TU4E-02

Towards Terahertz MMIC Amplifiers: Present Status and Trends

Lorene Samoska

Jet Propulsion Laboratory
4800 Oak Grove Drive
Pasadena, CA (USA) 91109

Outline

- Survey on fastest MMIC amplifiers to date
- Summarize previous solid state power amp results to date
- Example MMICs
- Power vs. Gate periphery, frequency
- Summarize previous LNA results to date
- Noise figure results
- Trends toward higher frequency

Motivation

- Provide an overview of the state-of-the-art in MMIC amplifiers
- Discuss highest power, highest frequency power amps
- Discuss highest frequency low noise amps
- Look at trends for the future of MMIC amplifiers.

Frequency Band Definitions

- W-Band: 75-110 GHz, also known as WR10 waveguide band
- D-Band: 90-140 GHz, also known as WR8 waveguide band
- G-Band: 140-220 GHz, also known as WR5 waveguide band
- WR3 Waveguide Band: 220-325 GHz

MMIC Design Above W-Band

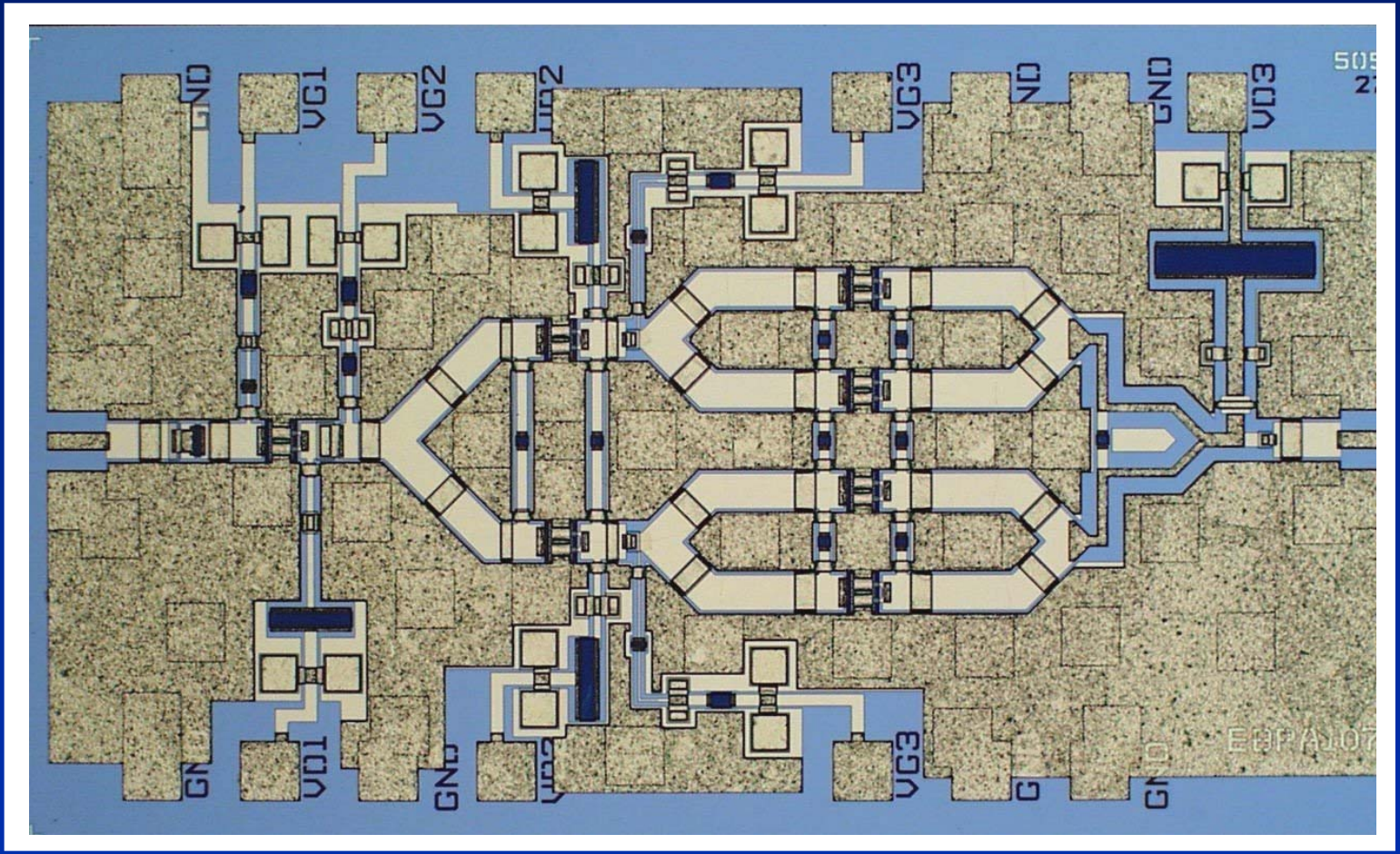
- Material: InP, gate lengths < 0.1μm (HEMT)
- Transmission lines will need to scale smaller, and also Tsub, vias, capacitors, and resistors.

	100 GHz	300 GHz
CPW Line (μm)	20 μm	20 μm
Electrical Length	6 degrees	19 degrees

1 μm ~ 1 degree of electrical length as the frequency approaches 300 GHz.

Power Amplifier MMICs

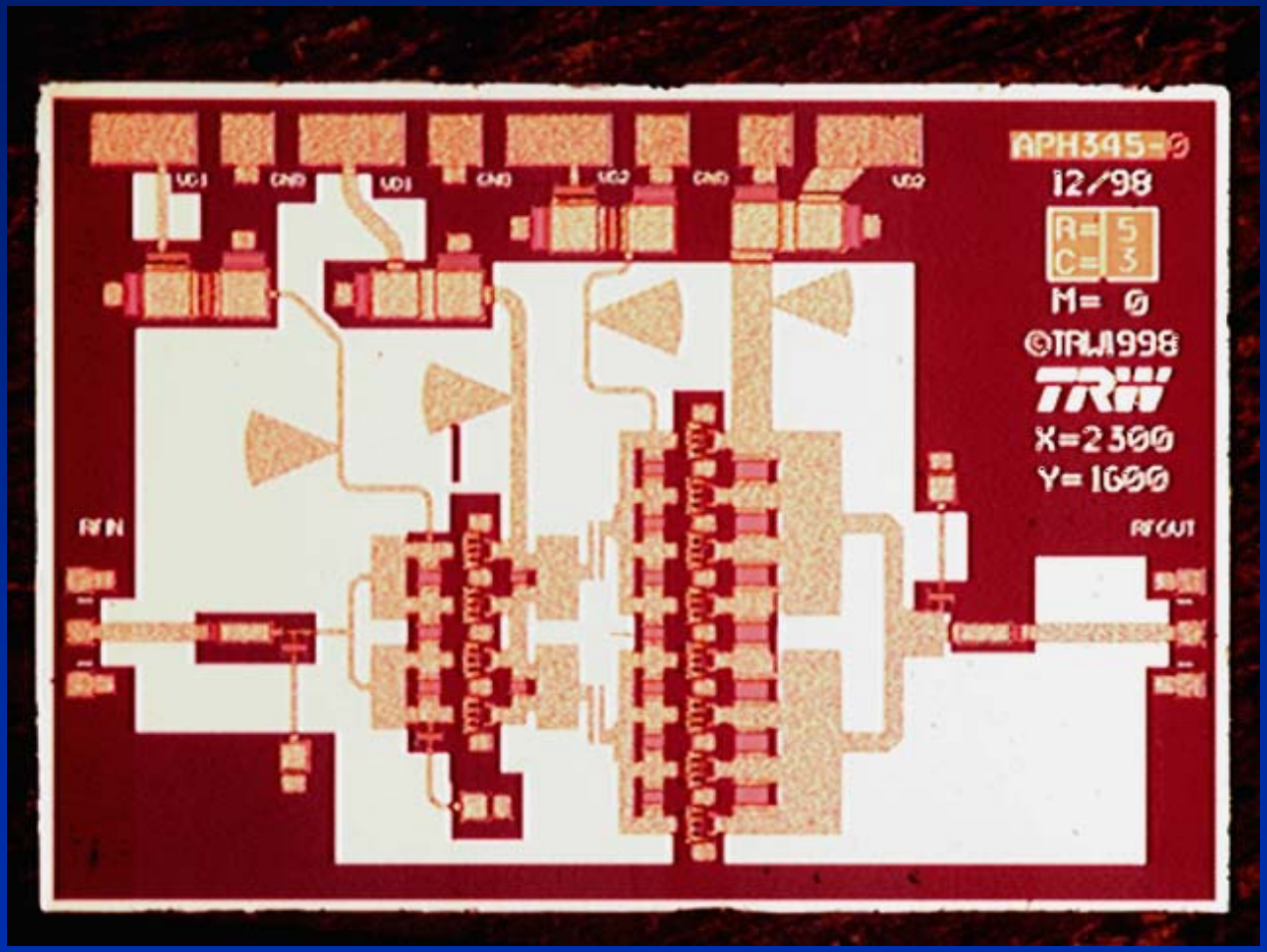
Examples: 4-way power combiner in CPWG



- 3-stages: 1-> 2 -> 4
- Output periphery 600 μm.

Reference: L. Samoska, E. Bryerton, IMS Digest, 2005

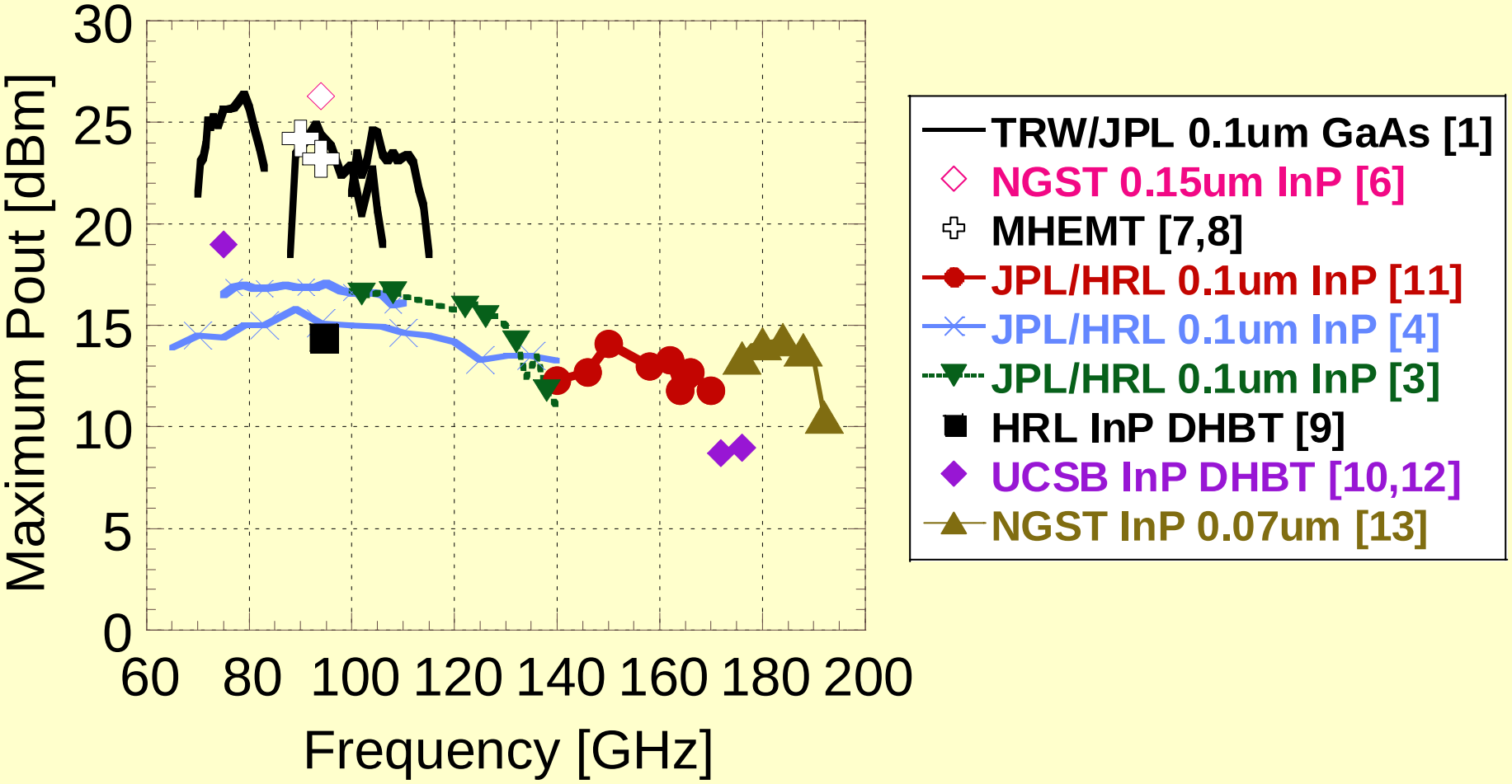
Example: 8-way power combiner in Microstrip



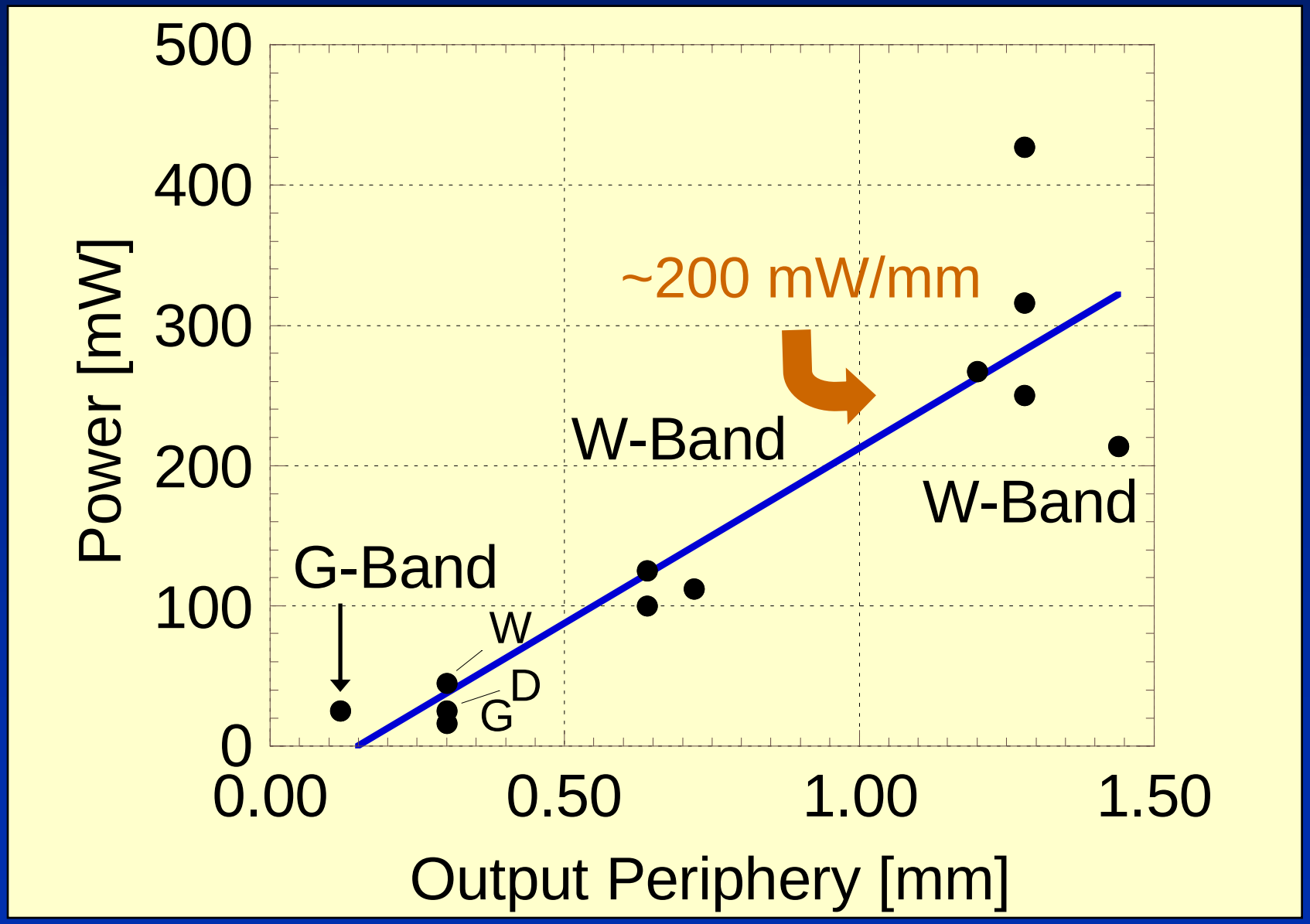
- 2-stages: 2 -> 4
- Output periphery 1.28 mm.

Reference: H. Wang, L. Samoska MTT Trans, Jan 2001.

Current State of the Art for MMIC PAs



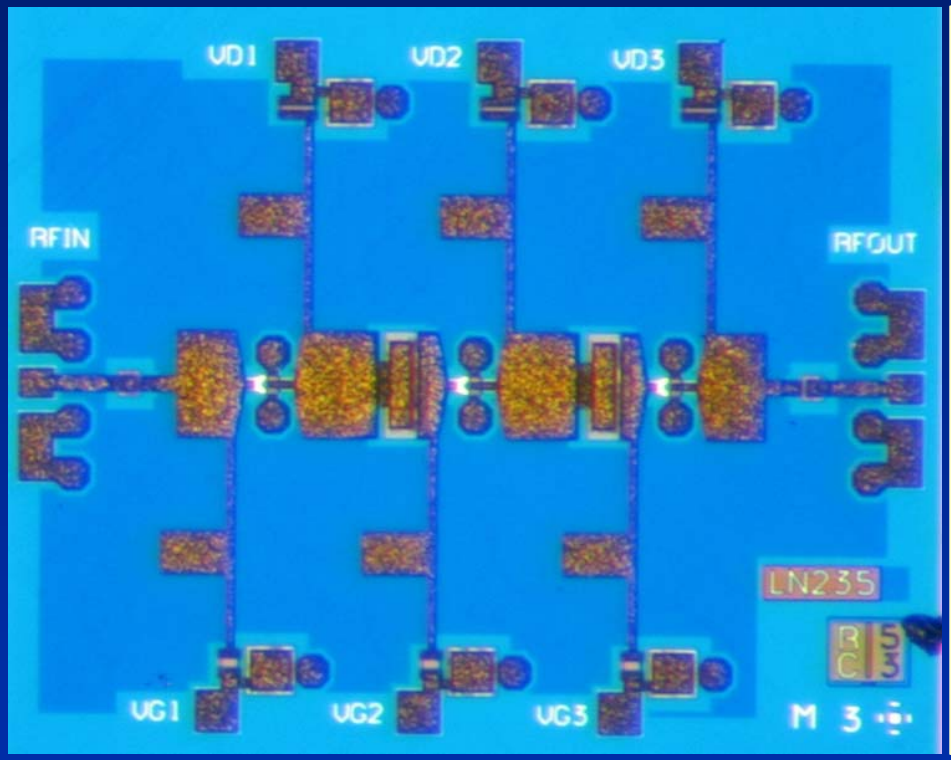
Power per Millimeter of Gate Width

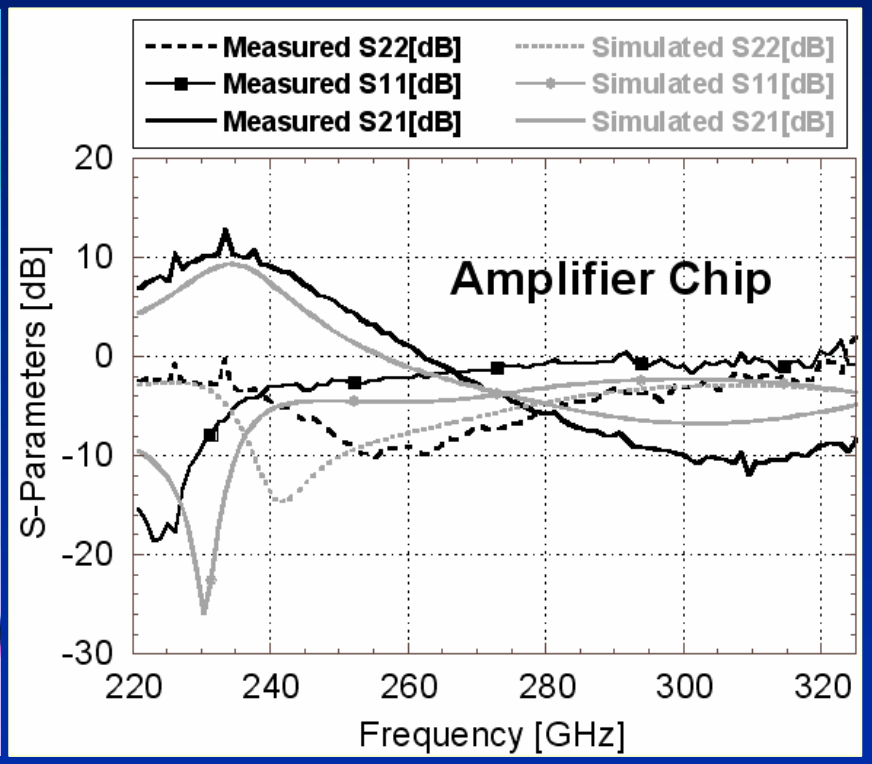


MMIC Low Noise Amplifiers

MMIC Low Noise Amplifiers

How high can they go?

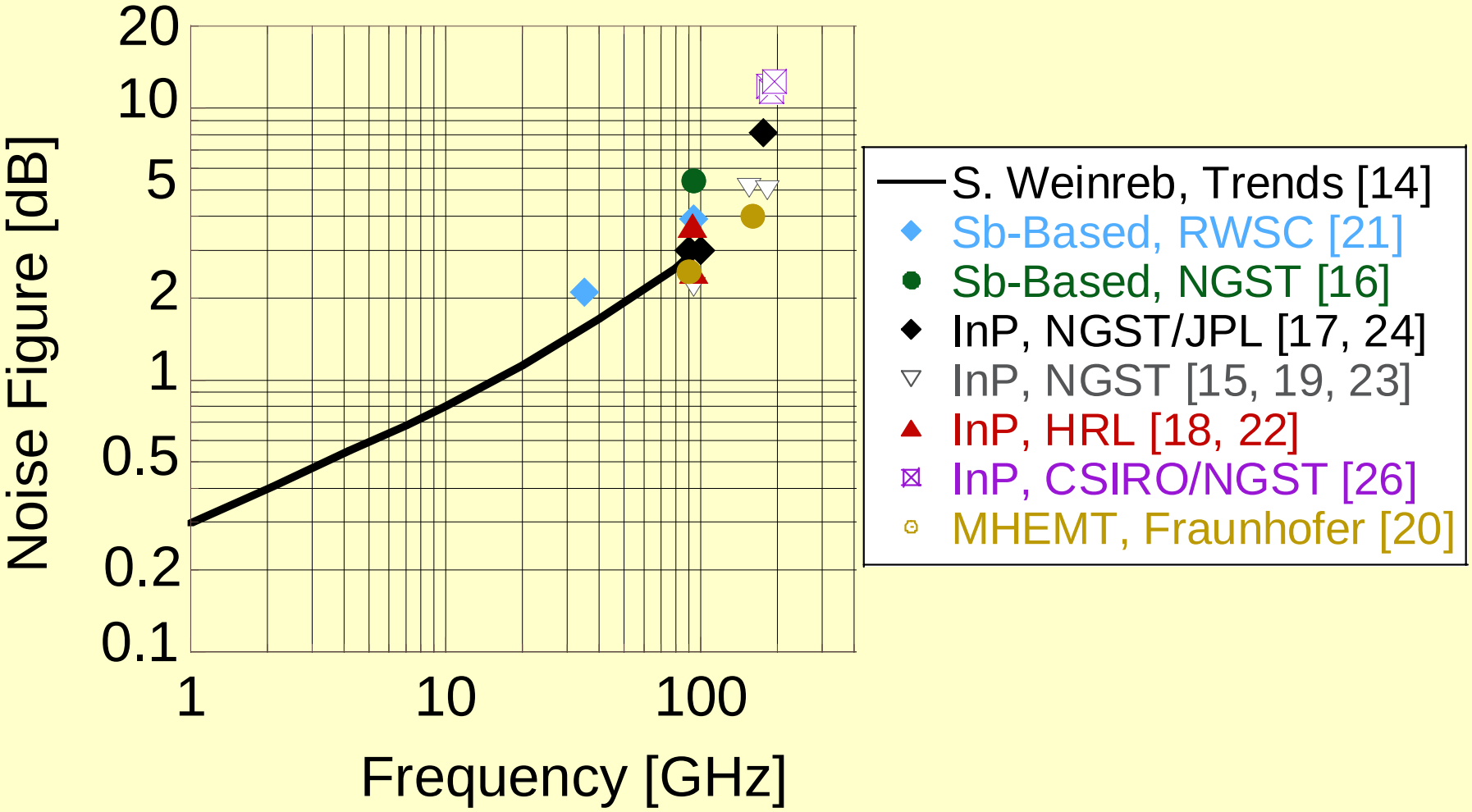




Reference: D. Dawson, L. Samoska, IEEE MWCL Dec., 2005.

For more info, see Thursday's Interactive Forum Session, A. Fung

MMIC Low Noise Amplifiers

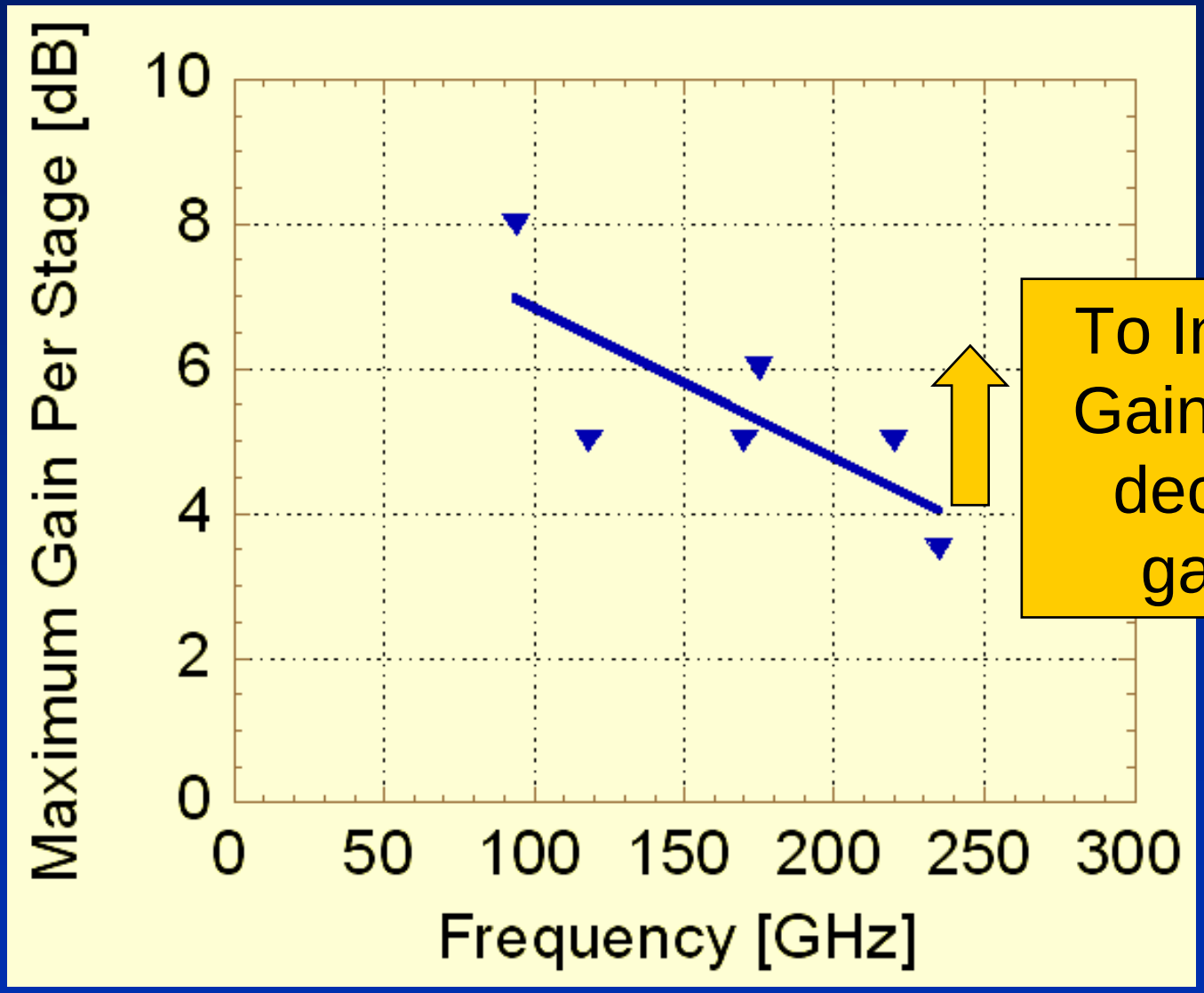


MMIC Low Noise Amplifiers

TABLE I: SUMMARY OF LNA MMIC AMPLIFIER DATA

	Frequency [GHz]	Technology	LNA Description	Noise Figure	Gain	Gain per Stage
W	77-105	0.1μm InP, 1999	4 stage (NGST/JPL)	3.0 dB	20 dB	5 dB
	67-100	0.1μm InP, 2005	4 stage (HRL)	2.5 dB	26 dB	6.5 dB
	91-97	0.1μm InP 2000	1-stage (NGST)	2.2 dB	8 dB	8 dB
	70-105	InP MHEMT,2005	2 Cascode Stage (Fraunhofer)	2.5 dB	20 dB	5 dB
	94	Sb-based, 2005	5-stage (RWSC)	3.9 dB	20 dB	4 dB
	94	Sb-based, 2005	3-stage (NGST)	5.4 dB	11 dB	3.7 dB
	85-119	0.1μm InP, 2000	4-stage (HRL)	3.7 dB	20 dB	5 dB
G	155	0.1μm InP, 1997	3-stage (NGST)	5.1 dB	10 dB	3 dB
	150-215	0.1μm InP, 1999	6-stage (JPL/NGST)	8.1 dB	15-27 dB	3-4 dB
	150-205	0.1μm InP, 1999	8-stage (HRL/JPL)	N/A	17 dB	2 dB
	160-200	0.08μm InP, 2001	3-stage (NGST)	5.5 dB	15 dB	5 dB
	180-205	0.1μm InP, 2001	3-stage (CSIRO/NGST)	12 ± 4 dB	15 dB	4 dB
	150-215	0.07μm InP, 2005	3-stage (NGST)	N/A	12 dB	4 dB
	175	InP HBT, 2003	1-stage (UCSB)	N/A	6 dB	6 dB
WR3	220	InP MHEMT, 2004	4-stage (Fraunhofer)	N/A	20 dB	5 dB
	220	InP MHEMT, 2005	1 Cascode Stage (Fraunhofer)	N/A	10 dB	5 dB
	235	0.07μm InP, 2005	3 stage (JPL/NGST)	N/A	10 dB	3.5 dB

MMIC Low Noise Amplifiers



To Increase the Gain per Stage, decrease the gate length

Trends

- Shorter gate lengths will lead to 300 GHz MMICs
- Predicted gain is 6 dB per stage at 300 GHz, for gate length of 35 nm.
- Up to G-Band, 200 mW/mm output power is achievable.
- Beyond G-Band, 100mW/mm is more feasible.

Acknowledgments

- Drs. Sander Weinreb and Todd Gaier of JPL, and Dr. Richard Lai of NGST and Dr. David Chow of HRL Laboratories, LLC for supporting data.
- This research was carried out in part at the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration.