Optics research for future receivers at NAOJ

Alvaro Gonzalez
National Astronomical Observatory of Japan

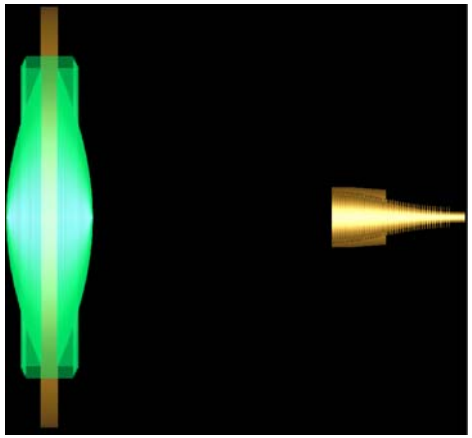
Outline

- *Follow-up to presentations by: D. Iono, T. Kojima*

- Optics for lower ALMA bands
  - Band 1 (35-50 GHz)
  - Band 2 (67-90 GHz)
  - Band 2+3 (67-116 GHz)
- Wideband RF components (band 7+8)
- New beam measurement system (30-1600 GHz)
- THz frequencies
- Future work: multibeam

Optics for mm-wave freqs

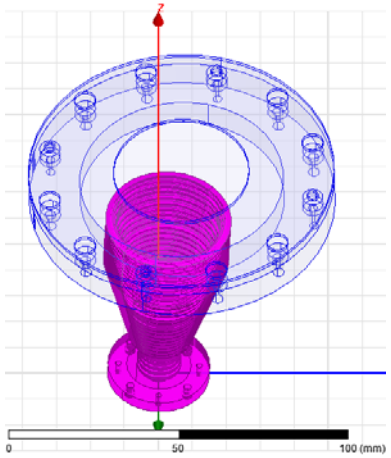
- Profiled corrugated horns
- Design of low-noise lens optics:
  - Band 1 (35-50 GHz), with ASIAA and UdC
  - Band 2 (67-90 GHz), with NRAO
  - Band 2+3 (67-116 GHz), with ESO, INAF, and UdC
- Support of measurements for b1 (Taiwan/Chile) and b2+3 (ESO) / Support for ALMA Eff. Calculator (NRAO)

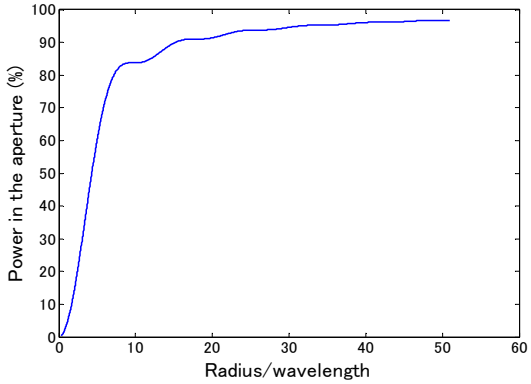


Other presentations by:
T. Huang (ASIAA),
P. Mena (UdC)

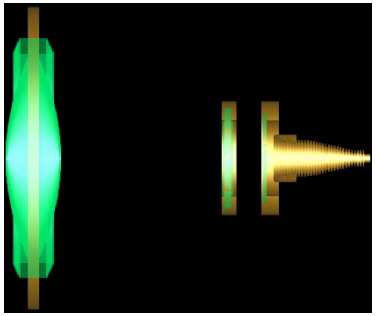
Challenges

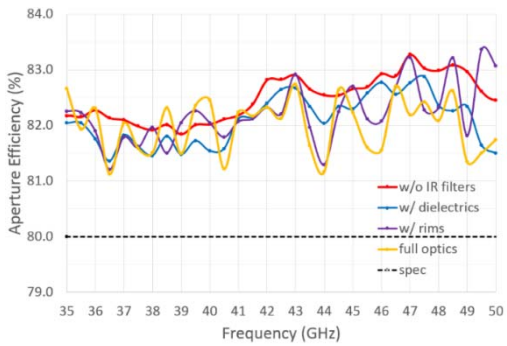
- Truncation at cryostat apertures
  - Limited aperture eff.
  - Large noise contribution

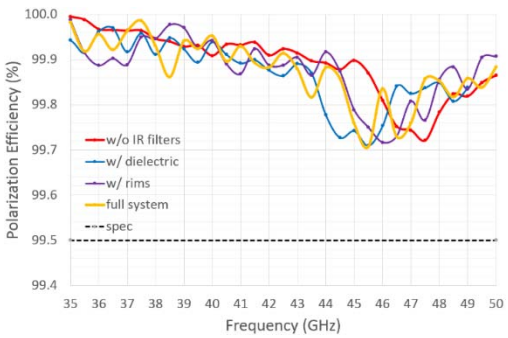


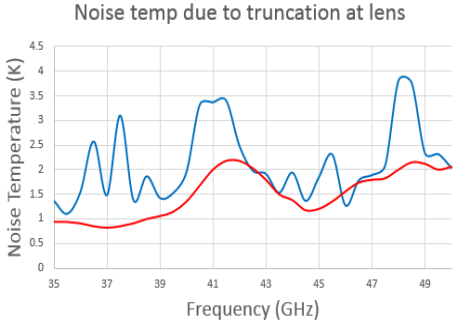


- Effect of IR filters on performance: aperture eff, polarization eff, noise temperature...



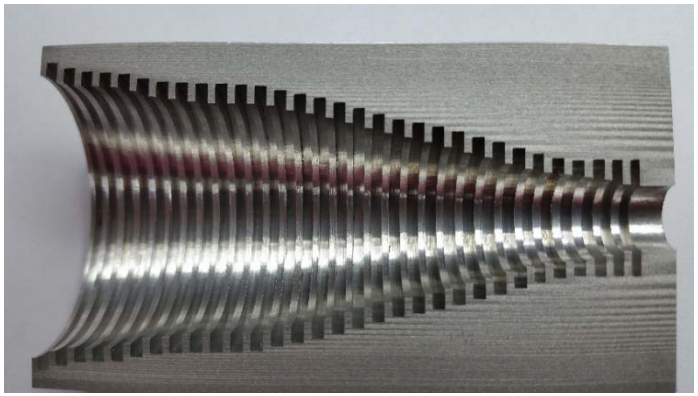


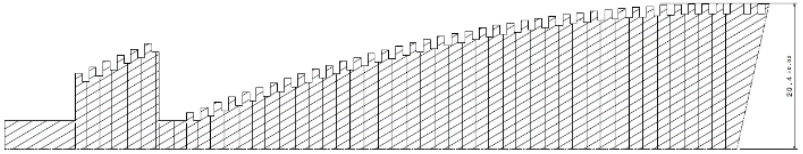




Band 1 (35-50 GHz)

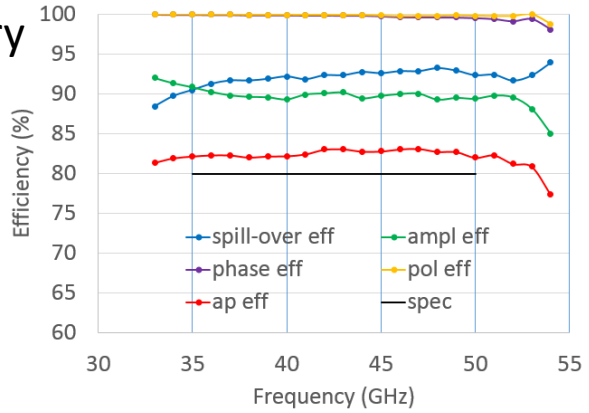
- Project led by ASIAA (Taiwan) in collaboration with NAOJ (Japan), NRAO (USA), Univ Chile, HIA (Canada)
- Optics based on lens (NAOJ) and profiled horn (UdC)

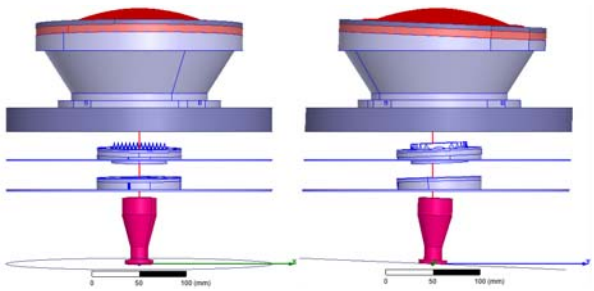


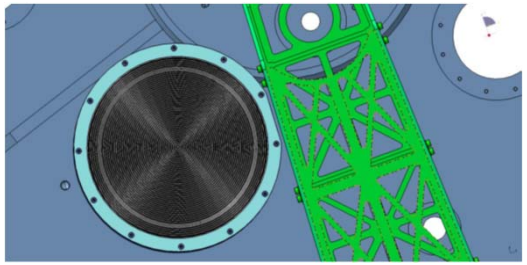


Gonzalez, EuCAP15

Max Ap. Eff from Airy pattern < 84.1%!

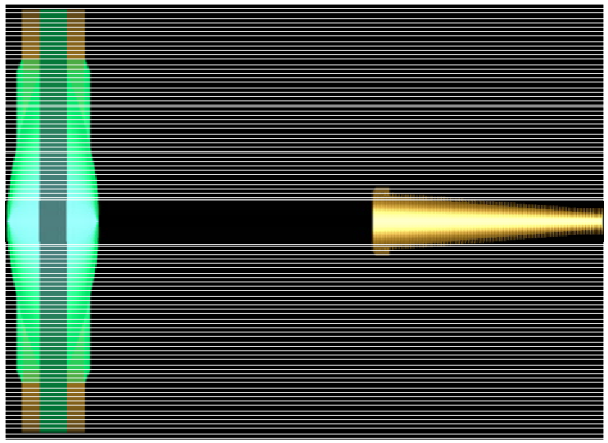


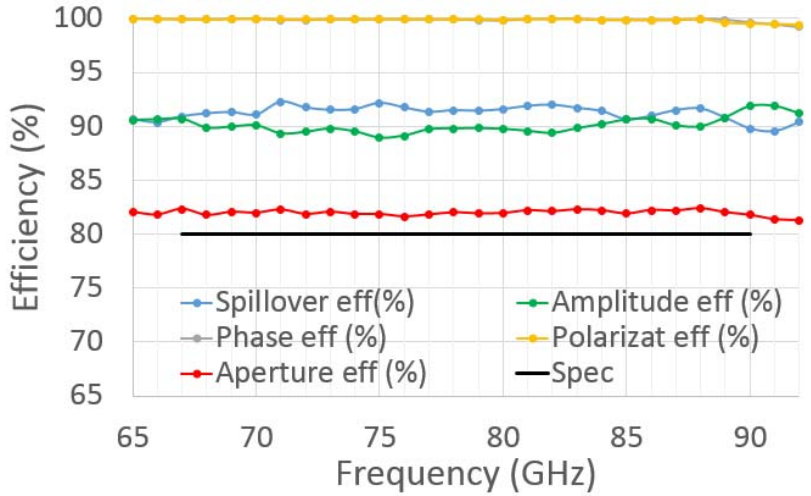




Band 2 (67-90 GHz)

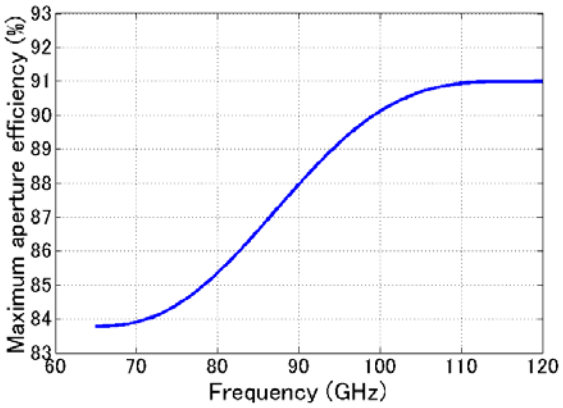
- NRAO project -> NAOJ contributes the rx optics design
- Lens just on top of cryostat to refocus the fields from a long conical horn (designed by NRAO / S. Srikanth)
- Maximum aperture eff from Airy pattern considerations is only 83.8%!
- Measurements at NRAO

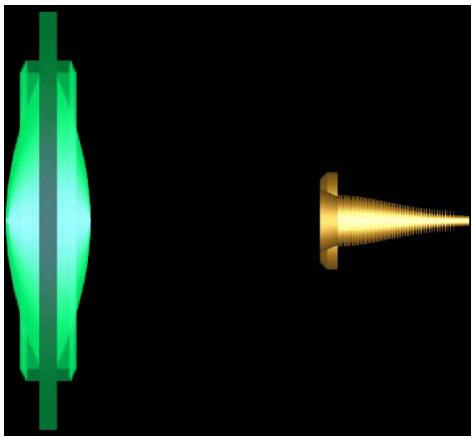


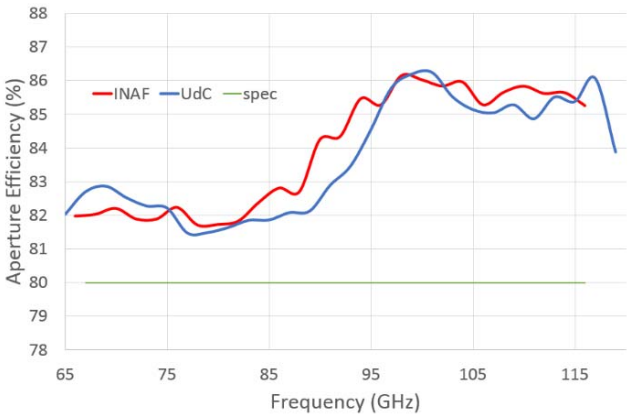


Band 2+3 (67-116 GHz)

- Project led by ESO in collaboration with INAF (Italy), NAOJ (Japan), Univ. Chile, RAL/Univ. Manchester (UK)
- Horns designed by INAF and UdC
- Optical designs with both horns done by NAOJ
  - Based on zoned lens just on top of cryostat top plate
- Maximum aperture eff changes with frequency

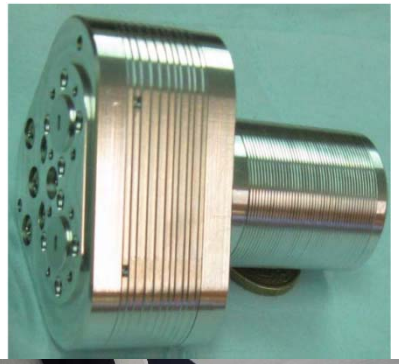


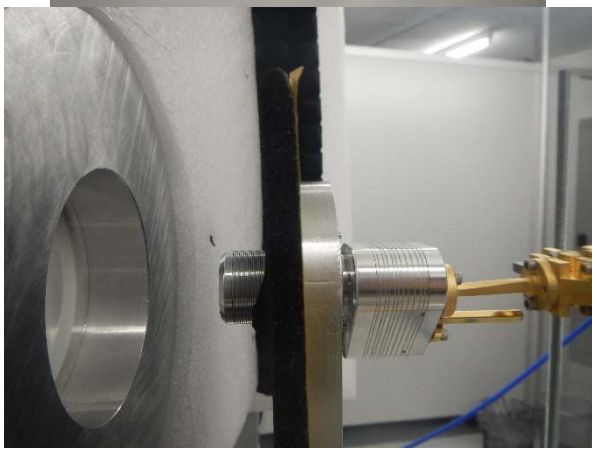


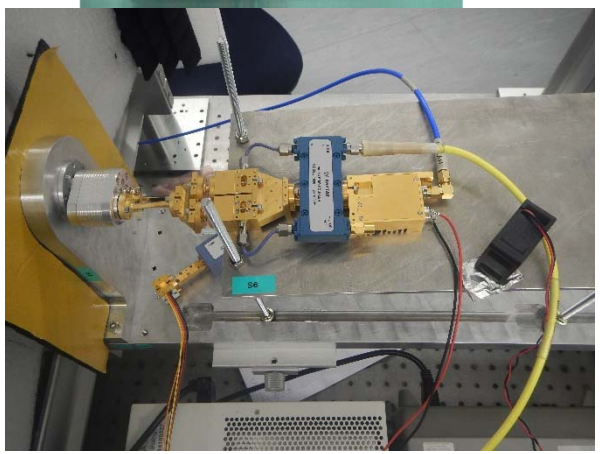


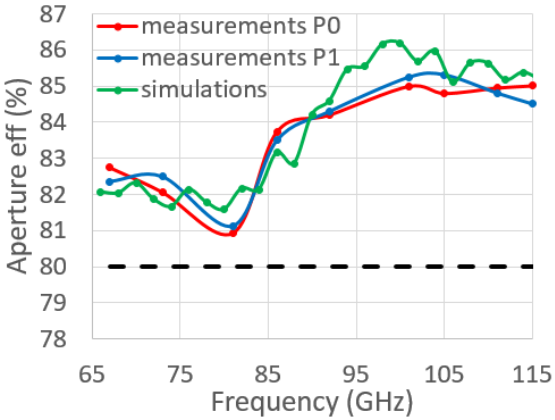
Band 2+3 measurements

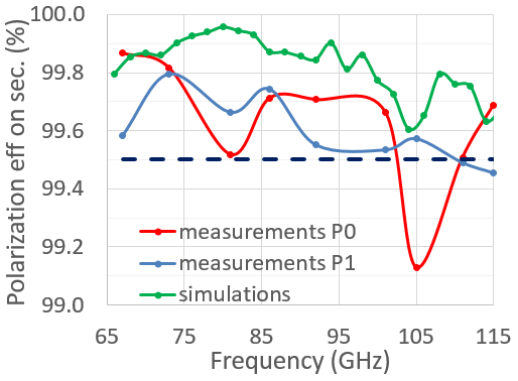
- Measurement campaign at ESO in Dec. 15
  - contributed automatic acquisition software development and analysis of results (far field transformation, Gaussian beam fitting, aperture efficiency calculations…)











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Band 7+8 (275-500 GHz)

- Fractional BW ~60%
- NAOJ High Jc SIS junctions — Poster by M. Kroug
- Collaboration with KASI for ASTE receiver
- Designs: — Poster by J-W. Lee (KASI)
  - Feed horn
  - 15dB LO coupler
  - 3dB coupler
  - B7+8 LO combiner
- Preliminary cold optics design with 2 mirrors

Band 7+8 (275-500 GHz)

- B7+8 feed horn
  - Strong collaboration with KASI (PhD student, B. Lee)
  - Two preliminary feed horn designs (NAOJ + KASI) merged
  - Optimization on-going

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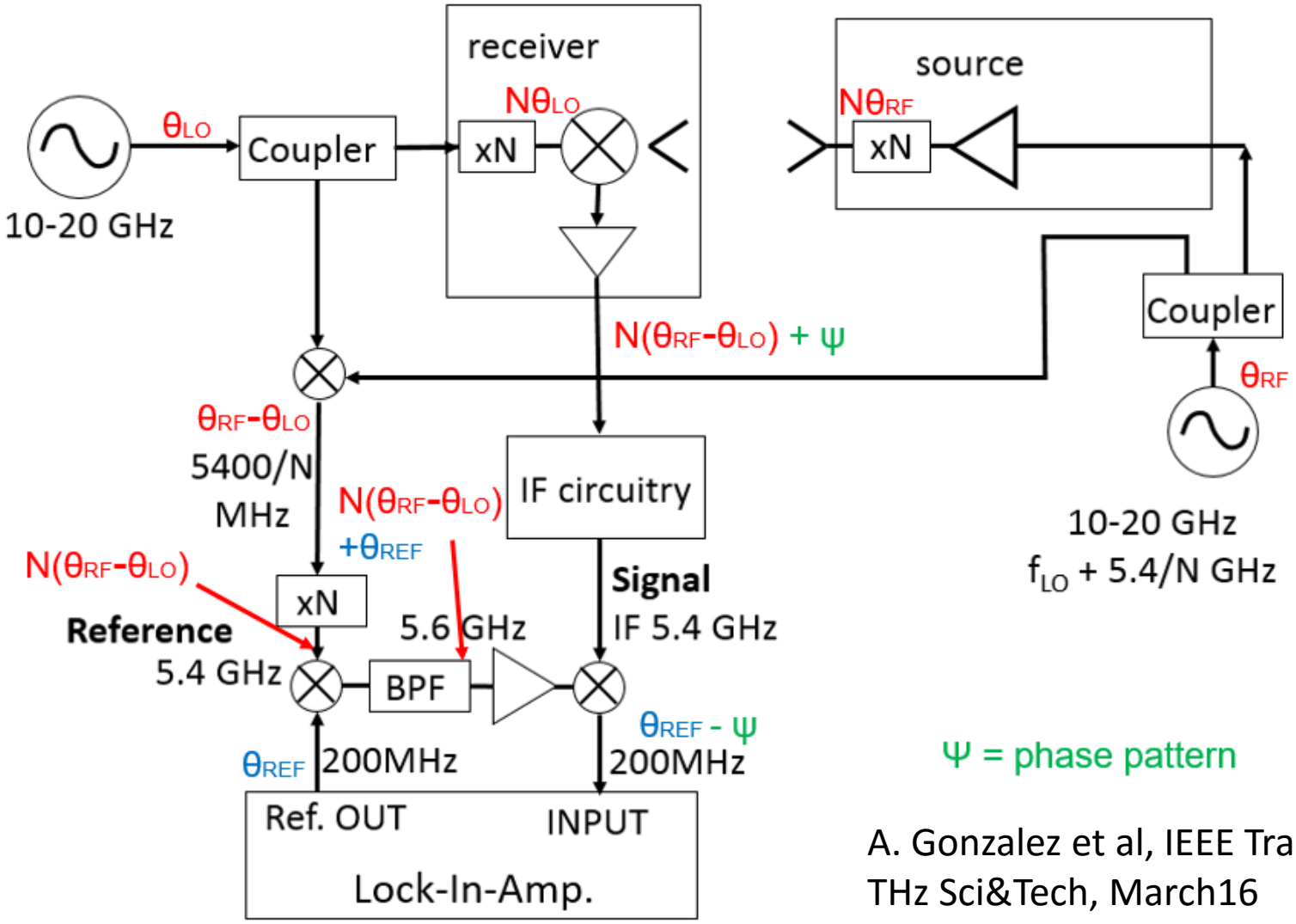
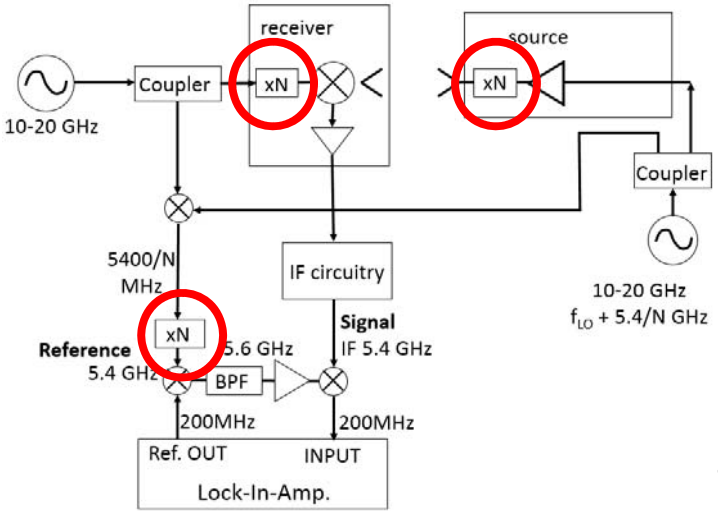
Implementation



ψ = phase pattern

A. Gonzalez et al, IEEE Trans THz Sci&Tech, March16

Re-configurability



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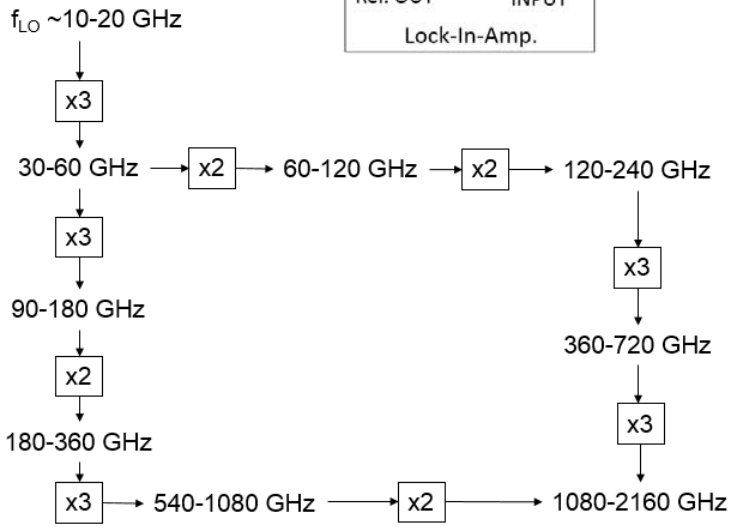
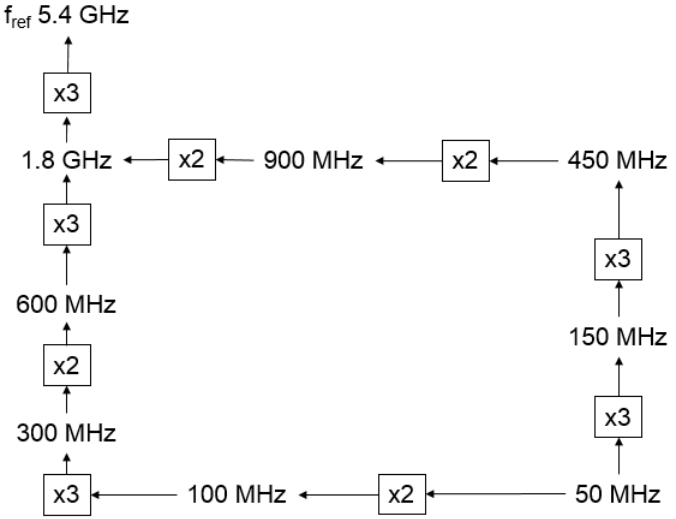
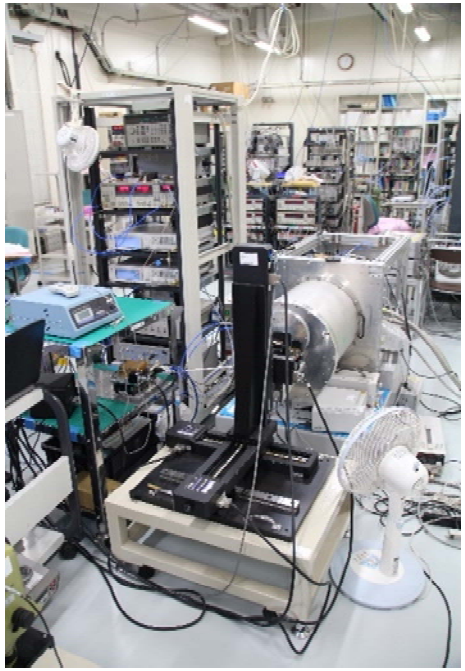




ASTE THz Rx (Univ. Tokyo)

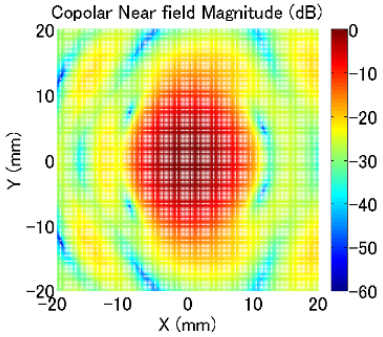
- Receiver cold beam patterns measured at 0.9 and 1.4 THz with reconfigurable measurement system

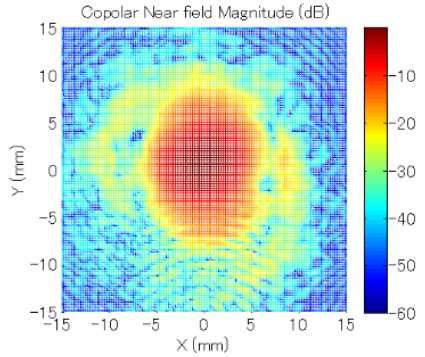
Problem with diagonal horn is well understood now thanks to this measurements!



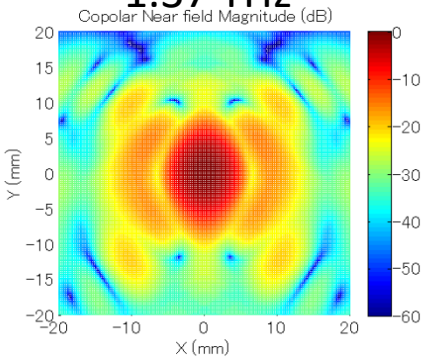
ASTE THz receiver (Univ. Tokyo/ Yamamoto lab) – GRASP simulation vs measurement (NF plane is different)

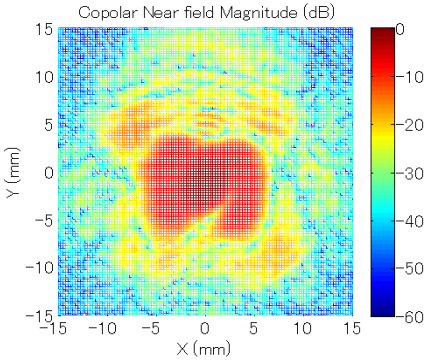
0.91 THz





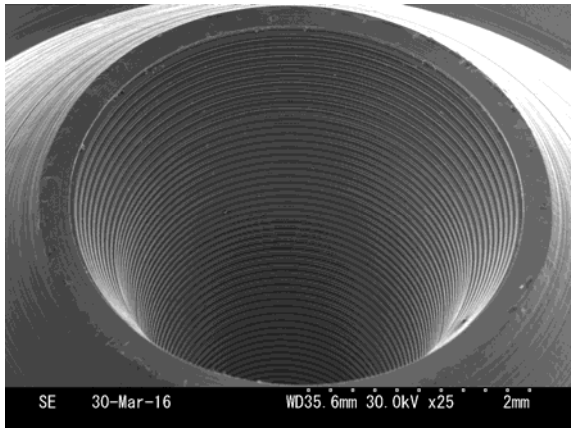
1.37 THz

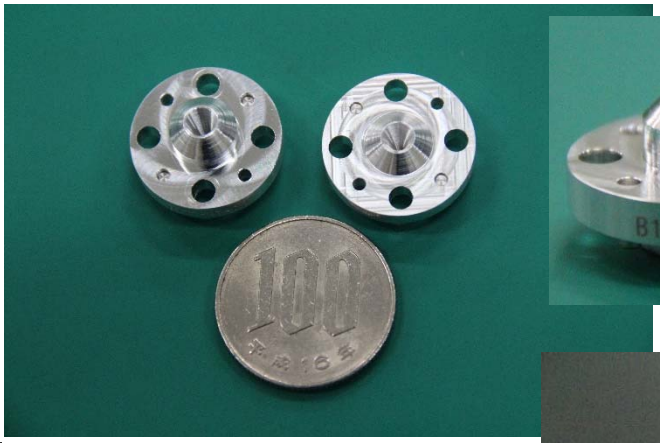


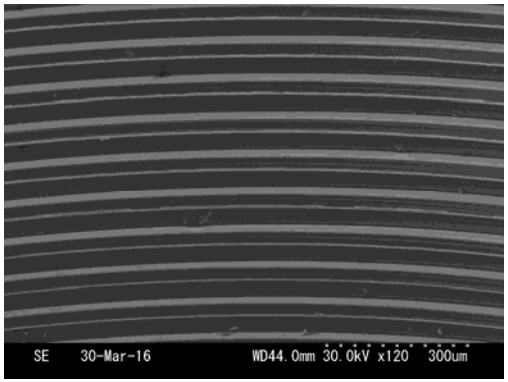


B11 (1.25-1.57 THz) corrugated horns

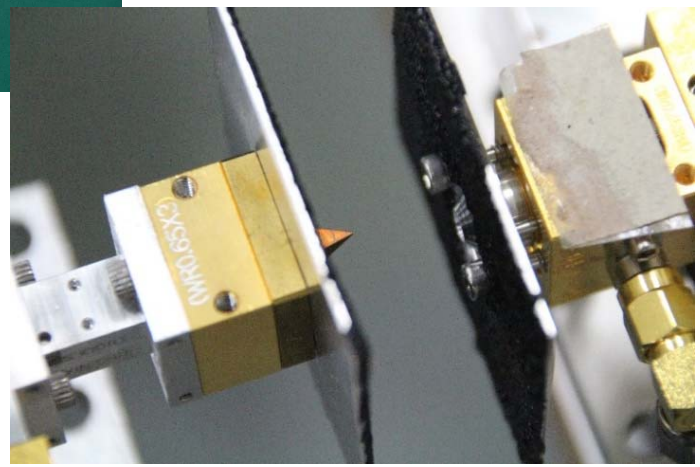
- 2 kinds of corrug. horns tested: profiled/conical
- Direct machined in 1 Aluminum block, including WG transition







Corrugations are
34 um wide
52 um deep



B11 (1.25-1.57 THz) corrugated horns

- Conical corrugated horns fabrication was successful by direct machining of a single Aluminum block!
  - Including circular to rect. WG transition

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Conclusions

- NAOJ Future Receiver Development Group focuses on:
  - ALMA 1, 2, 2+3 optics
  - UWB (7+8)
  - THz
  - Multibeam

See T. Kojima's presentation

- Good results in first 3 topics
- Multibeam research to be started soon
  - W. Shan: planar OMT / integrated multibeam receiver
  - Optimum coupling to offset pixels
  - Problem of small cryostat apertures vs #pixels