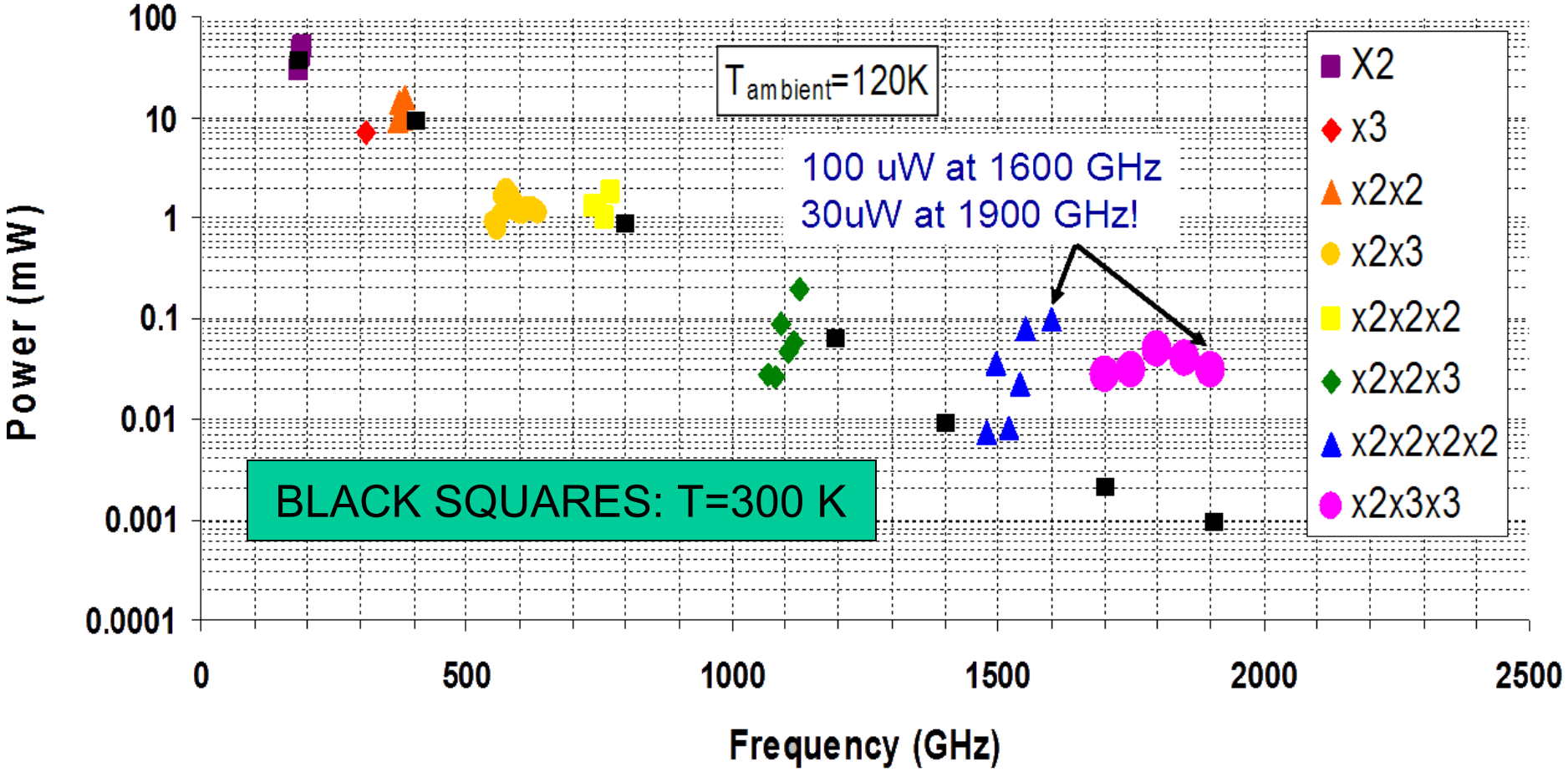




Chains for 1.5 – 1.9 THz

Schottky Multipliers State of the Art

Output Power, JPL Multiplier Chains



Recently developed enabling techniques

- Planar Schottky diode proceses
- W-band MMIC power amplifiers
- Advanced modeling of electromagnetic circuit structures and Schottky diodes
- High-precision, computer-controled machining of waveguide blocks

Options for Future Development

- More efficient higher freq power amps? InP, pHEMT
- Improve bandwidth— better designs, re-configurable
- Simplify chain construction— micro-machined blocks, increased integration
- Planar device/modeling— increase yield, increase throughput and uniformity, reduce time to completion
- Power combining— increase output power by adding mulitiplier outputs together
- Higher doping/smaller anodes— increase efficiency at high frequencies

Technology Roadmap I

Category	Current	Mid-Term	Far-Term
Source/device: technology & type	Schottky diode/ Multiplier chain	same	same
Peak & Average Power (W)	40 mW @ 200 GHz 2 uW @ 2000 GHz	X 4	X 10 or more?
Duty: Pulse duration (sec); repetition rate (Hz)	N/A	N/A	N/A
Frequency Tuning Range (GHz)	200 – 2000	– 2500	same
Bandwidth (GHz)	15 % @ 200 GHz 10 % @ 2000 GHz	20 %	same
Efficiency (%)	0.1% @ 200 GHz 1e-6% @ 2000 GHz	X 5	??
Size/wt (device/source*) * Including power supply and other ancillary equipment	10-40 cm^3/1600 cm^3 60-250 gm/5 kg	100 cm^3 1 kg	same

Technology Roadmap II

Category	Current	Mid-Term	Far-Term
Packaging/environmental: laboratory, commercial/industrial, or military	Spaceflight qualified	same	same
Specialized supporting equipment	DC power	same	same
Supplier content for critical components/equipment: in-house, commercial; foreign, domestic	In-house for diodes, com-mercial for PA	Commercial, given enough market	same
Technology status: development/engineering/production	ALL THREE	ALL THREE	ALL THREE
Other distinguishing features:	Same technology widely tunable and usable over wide frequency range.		

Concluding Remarks

- Multiplier chains (200 to 1200 GHz) are now possible that are
  - Robust, flight qualified
  - Broadband (10 to 15 %)
  - Cool-able
- Chains covering 0.2 to 1.9 THz were developed
- Produced 24 μW continuous power (cooled) at 1.78 THz
- Frequency range of 2-3 THz is attainable
- Wider bandwidths (>10%) are attainable
- Higher output power is possible with power combining techniques