THz Electronics

Imran Mehdi & Peter Siegel

Collaborators: Jean Bruston, Robert Dengler, Michael Gaidis, Karen Lee, Tracy Lee, Robert Lin, Frank Maiwald, Suzanne Martin, Barbara Nakamura, John Oswald, Lorene Samoska, Erich Schlecht, Peter Smith, and Jim Velebir

Jet Propulsion Laboratory
California Institute of Technology

Presented at the 24th Intl. Conf. On Infrared and Millimeterwaves

Advanced Local Oscillator Development for Millimeter and Submillimeter-wave Applications

Acknowledgment

- The research described in this presentation was carried out at the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration.

JPL - Submillimeter-Wave Advanced Technology - I. Mehdi 8/13/1999

Outline

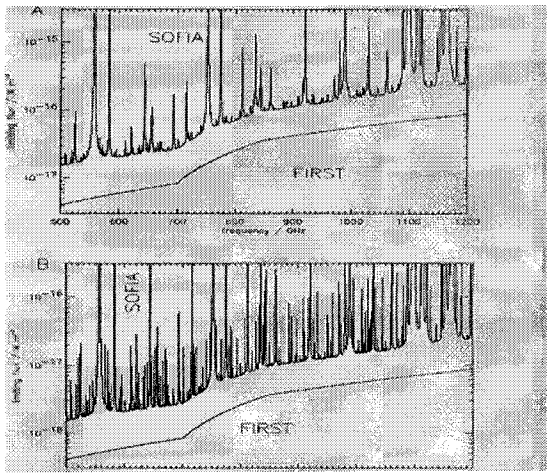
- Introduction-Mission objectives, technology roadmap
- W-band power amplifier status
- THz devices
- Balanced planar doublers
- The "new frontier"
- Conclusion

Advanced Local Oscillator Development for Millimeter and Submillimeter-wave Applications

Introduction-The FIRST mission

- Far Infrared and Submillimetre Telescope (FIRST) is a European cornerstone mission whose objective is to study the formation and evolution of galaxies in the early universe and stellar formation
- Heterodyne instrument has 7 channels (625-157 micron coverage) with state-of-the-art detection capability(SIS and HEB mixers)
- Launched in 2007 in the L2 orbit

Introduction-The FIRST mission



A comparison of the spectral flux density detection limits of FIRST and SOFIA for resolving power of (A) 1000 and (B) 100,000 [from Nick Wyborn FIRST System Engineer]

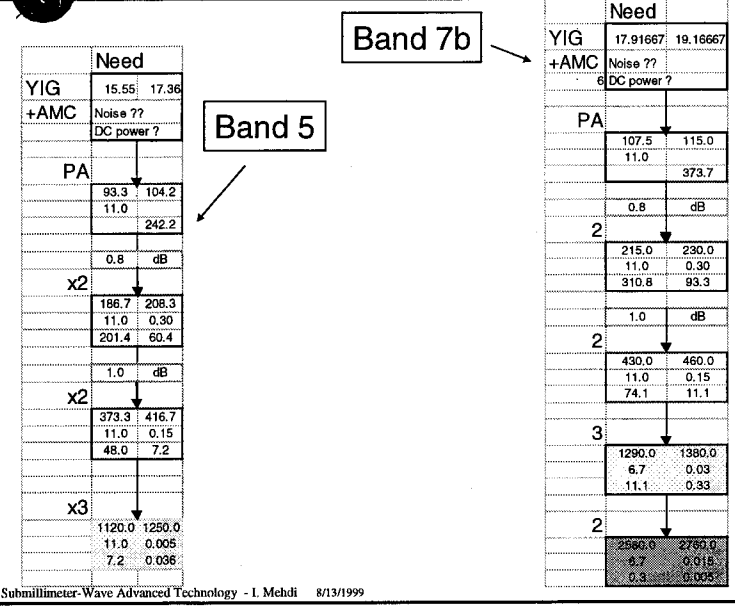
Advanced Local Oscillator Development for Millimeter and Submillimeter-wave Applications

LOCAL OSCILLATOR BANDS FOR FIRST

Initial bands	71-79 GHz	80-92 GHz	88-99 GHz	92-106 GHz	106-112.5 GHz
x2	142-158	160-184	176-198	184-212	212-225
x2 x2	284-316	320-368	352-396	368-424	424-450
x2 x3		480-552 Band 1a		552-636 Band 1b	
x2 x2 x2		640-736 Band 2a	704-792 Band 2b	736-848 Band 3a	848-900
x2 x2 x3	852-948 Band 3b	960-1104 Band 4a	1056-1188 Band 4b	1104-1272 Band 5 (36 μW)	1272-1350
x2 x2 x2 x2			1408-1584 Band 6a (1.2 μW)		
x2 x2 x3 x2	1704-1896 Band 6b (1.2 μW)			2400-2544 Band 7a (1.2 μW)	2544-2700 Band 7b (1.2 μW)

Proposed local oscillator bands for FIRST. The required power levels assume a 27% diplexer coupling and a 50% margin on the power levels required at the focal plane unit. (For bands 6 and 7 single polarization is assumed)

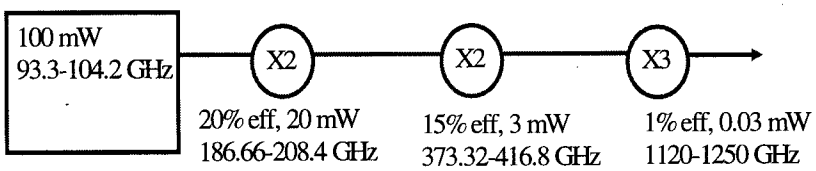
JPL - Submillimeter-Wave Advanced Technology - I. Mehdi 8/13/1999



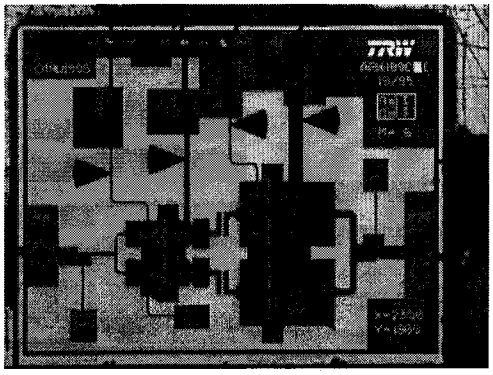
Advanced Local Oscillator Development for Millimeter and Submillimeter-wave Applications

Technical Task: Band 5 (for FIRST)

(1130-1240 GHz)



TRW MMIC PA Chip

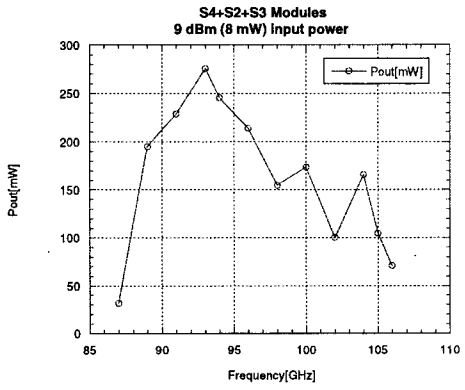


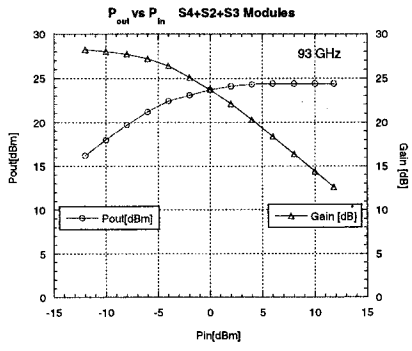
- 0.1 um PHEMT process
- 50 um thick substrate
- f_t = 200 GHz
- 64 finger device cell (output)
- on-chip bias network
- 50 ohm matching in/out
- 2.3 mm x 1.8 mm

Ref: R. Lai et. al, "A high efficiency 0.15 um 2-mil thick InGaAs/AlGaAs/GaAs V-band power HEMT MMIC," IEEE GaAs IC Symposium Digest, Nov. 1996.
M. D. Biedenbender et al, "A 0.1 um W-band HEMT production process for high yield and high performance low noise and power MMIC's," 16th GaAs IC Symposium, 1994.

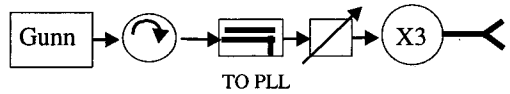
Advanced Local Oscillator Development for Millimeter and Submillimeter-wave Applications

Measured PA output power





Test with a SIS 278 GHz receiver at CSO on Mauna Kea, Hawaii



(a)

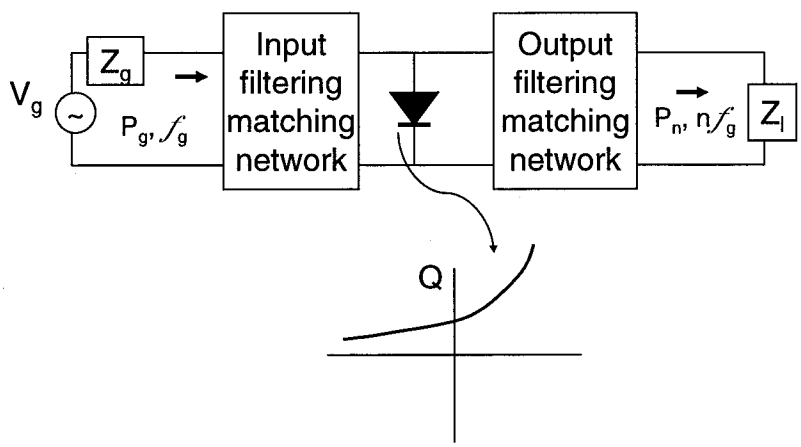
$T_{rec} = 22.5$ K

(b)

$T_{rec} = 21.3$ K

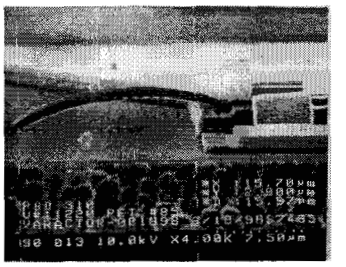
Advanced Local Oscillator Development for Millimeter and Submillimeter-wave Applications

Frequency multiplication

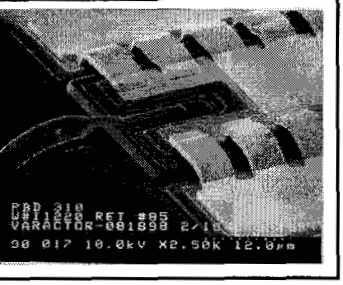


JPL - Submillimeter-Wave Advanced Technology - I. Mehdi 8/13/1999

THz Devices

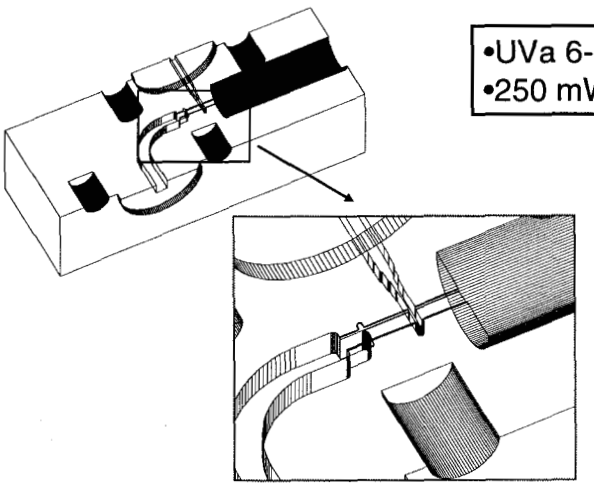


- 4-anode 310 GHz chip
- 480x160x50 microns
- Anode is 1.5x9.3 microns
- Stepper process
- RIE is used for chip separation



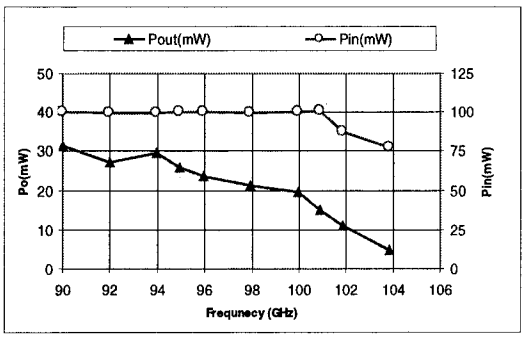
Advanced Local Oscillator Development for Millimeter and Submillimeter-wave Applications

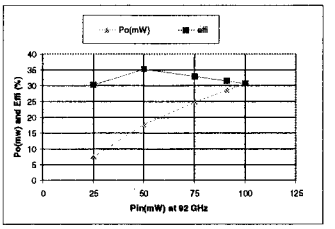
Balanced Doublers on quartz substrates

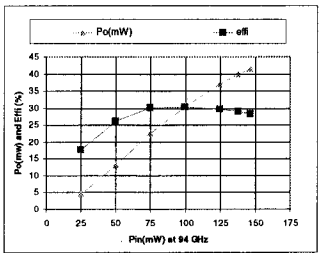


- UVa 6-anode chip
- 250 mW input power

Balanced Doublers on quartz substrates

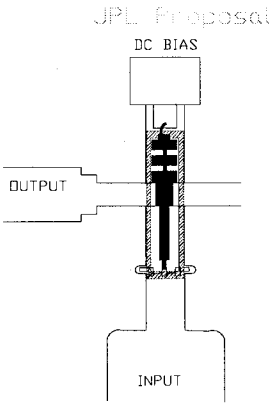




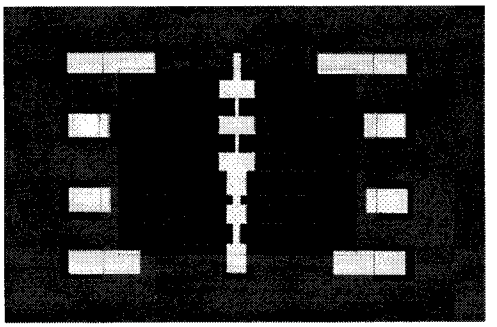


Advanced Local Oscillator Development for Millimeter and Submillimeter-wave Applications

JPL Substrate-less Concept

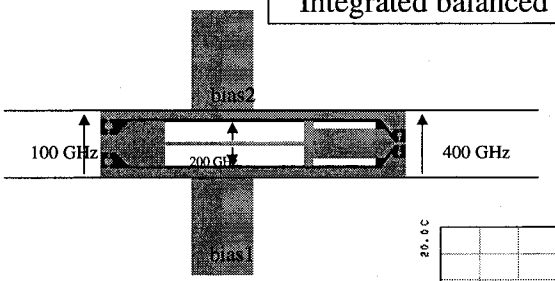


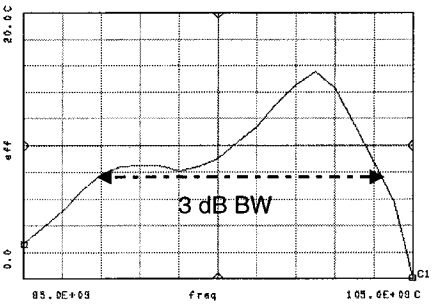
- No quartz substrate
- Fully integrated chip
- 2-mil substrate frame
- Metal tabs for bonding



JPL - Submillimeter-Wave Advanced Technology - I. Mehdi 8/13/1999

Integrated balanced doubler to 400 GHz

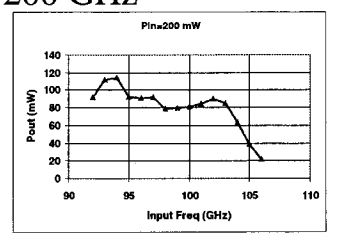


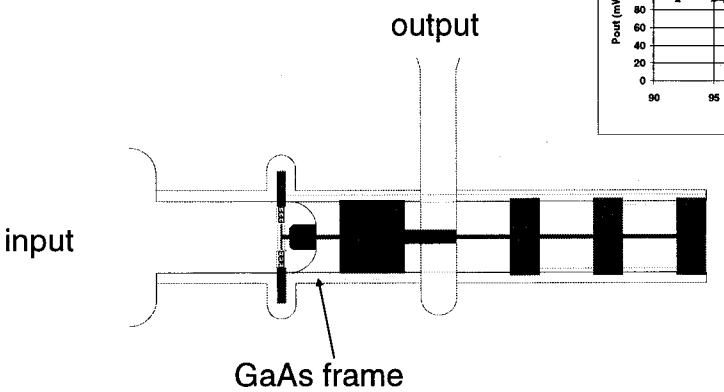


- Efficiency vs. Input frequency for x2x2 circuit.
- Input power is 26mW.
- (Simulation includes substrate, ohmic losses, all diode effects)

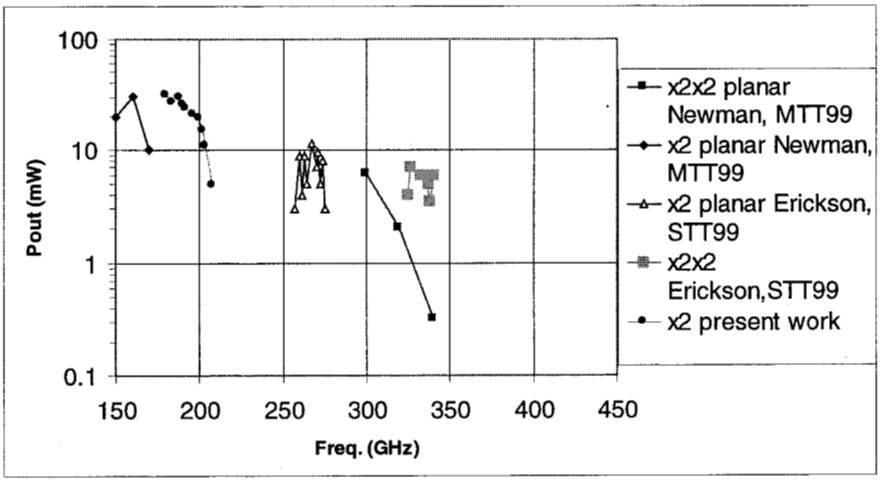
Advanced Local Oscillator Development for Millimeter and Submillimeter-wave Applications

Substrate-less design for 200 GHz





Recent planar balanced multipliers



Advanced Local Oscillator Development for Millimeter and Submillimeter-wave Applications

Conclusion

- In order to generate decent power at 1 THz and beyond high power sources at 100 GHz must be used--Power amplifiers are the answer!
- Schottky devices with extremely high cutoff frequencies are possible--process must be robust, repeatable and critical dimensions must be precisely known.
- New ways and novel technologies must be explored to enable frequency multipliers in the THz range that are robust and flight worthy.