THz frequency multiplier chains based on planar Schottky diodes

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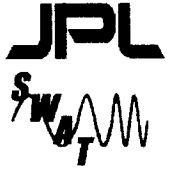


Outline:

- Motivation

-Design of the THz frequency multiplier chain

- Performance

- Output power leveling scheme

- Optical interface requirements

- Summary

Motivation

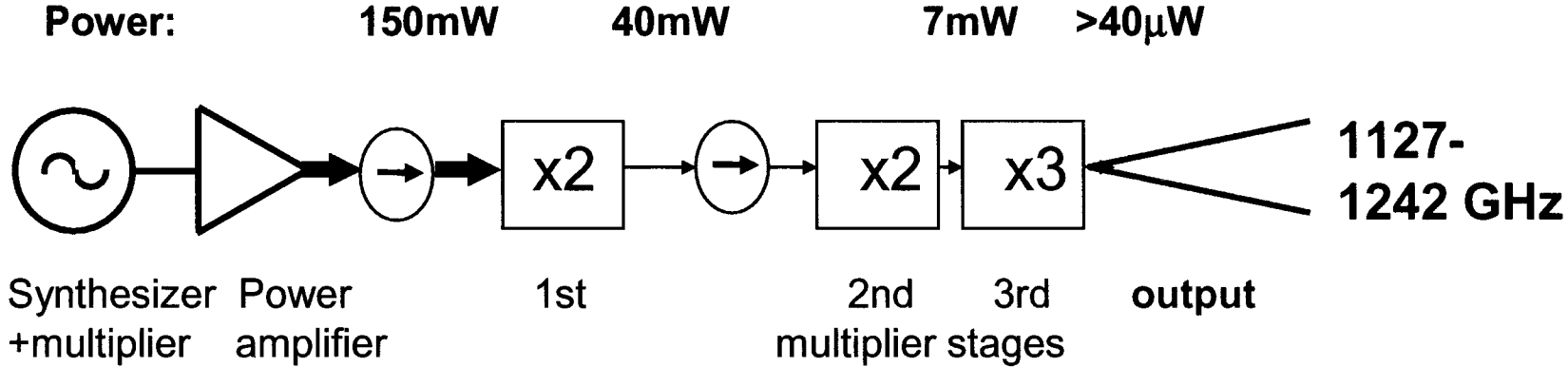
Development of components for space-based heterodyne sensor technology

for

High resolution spectroscopy with HIFI (Herschel)

Need: **Sufficient LO power at THz frequencies**

Goal: **Compact solid state frequency chain**



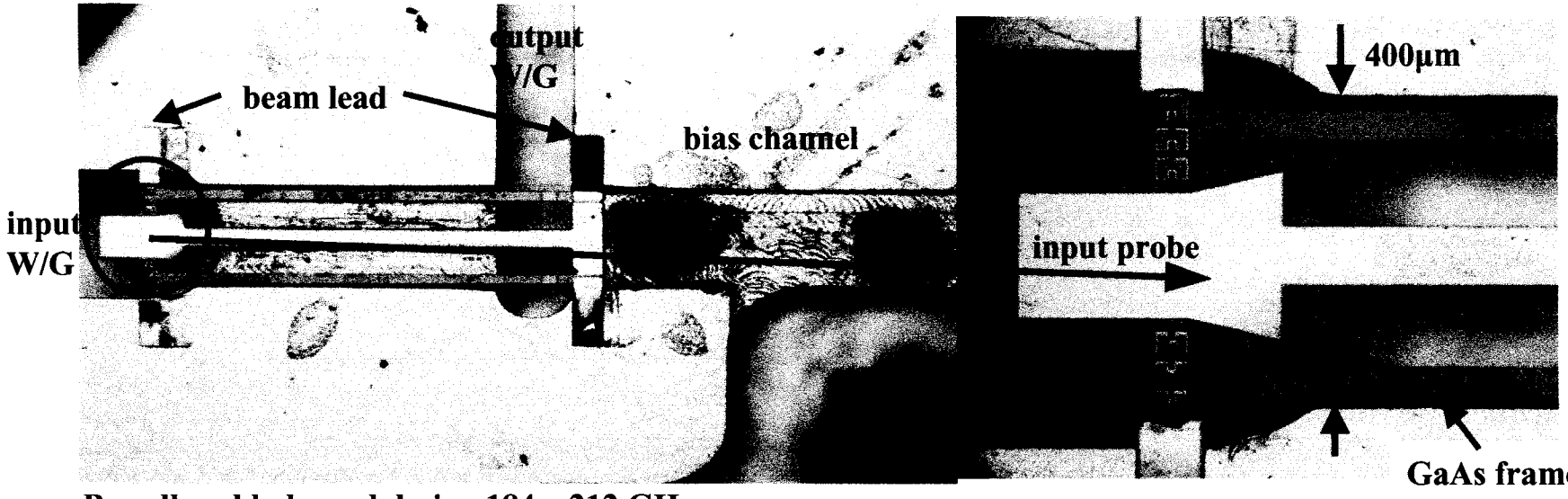
Design of a (x2x2x3) 1200GHz local oscillator chain

- Designs are based on an iterative process to optimize multiplier performance
- Two different diode fabrication technologies at JPL
    - substrate less or framed designs for f<1THz
    - monolithic membrane diode (MoMeD) design for f>1THz
- Machining tolerances +/- 2μm
- Operating conditions: input power (more than 150mW) and temperature (120K)
- Design of in-line and simple to assemble waveguide multiplier blocks
- E-plane split block machined from brass and gold-plated.
    - Last stage block has a diagonal feed horn integrated.

For example:

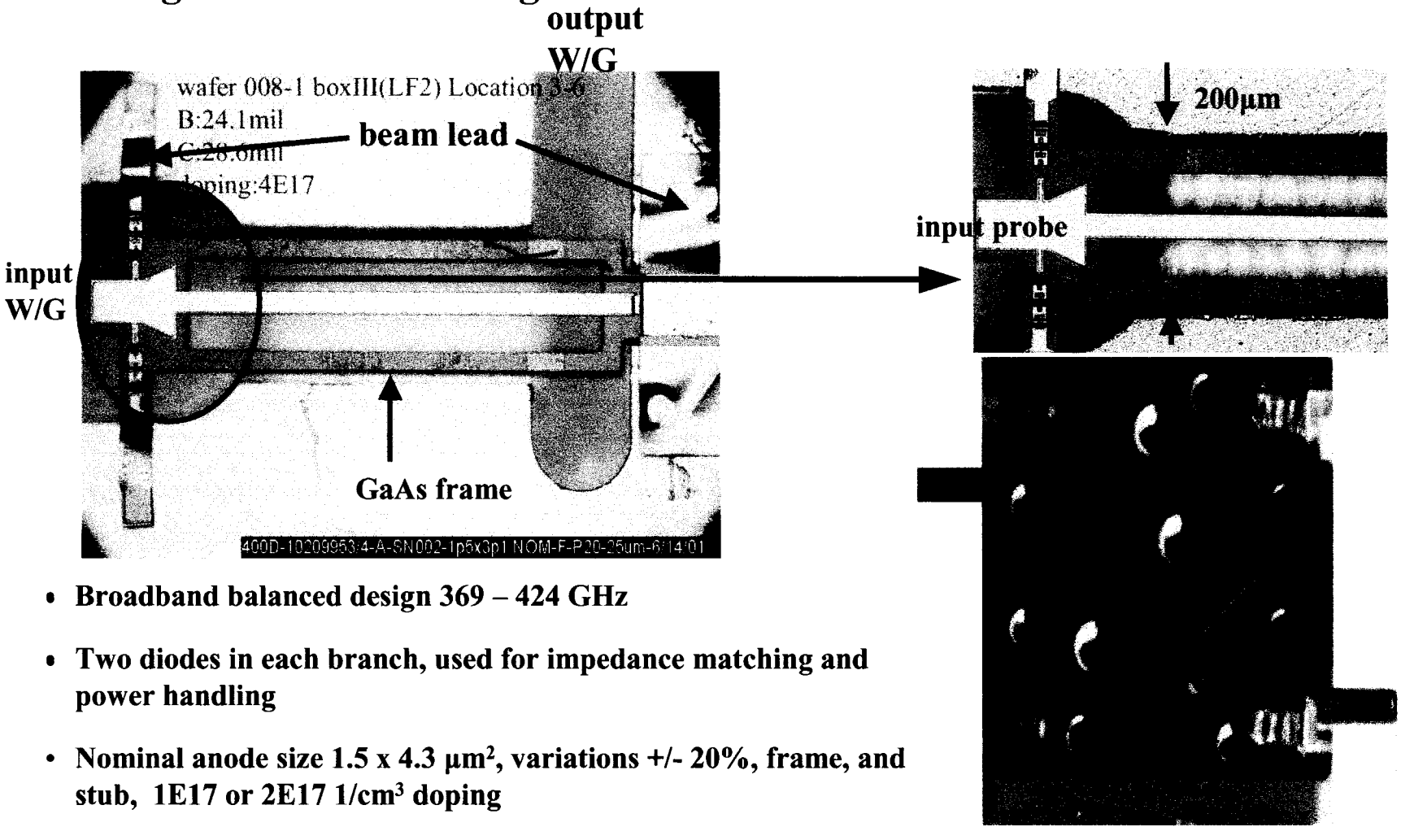
- Band 5a: 1127 – 1178 GHz (RF input 93.91 - 98.17 GHz)
- Band 5b: 1192 – 1242 GHz (RF input 99.33 - 103.50 GHz)

Design of the first stage doubler in the x2x2x4 local oscillator chain



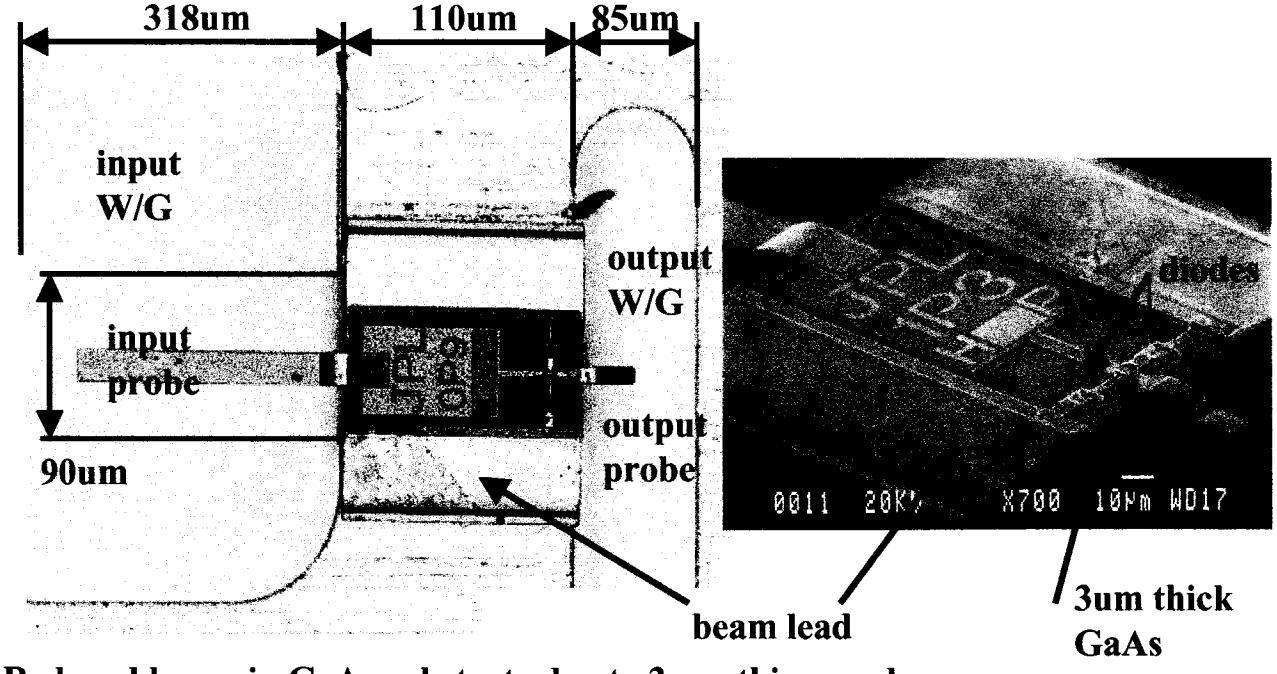
- Broadband balanced design 184 – 212 GHz
- Three diodes in each branch, used for impedance matching and power handling
- Nominal anode size 3.0 x 12.0 µm^2, variations +/- 20% and frame, 1E17 or 2E17 1/cm^3 doping
- Substrate removed to reduce losses
- Reduced waveguide height in input and output waveguides to accommodate impedance matching
- No mechanical tuning element

Design of the second stage doubler in the x2x2x4 local oscillator chain



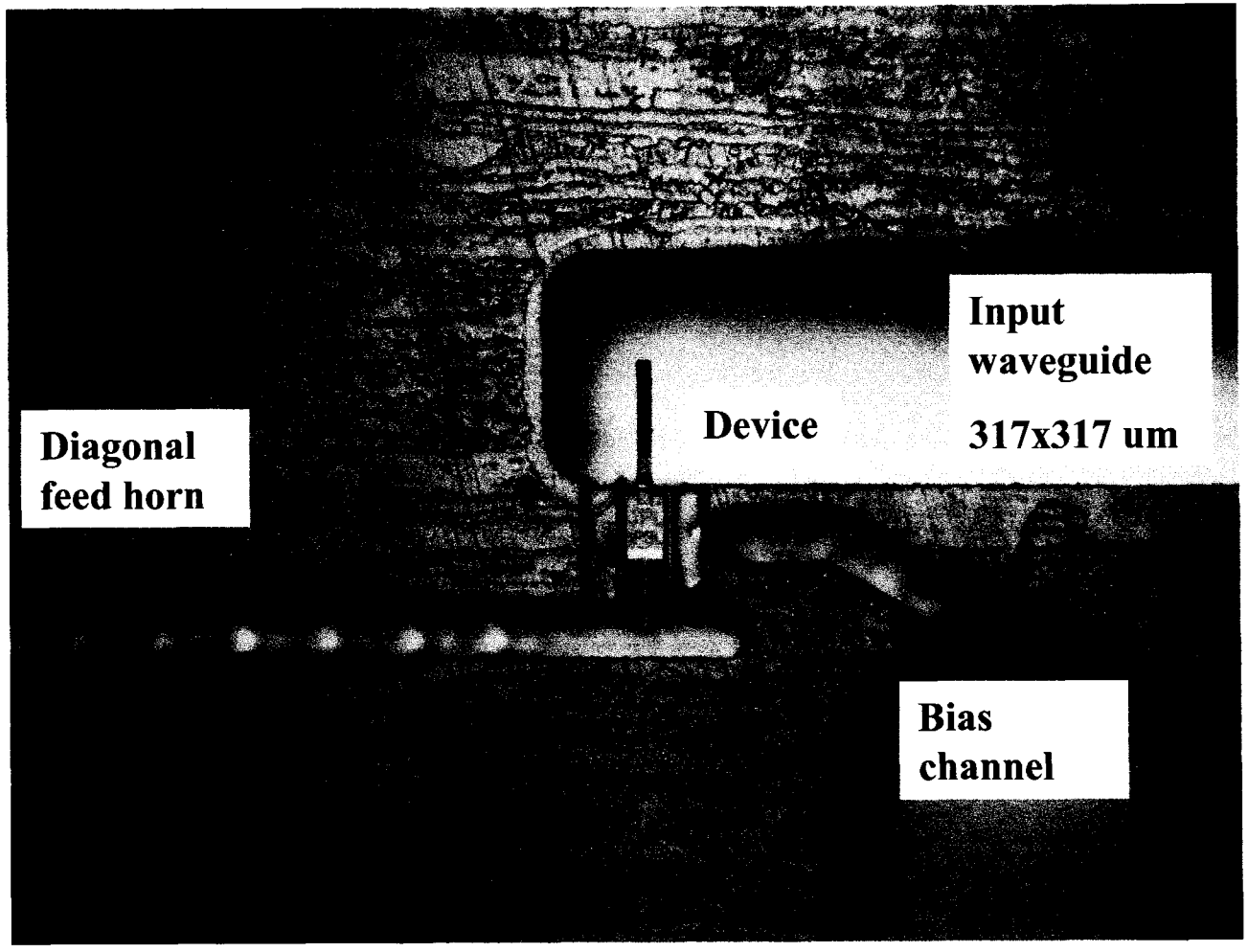
- **Broadband balanced design 369 – 424 GHz**
- **Two diodes in each branch, used for impedance matching and power handling**
- **Nominal anode size 1.5 x 4.3 µm², variations +/- 20%, frame, and stub, 1E17 or 2E17 1/cm³ doping**

Design of the third stage tripler in the x2x2x3 local oscillator chain

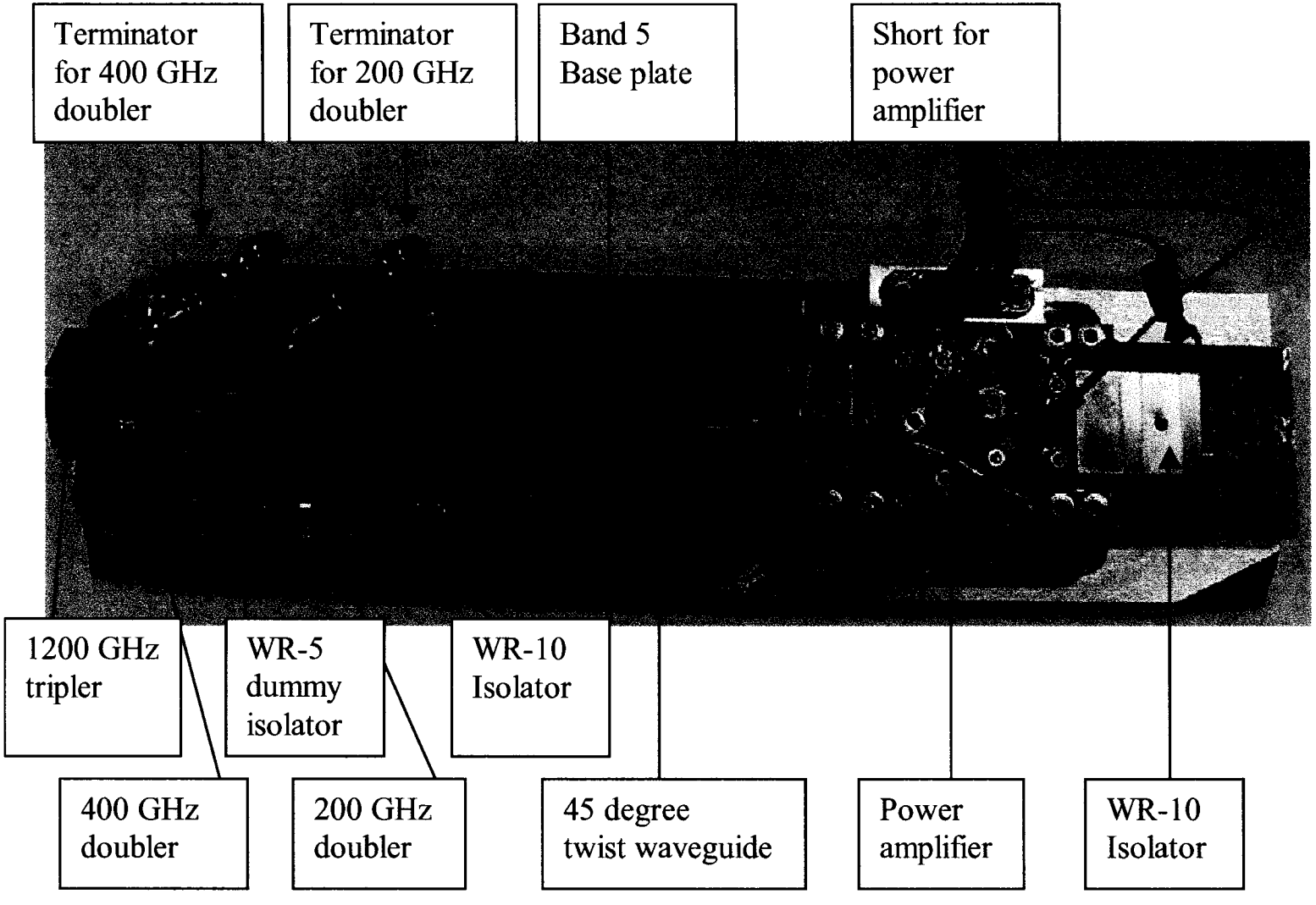


- Reduced losses in GaAs substrate due to 3 µm thin membrane.
- Beam leads for mechanical support and ground contact.
- Beam leads as RF probes in the input and output waveguides.
- Several device variations (anode, bias).
- Nominal anode size 0.4 x 0.9µm^2, variations +/- 20%, 5E17 1/cm^3 doping.
- Broadband balanced design 1127 - 1242 GHz.

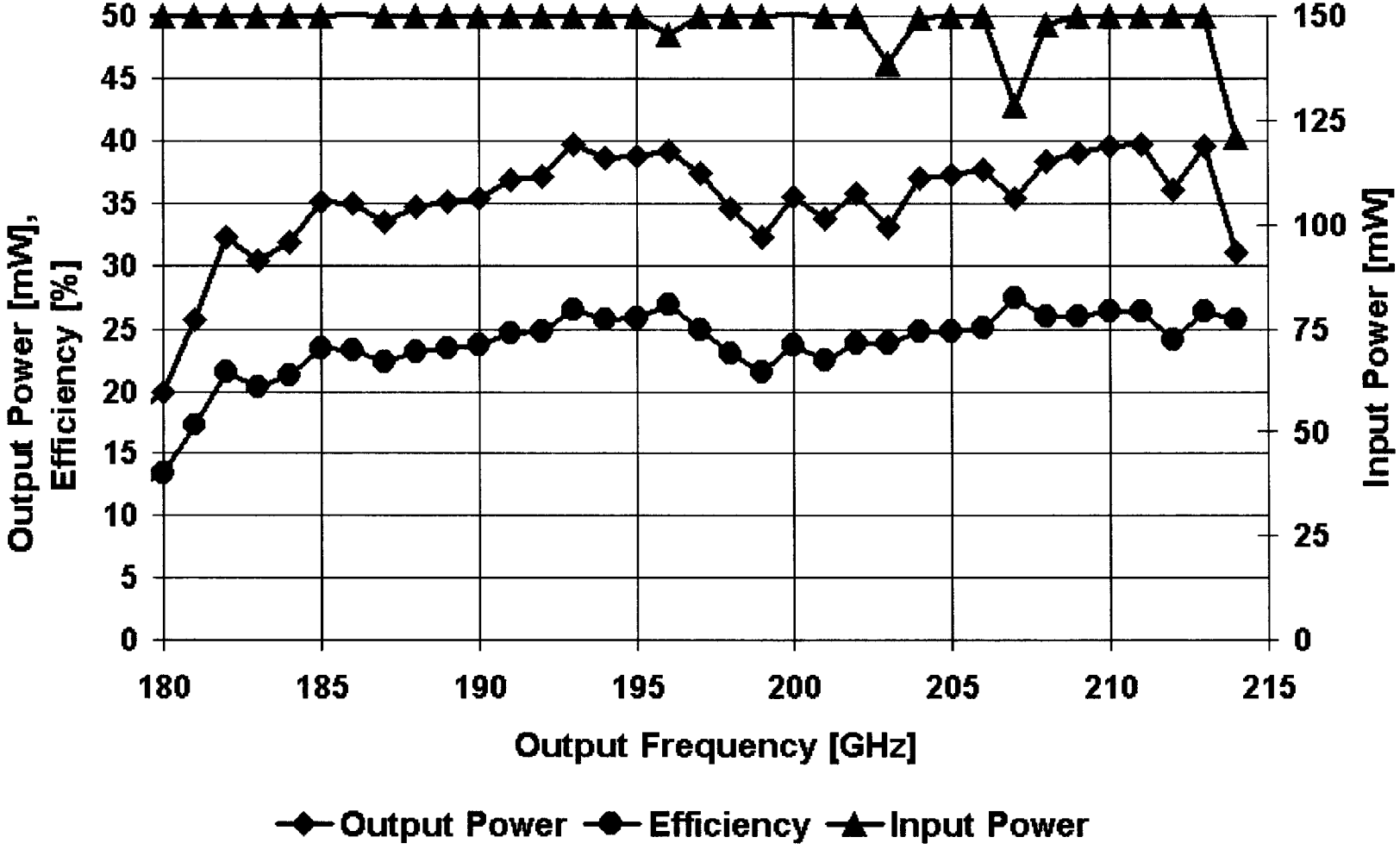
Design of the third stage tripler in the x2x2x3 local oscillator chain cont.



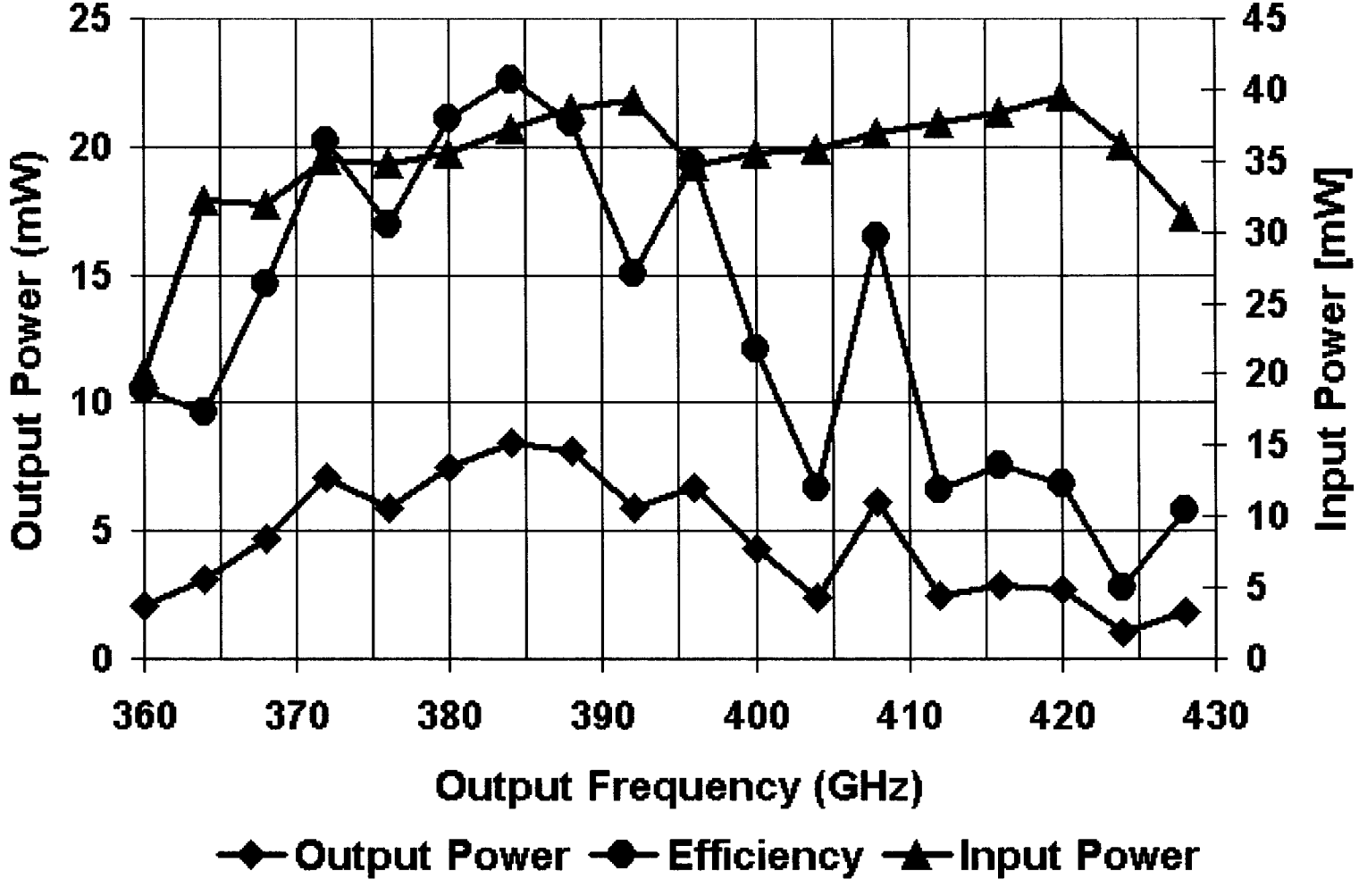
Design of the (x2x2x3) 1200GHz local oscillator chain



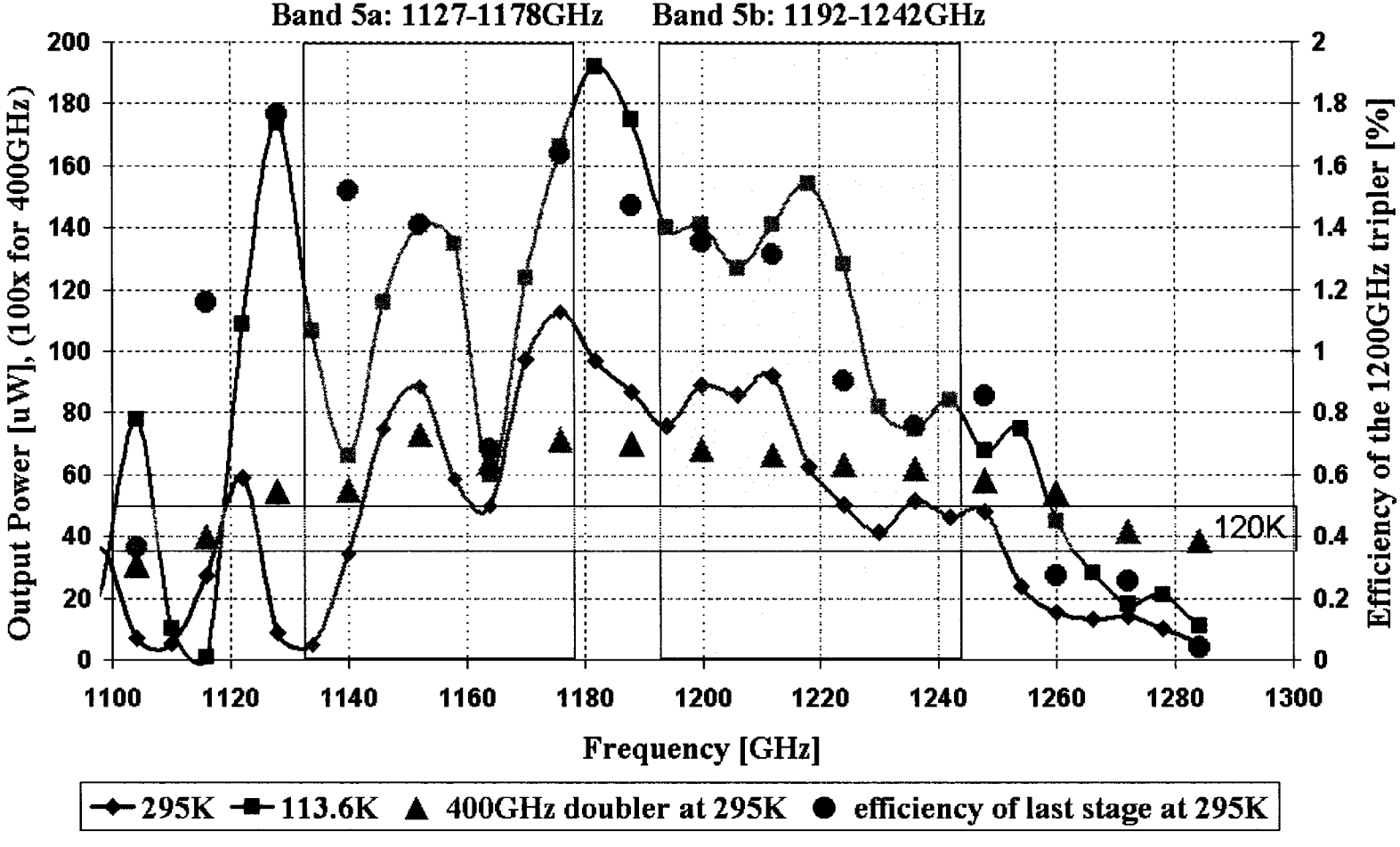
Performance of the first doubler in the x2x2x3 local oscillator chain



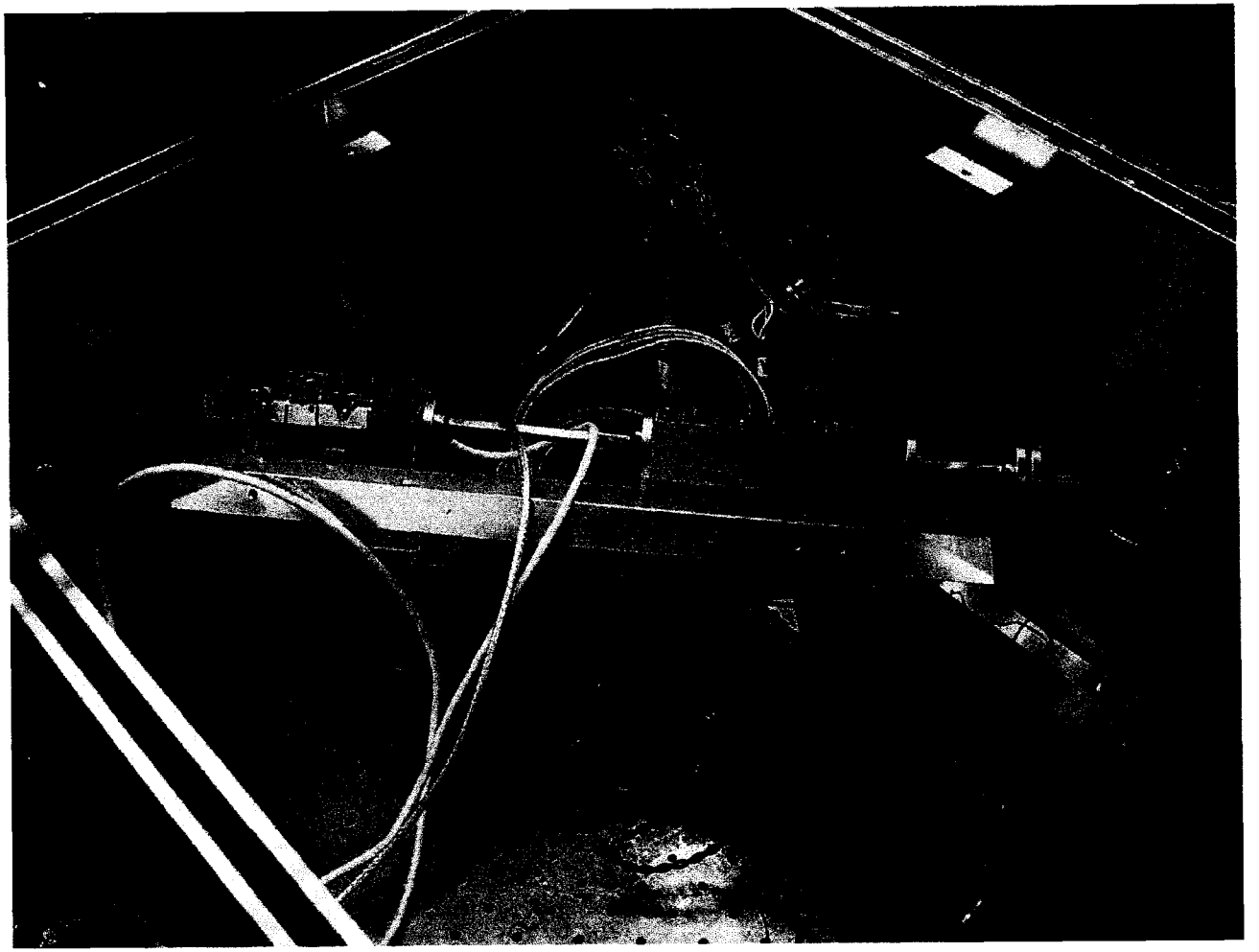
Performance of the second doubler in the x2x2x3 local oscillator chain



Performance of the third stage in the x2x2x3 local oscillator chain



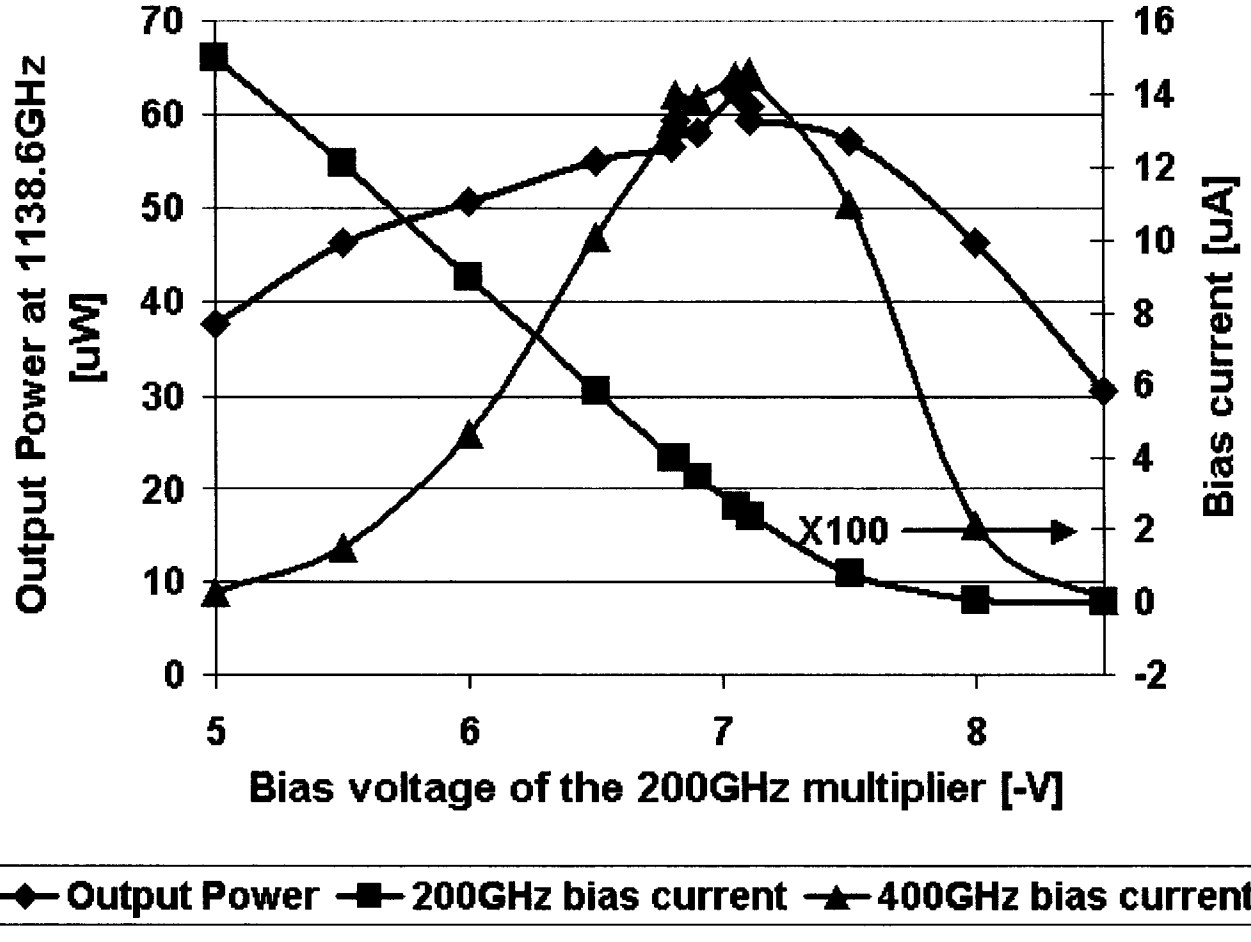
120K test bench for measurements



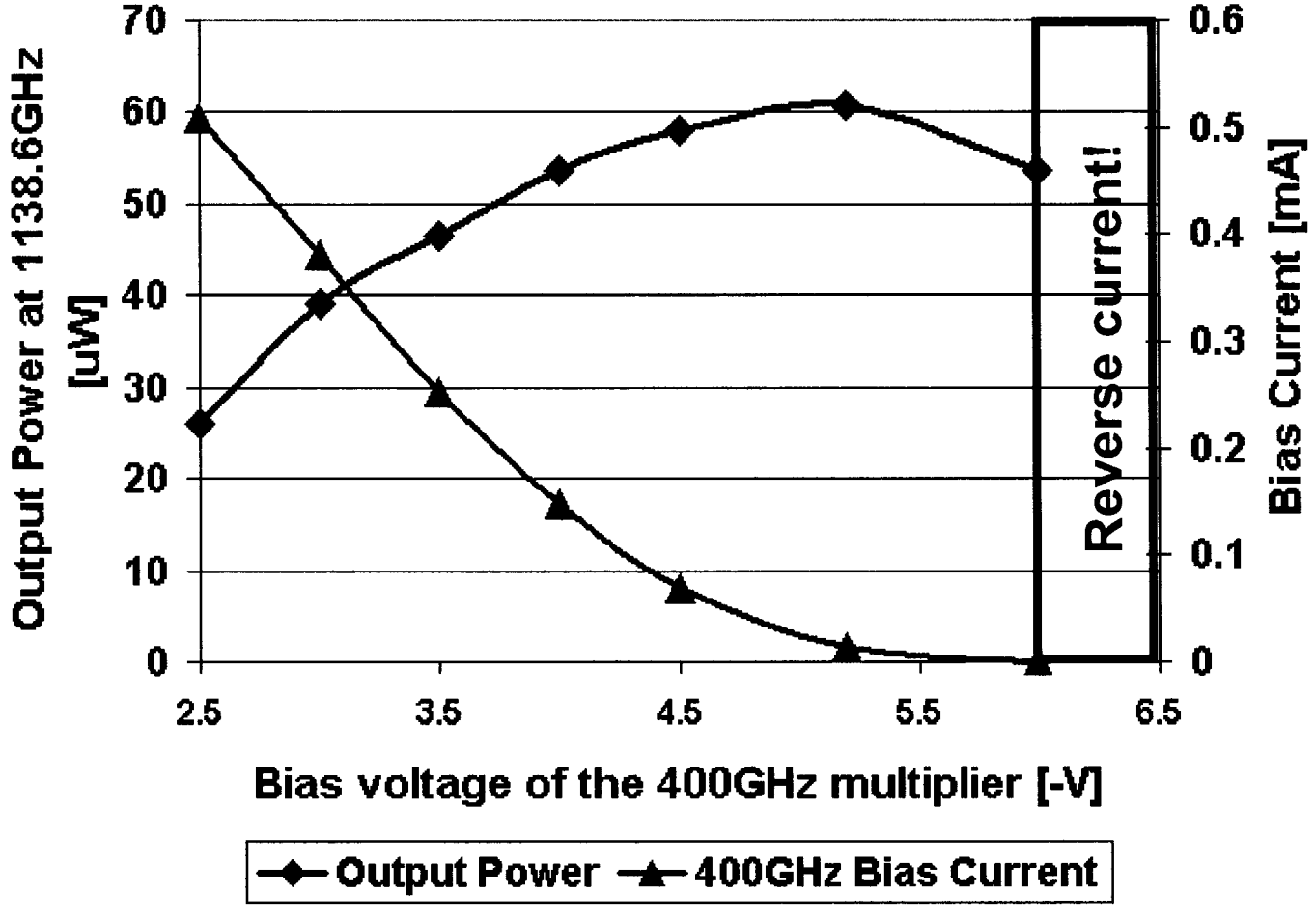
Output power leveling

- No mechanical tuner
- Frequency multiplier in the x2x2x3 LO chain:
  - 200GHz doubler
  - 400GHz doubler
  - 1200GHz tripler (bias-less)
- Power amplifier
  - Drain voltages
  - Gate voltages
- Electronic attenuator (under development by Neal Erickson, UMass)

THz chain power tuning with the first stage x2



THz chain power tuning with the second stage x2



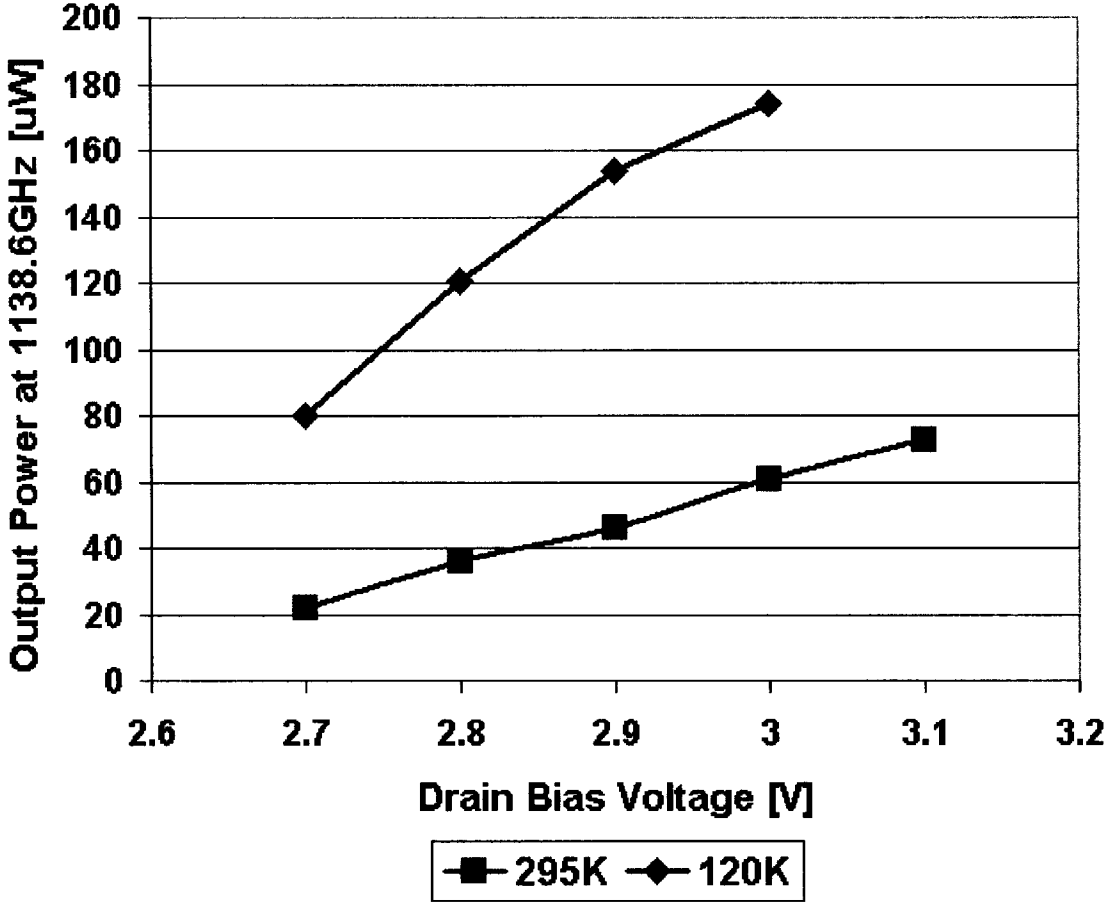
Concerns when tuning the output power with the multiplier bias

- Reliability of diode device
- Limited bias voltage range
- Limited bias current range
- Have to be carefully to avoid voltage swing close to breakdown (only the average voltage is monitored)

•Solution:

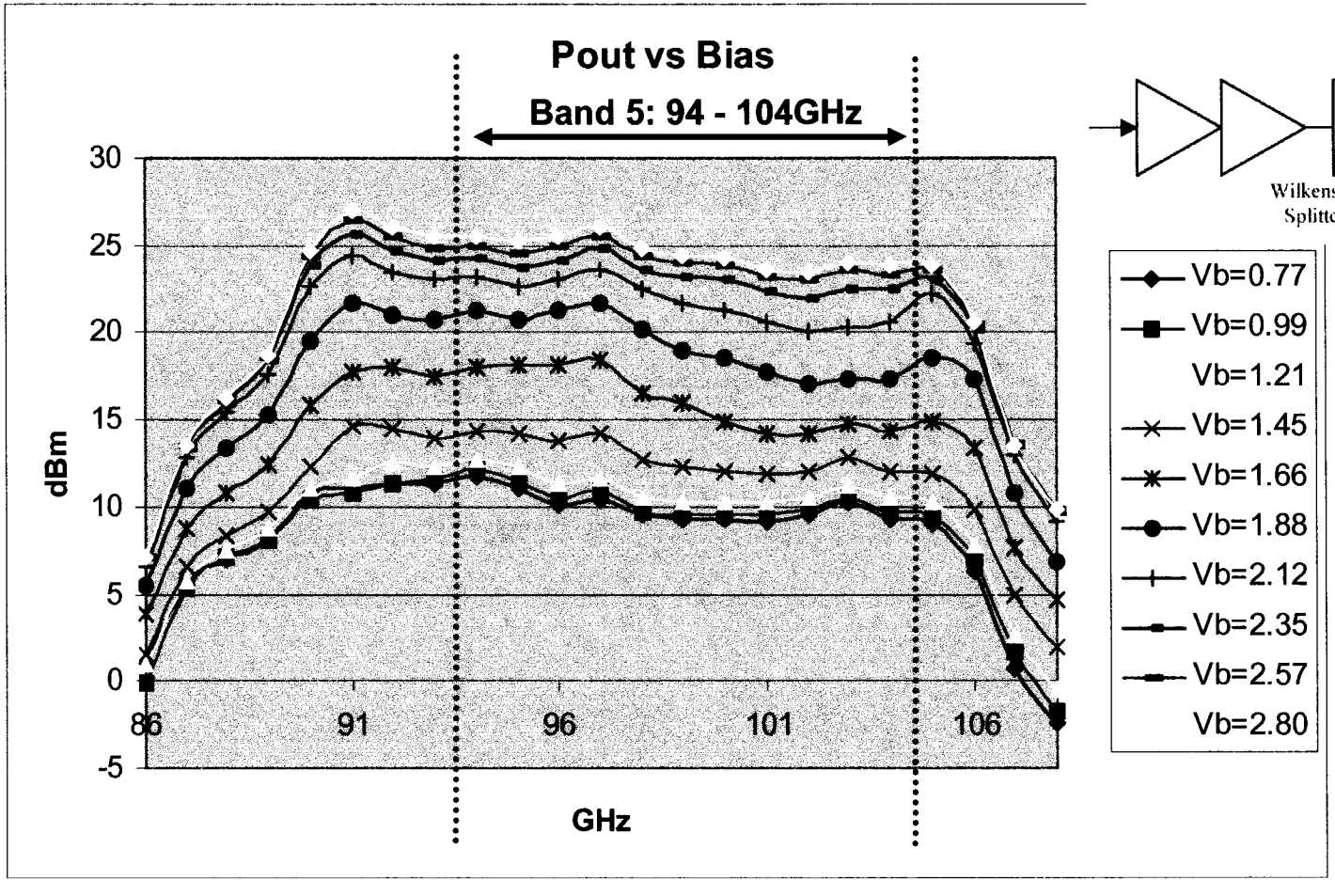
Primary tuning with the power amplifier while finer adjustments can be made with multiplier bias

THz chain power tuning with the power amplifier bias



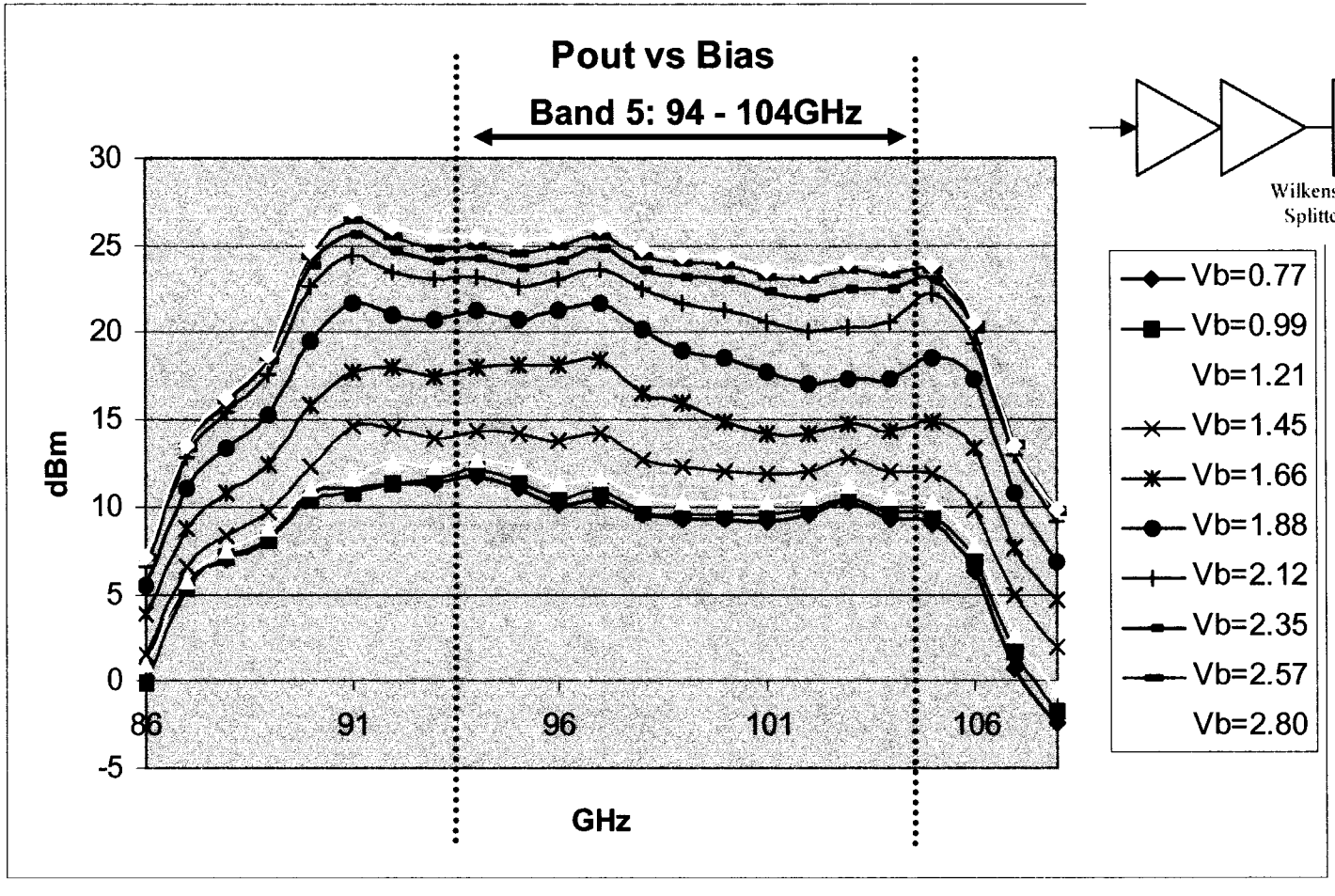
- Gate bias is 0V
- Input power is 3.5dBm
- Bias voltages on the 200 and 400 GHz doublers are constant

Power amplifier (PA) output power vs. PA drain voltage



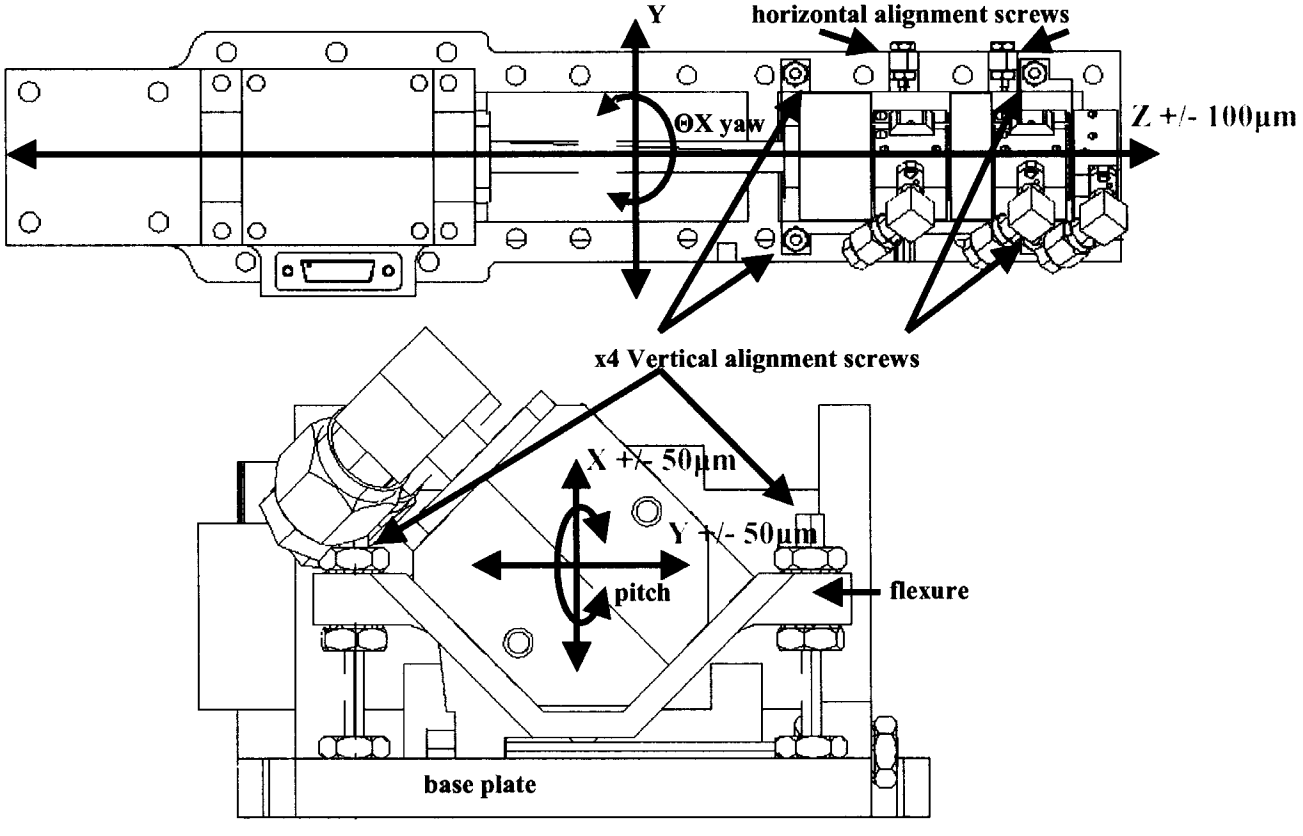
S/N 102 output power vs. drain voltage at 120K with +0dBm input

Power amplifier (PA) output power vs. PA drain voltage



S/N 102 output power vs. drain voltage at 120K with +0dBm input

Axis definition and tolerances specification

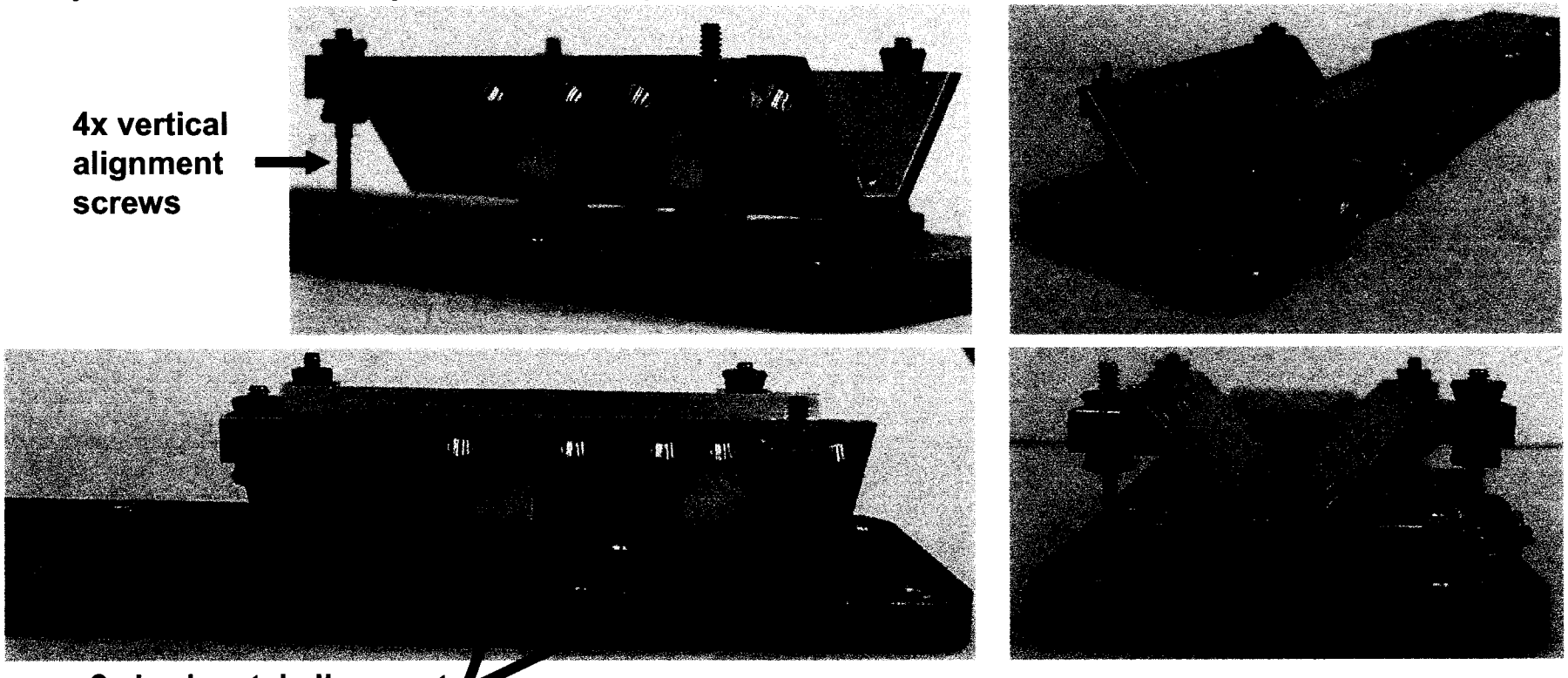


Alignment Flexure

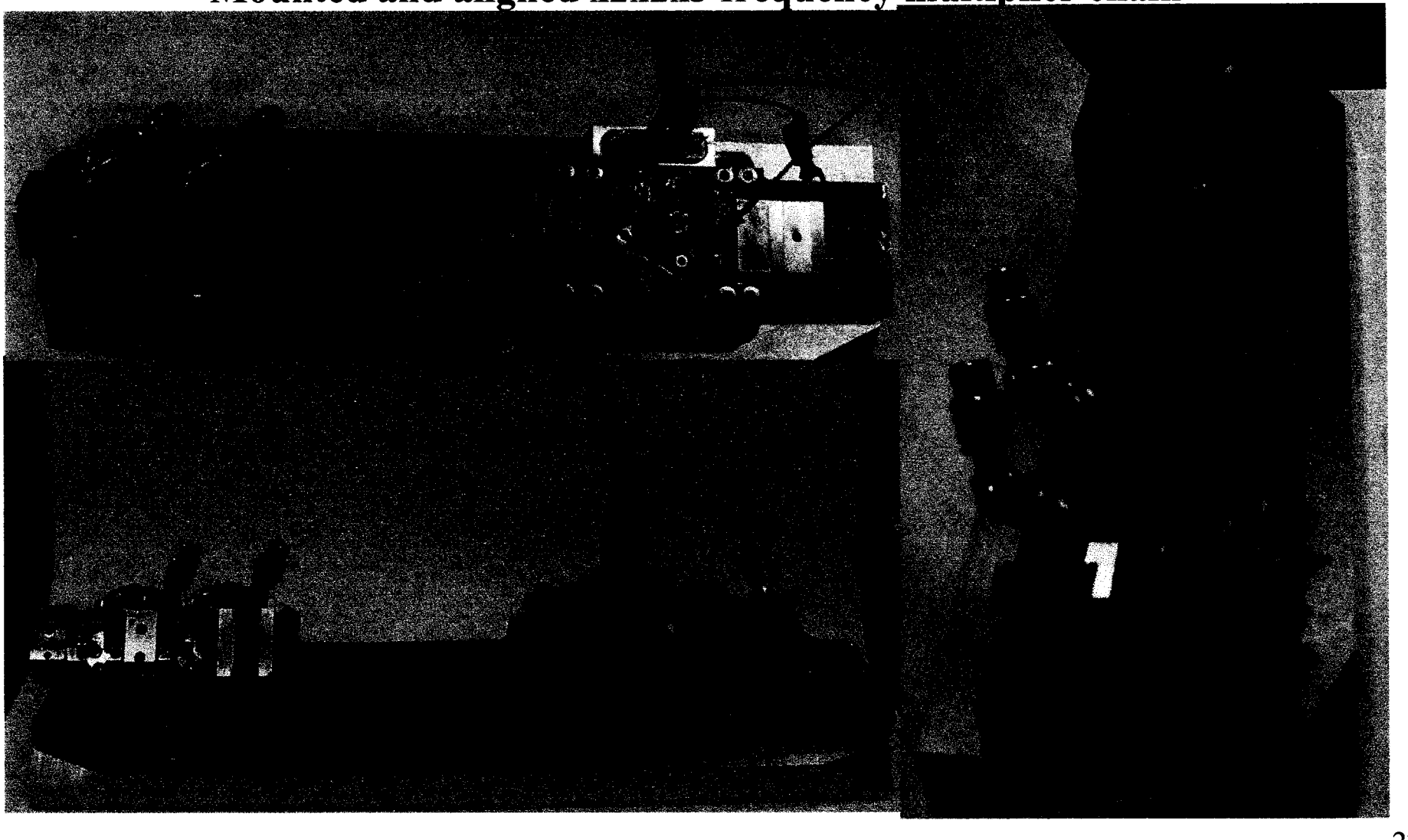
Material: base plate, horizontal screws, and saddle aluminum

vertical screws stainless steel

Adjustment: x,y plane maximal 70µm, z axes is defined by length of THz chain



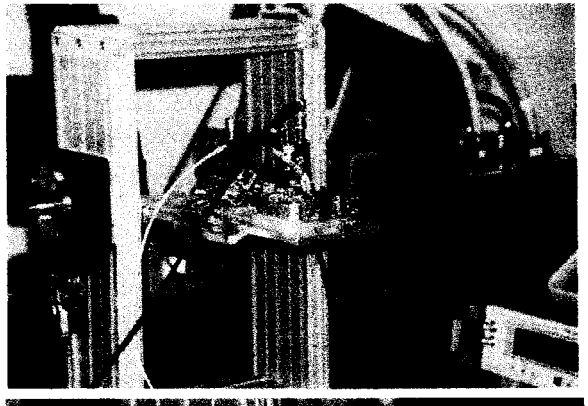
Mounted and aligned x2x2x3 frequency multiplier chain

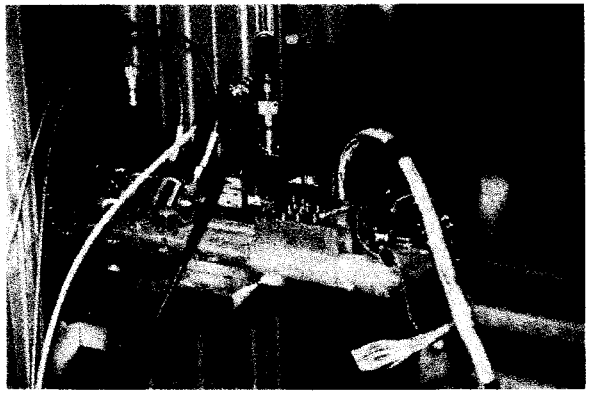


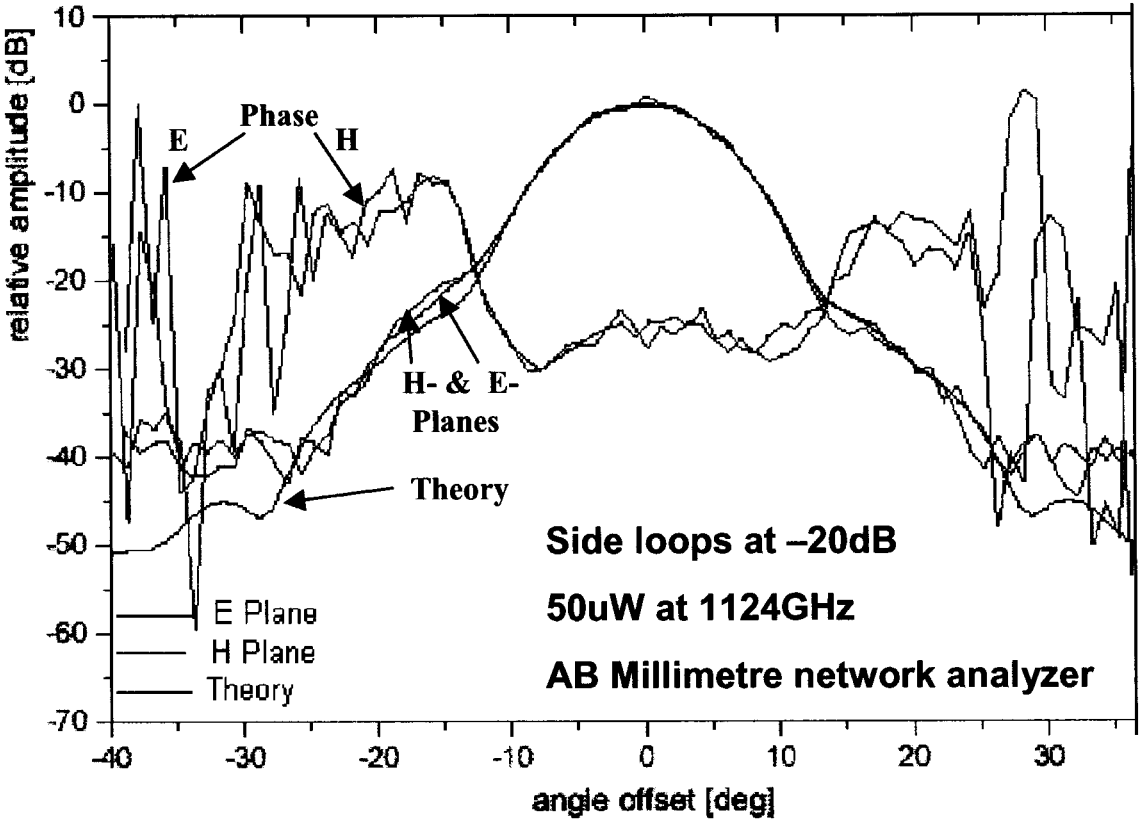
Beam pattern measurement

(performed at the MPIfR (Max-Planck-Institut fuer Radioastronomie) in Bonn/Germany

by Christoph Kasemann and Thomas Klein.)







Summary

- Design and realization of a x2x2x3 multiplier frequency chain for Band 5 of HIFI/Herschel
- Design is easy to assemble, robust, flight suitable
- Measured RF results:
  - Bandwidth 1120 – 1255GHz, Output power > 60uW at 120K
  - Bandwidth 1140 – 1250GHz, Output power > 35uW at 295K
- Beam pattern, side loobs < 20dB
- Mechanical Design meets subsystem requirements

Future work

- further assessment of power handling
- qualify hardware for flight
- Confirm save operating conditions
- Investigating high frequency chains
  1400-1900GHz for band 6, x16, x18, and/or x24

Acknowledgment

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- **Support of the Submillimeter-Wave Advanced Technology Group, Supervisor Dr. Peter Siegel**

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