

# Waveguide-Integrated Photoconductive Receiver for THz Wireless Links

The 49th International Conference on Infrared, Millimeter, and Terahertz Waves  
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<sup>2</sup>Technische Universität Berlin, Institut für Festkörperphysik, Hardenbergstr. 36, 10623 Berlin, Germany



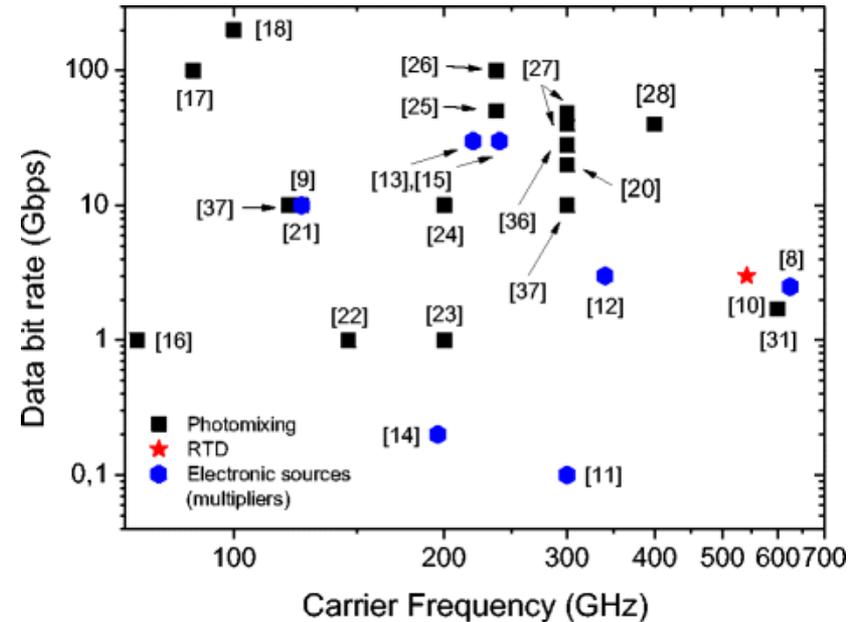
# THz communication links

## Electronic solutions

- Electronic oscillators + mixers
- High power
- Low bandwidth/tuneability

## Photonics driven solutions

- Photomixers
- Lower power output
- Large bandwidth/tuneability
- Low phase noise
- Integration with fibre-optic networks

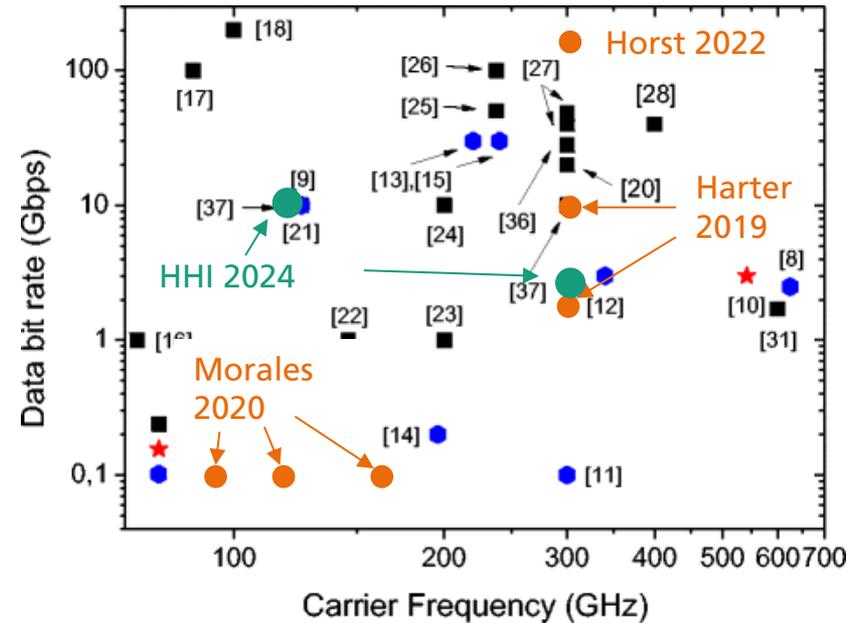


Ducournau, Guillaume, et al. "THz communications using photonics and electronic devices: the race to data-rate." *Journal of Infrared, Millimeter, and Terahertz Waves* 36 (2015): 198-220.

# THz communication links

## Full photonic links

- Photonic Tx and Rx
- Few links demonstrated
- Still not competitive



Ducournau, Guillaume, et al. "THz communications using photonics and electronic devices: the race to data-rate." *Journal of Infrared, Millimeter, and Terahertz Waves* 36 (2015): 198-220.

# THz communication links

## Full photonic links

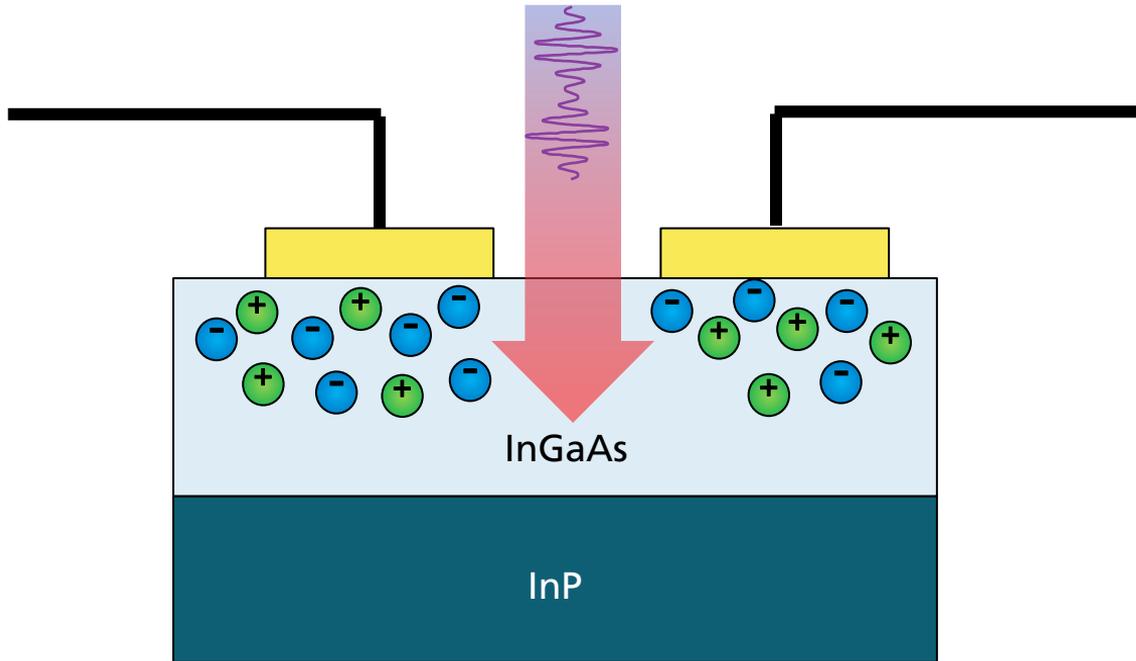
- Photonic Tx and Rx
- Few links demonstrated
- Still not competitive

**Better photonic Rx needed!**



Ducournau, Guillaume, et al. "THz communications using photonics and electronic devices: the race to data-rate." *Journal of Infrared, Millimeter, and Terahertz Waves* 36 (2015): 198-220.

# Photonic CW THz receivers



Light excites charge carriers

➤  $n_{e,h} \sim I_{Opt}$

➤  $G_{PCA} \sim n_{e,h}$

Antenna captures THz wave

➤  $U_{PCA} \sim E_{THz}$

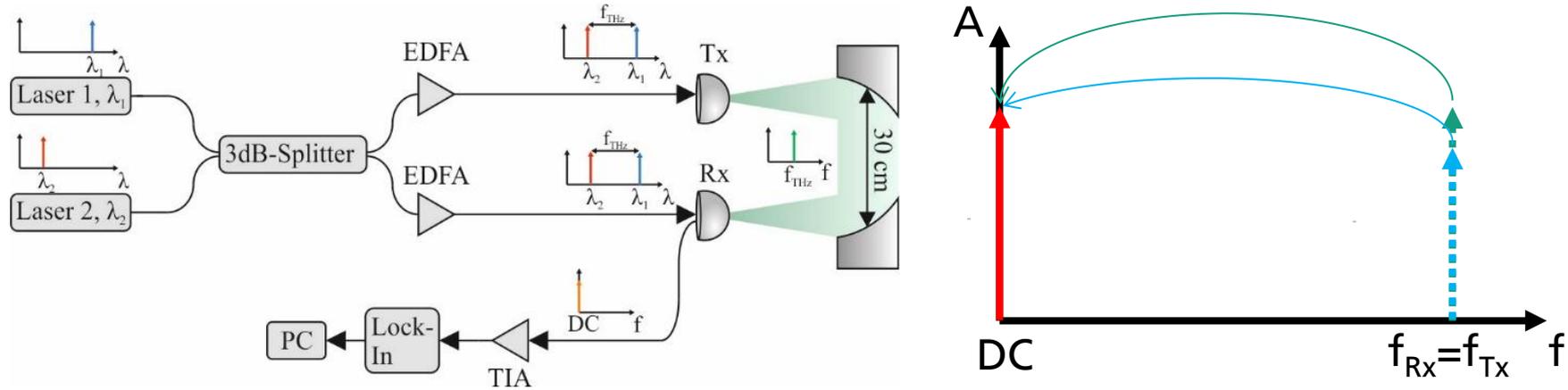
Current flows through PCA

➤  $I_{PCA} = G_{PCA} \cdot U_{PCA}$

➤  $= \frac{A}{2} \left( \cos \left( (\omega_{THz} - \omega_{opt})t \right) \right)$

# Requirements for Photonic THz Receivers

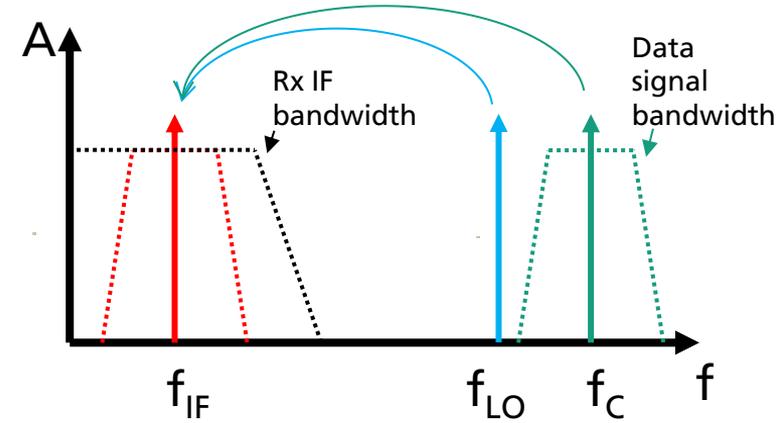
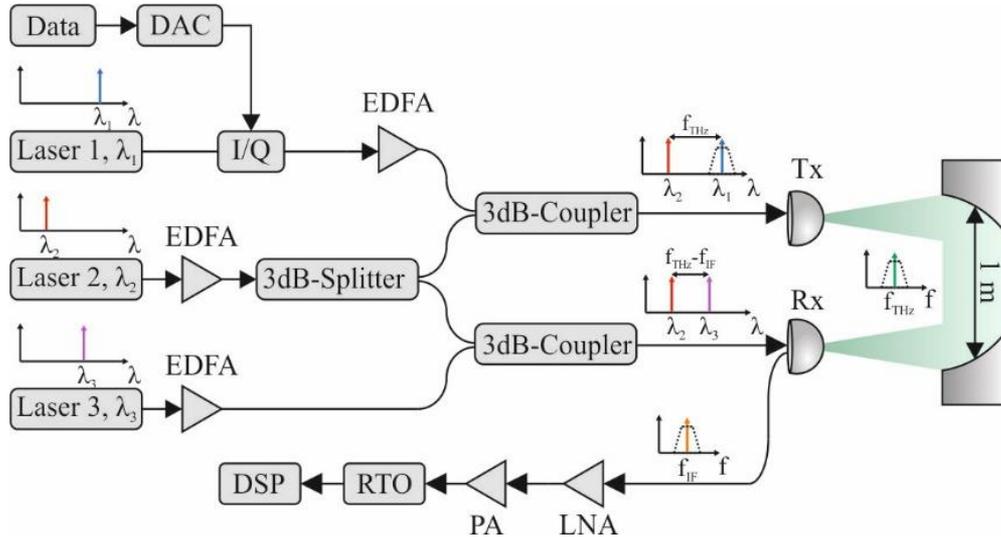
## Spectroscopy



➤ Large THz bandwidth

# Requirements for Photonic THZ Receivers

## Communication



➤ Large IF bandwidth

# Previous receiver

## Semiconductor material

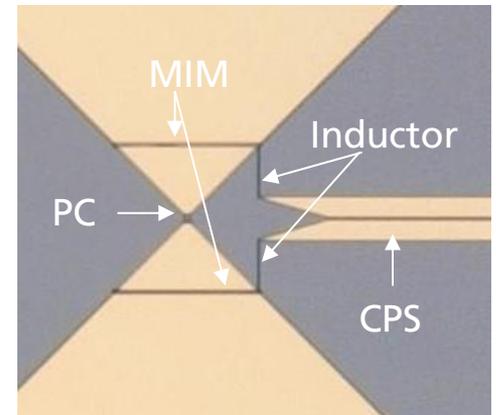
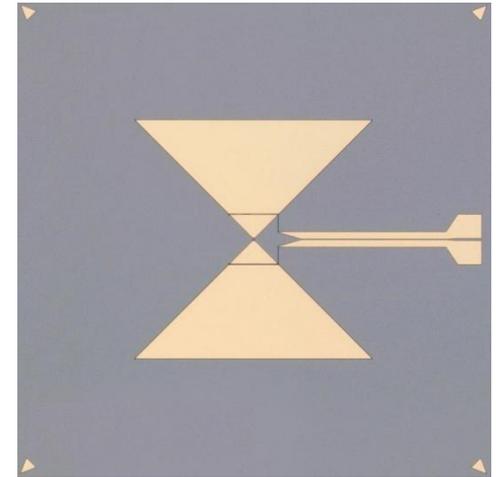
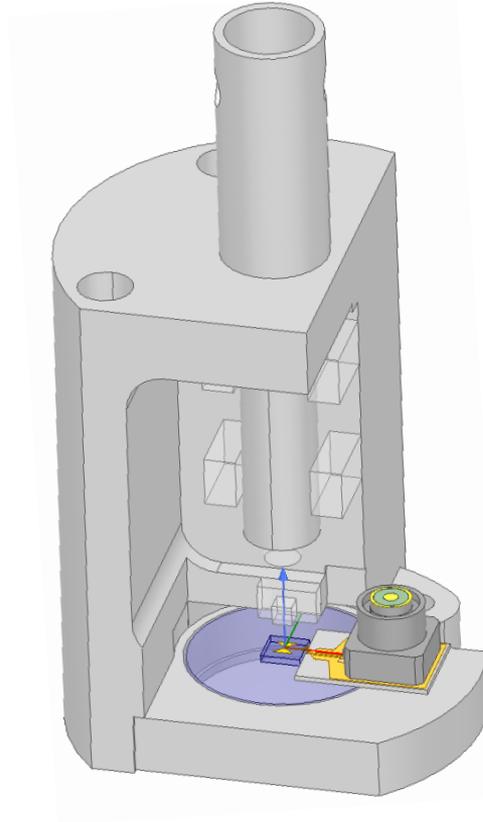
- InGaAs:Fe
- 350  $\mu\text{m}$  InP:Fe substrate

## RF passive structures

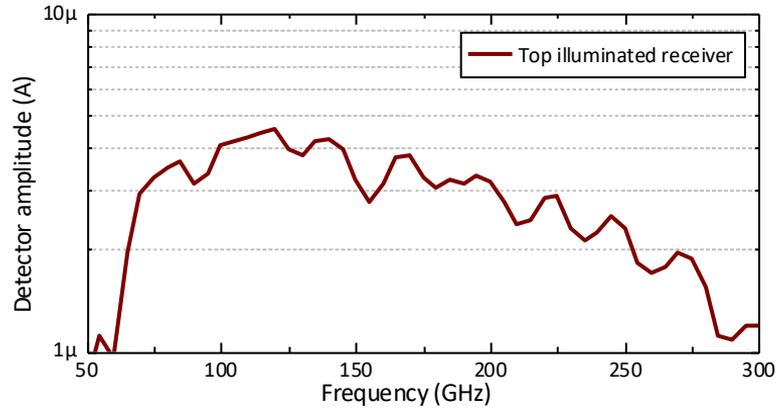
- MIM capacitor as highpass
- Inductive lines as lowpass
- CPS line for Signal transmission

## Packaging

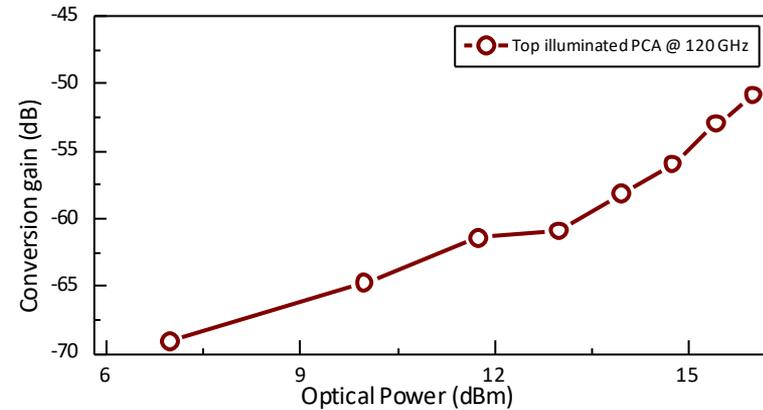
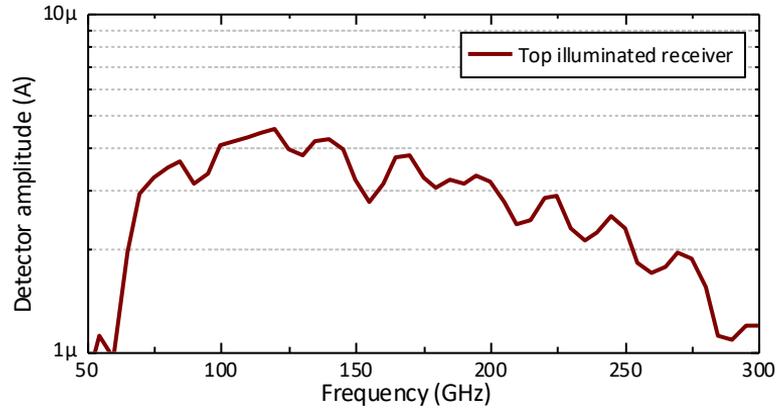
- RF connector on ceramic
- Cylindrical pig-tailed Module
- Top illumination of PCA



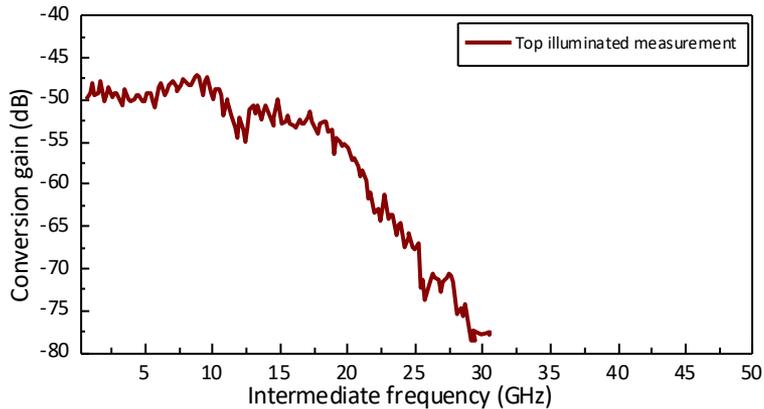
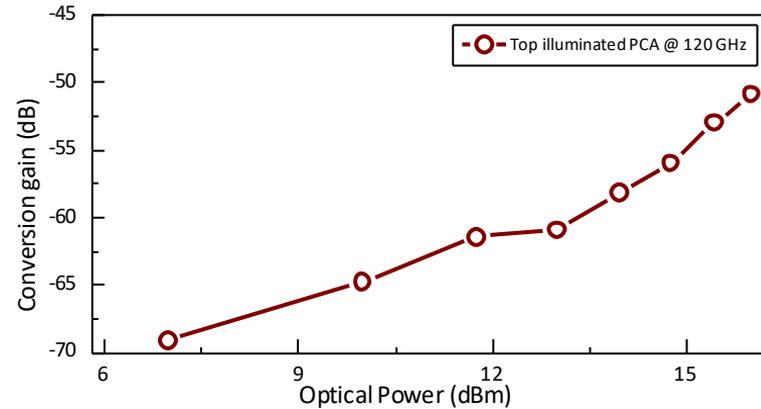
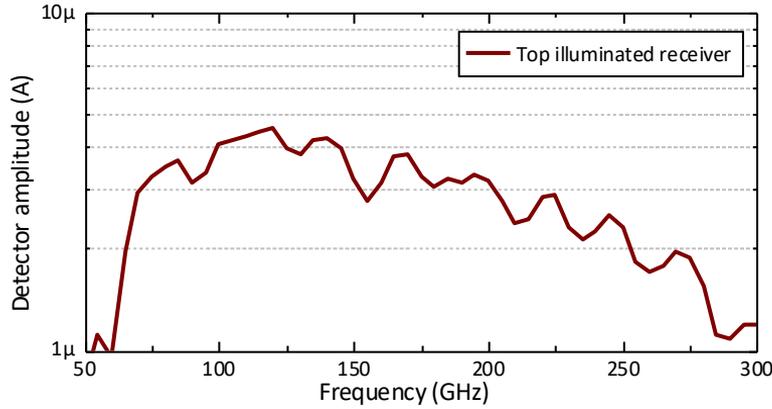
# Characterization results with top-illuminated PCA



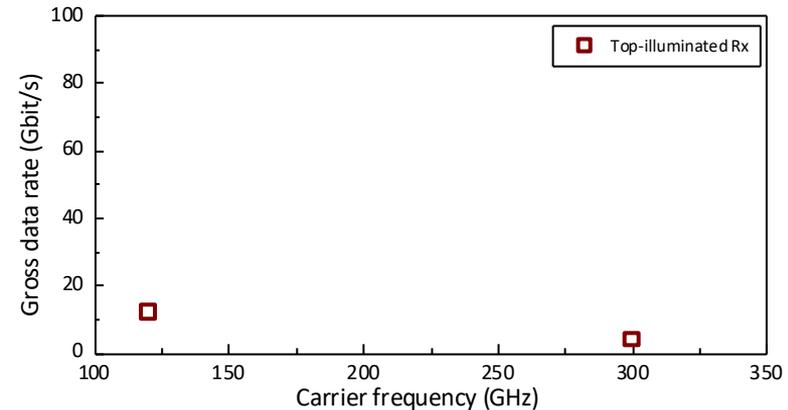
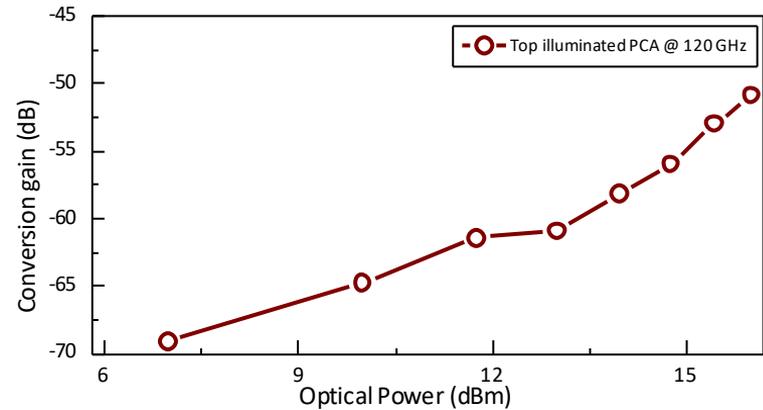
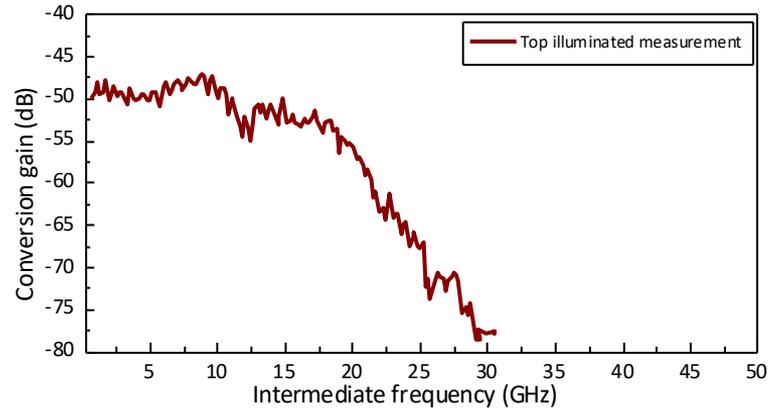
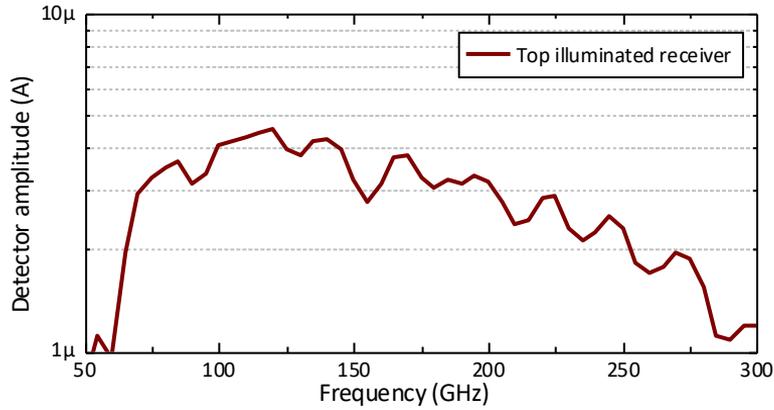
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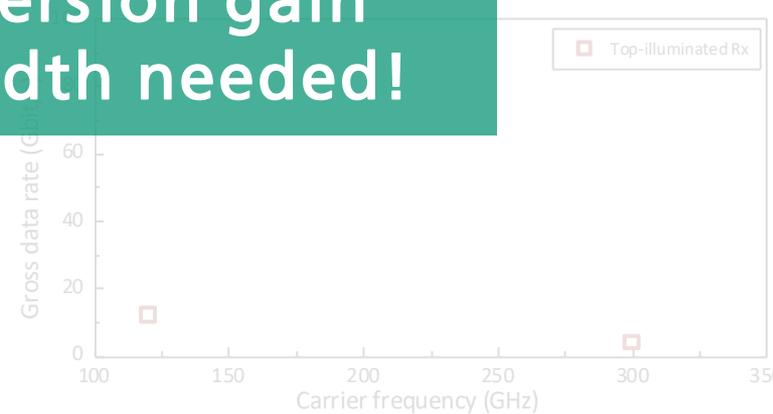
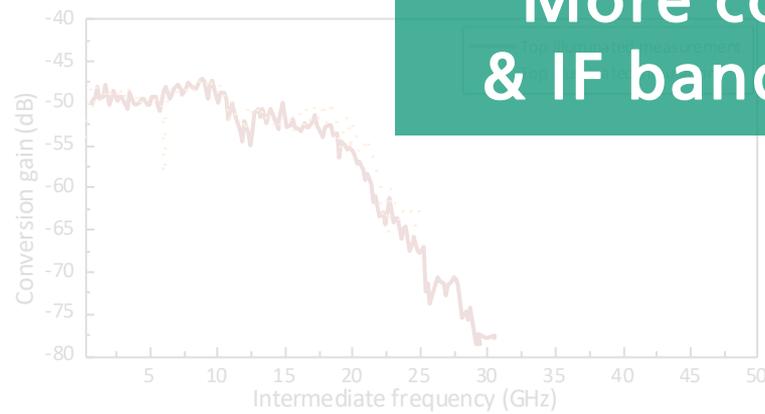
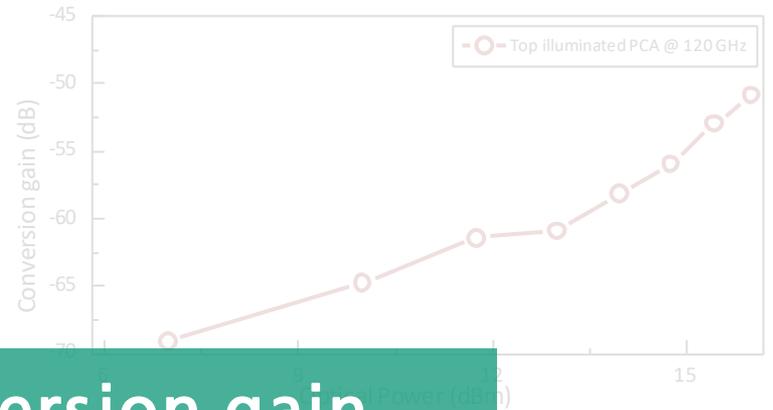
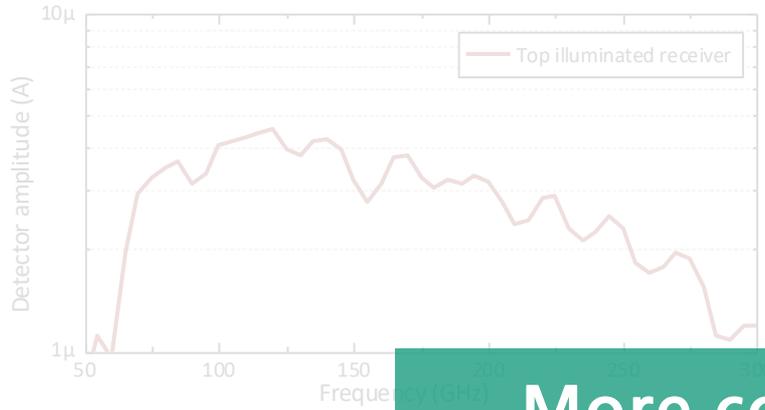
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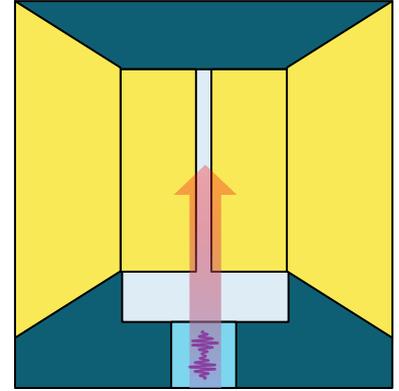
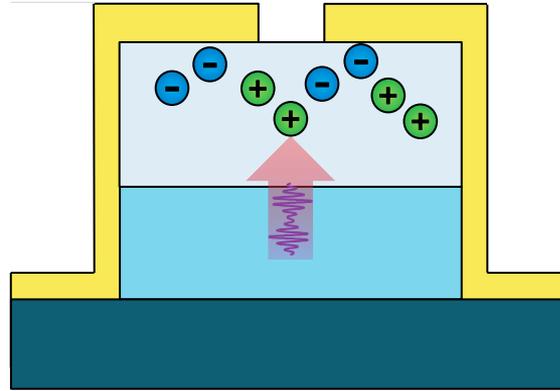
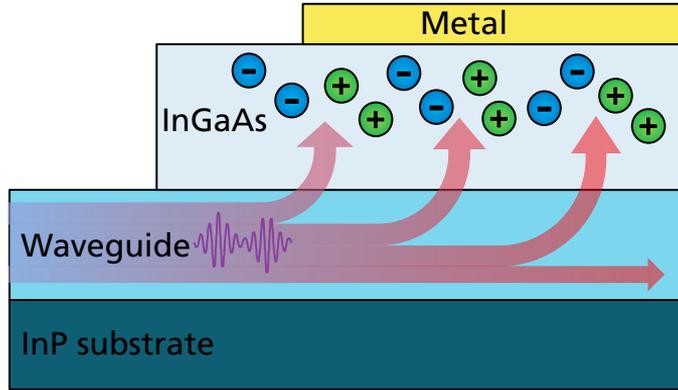


# Previous results



**More conversion gain & IF bandwidth needed!**

# Waveguide integrated PCAs



## Evanescent coupling from waveguide

- Absorption depends on length
- Absorption confined to thin InGaAs layer

## No interdigitated fingers necessary

- Gap has lower capacitance

# WIN-PCA heterodyne detector

## Semiconductor

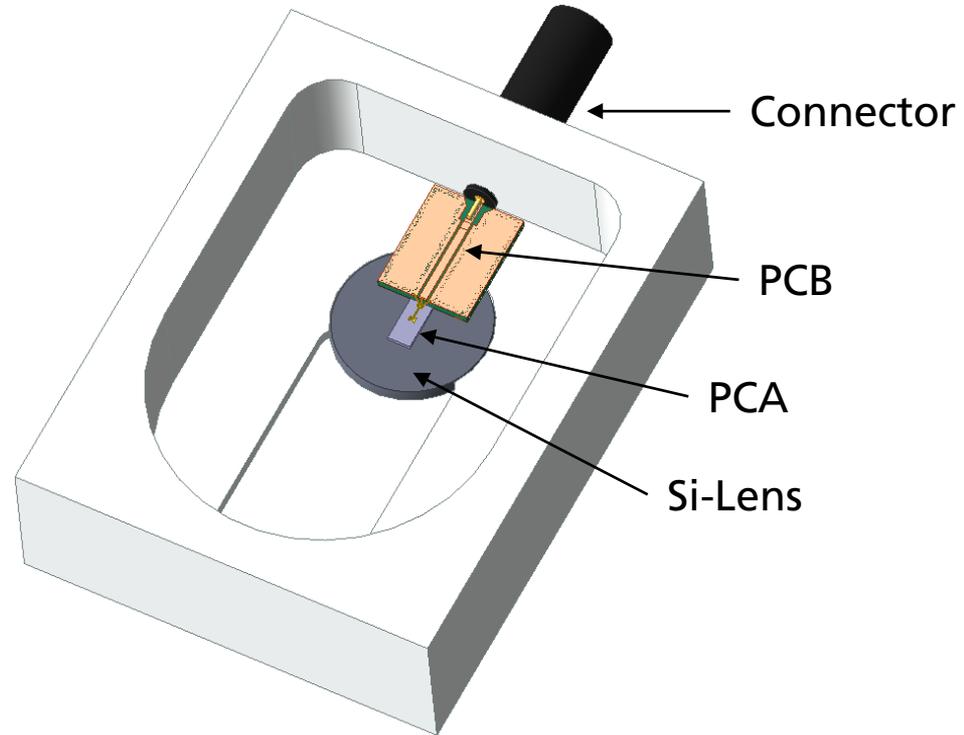
- InGaAs:Fe on optical waveguide
- 250  $\mu\text{m}$  InP:Fe substrate

## RF passive structures

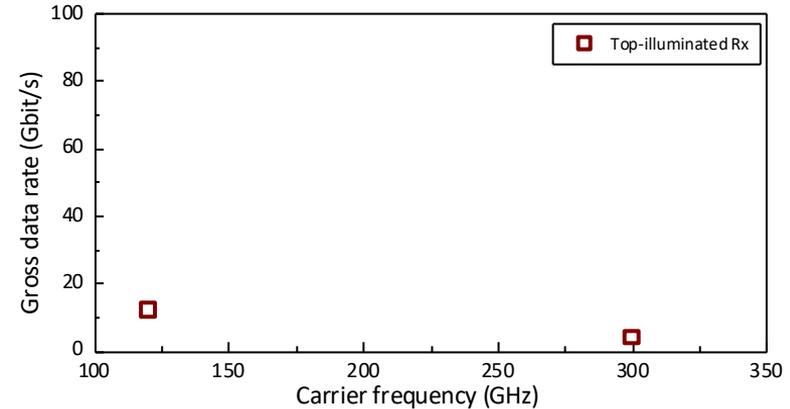
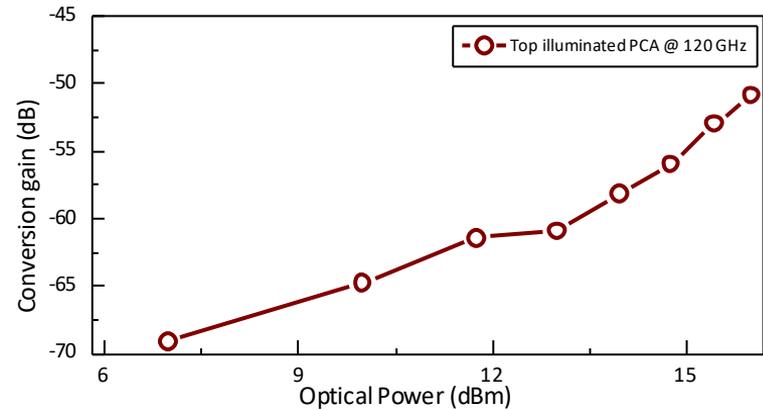
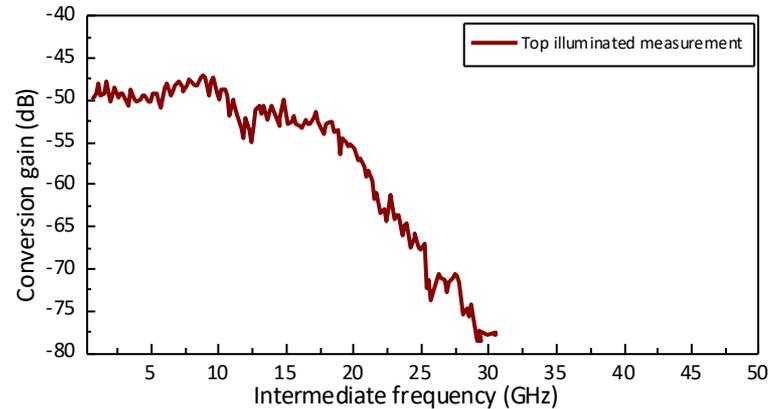
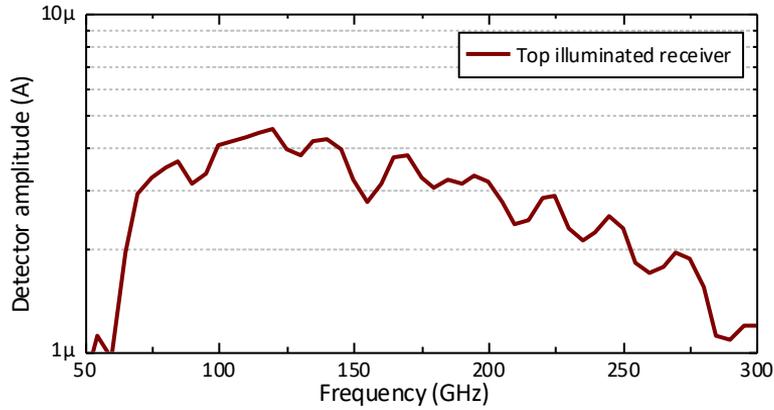
- Inductive lines as lowpass
- CPW line for Signal transmission

## Packaging

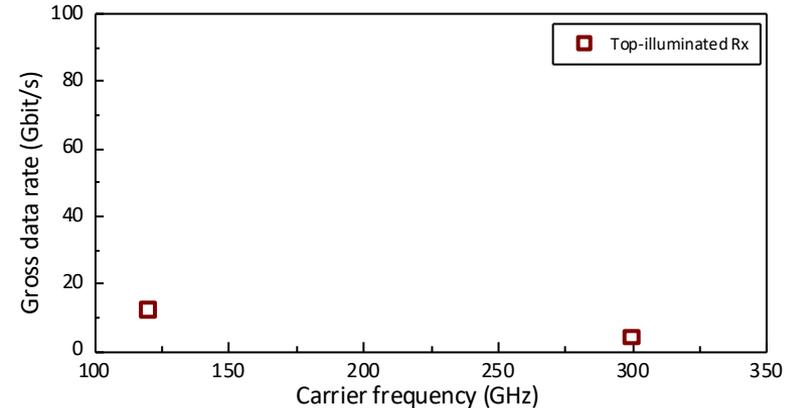
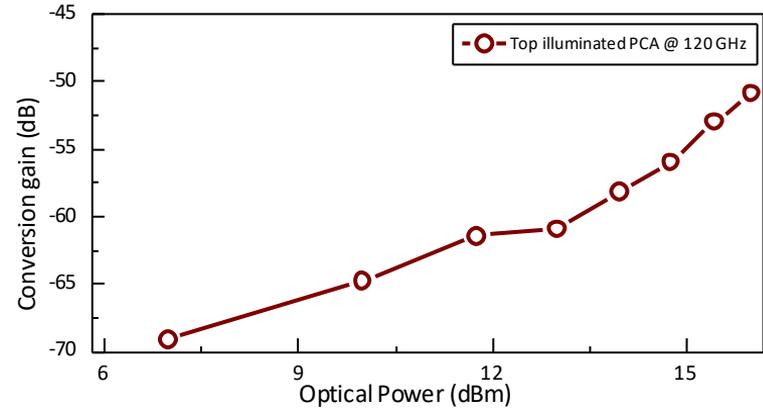
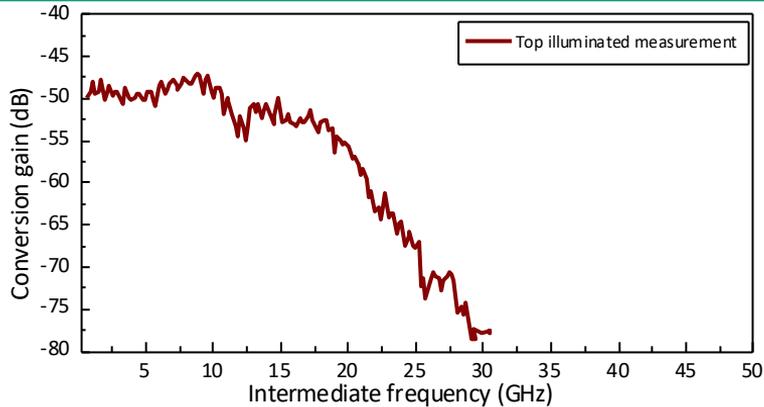
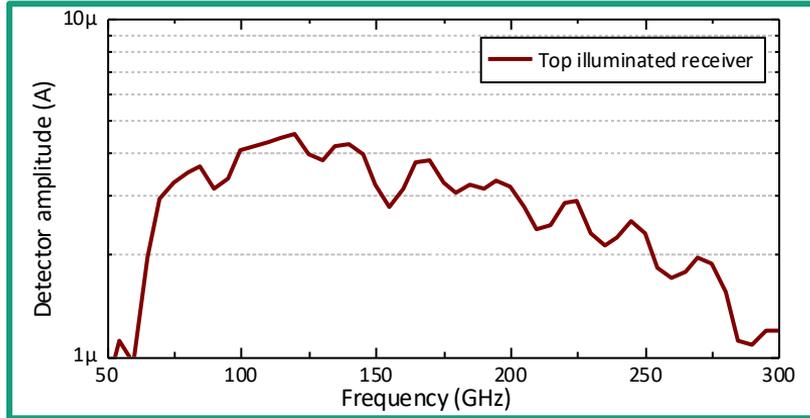
- FR-4 interposer
- Wall-mount SMA connector
- Edge coupled win-PCA
- Pig-tailed Module



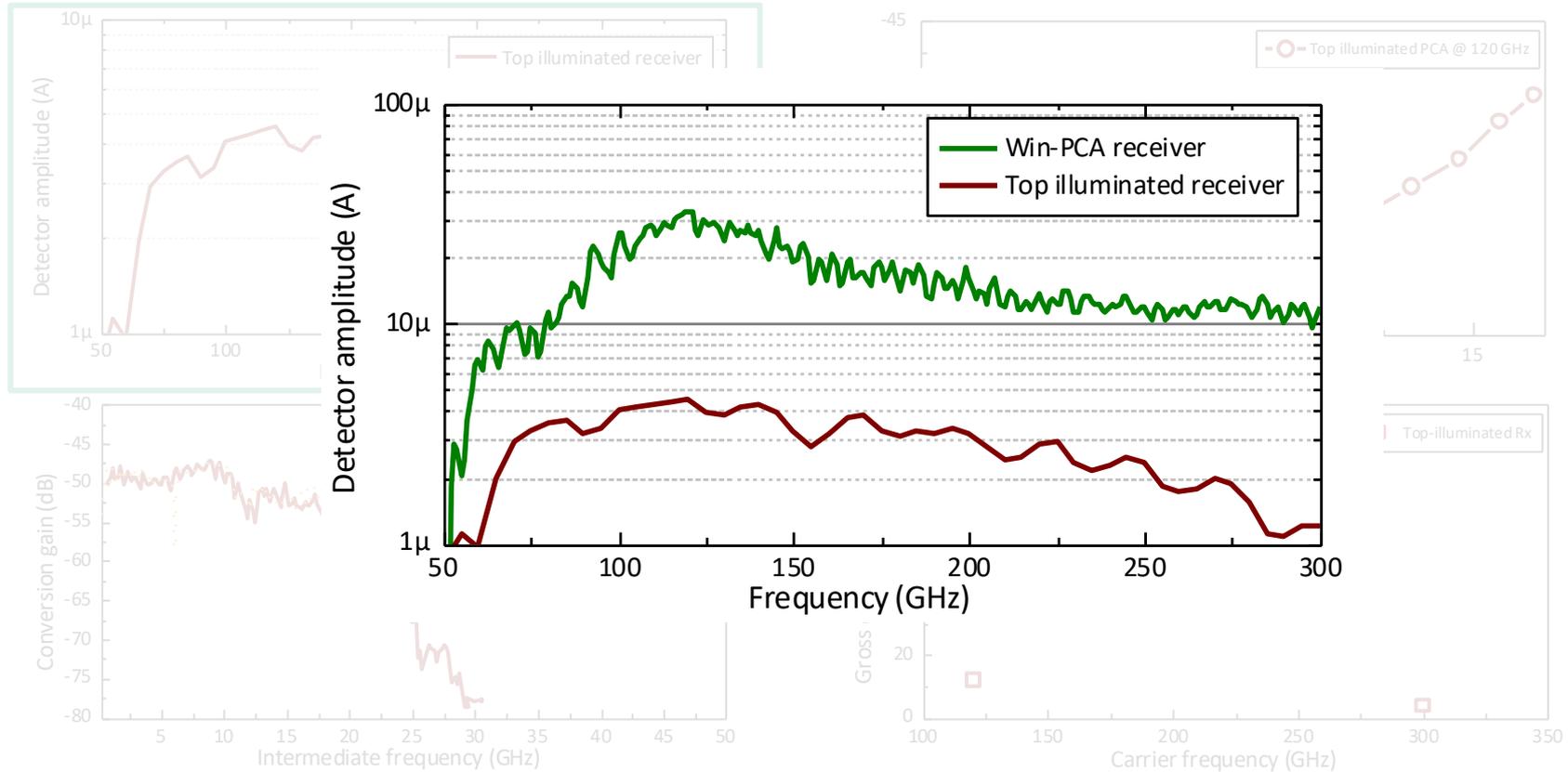
# Characterization results with win-PCA



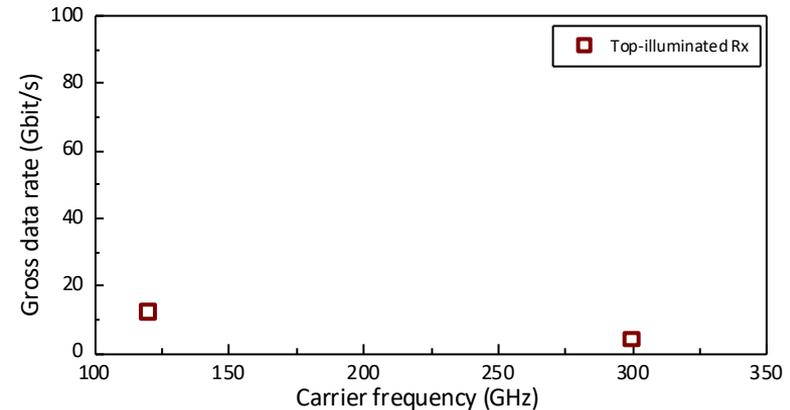
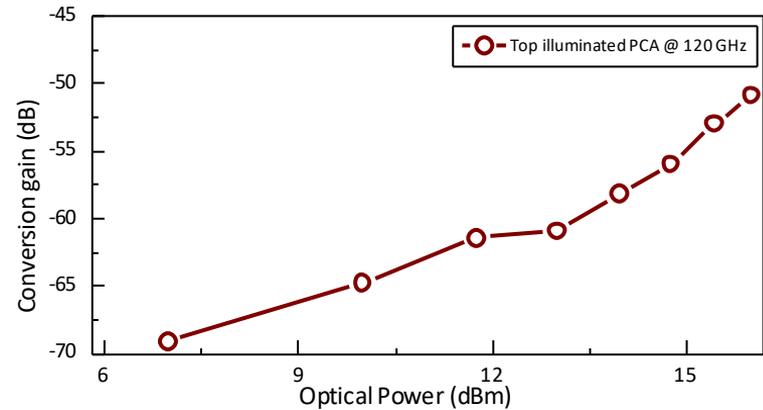
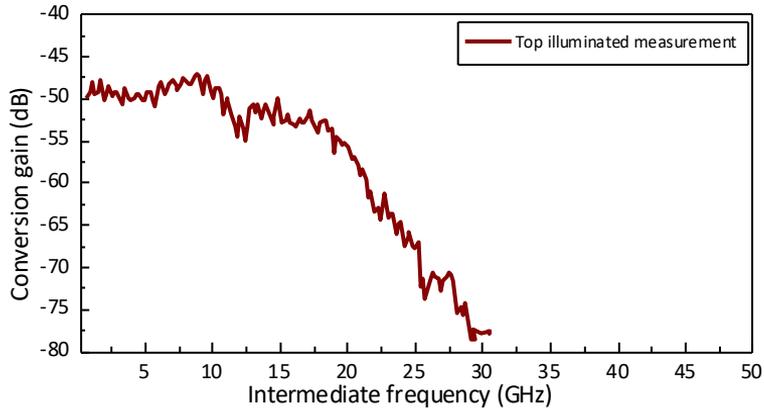
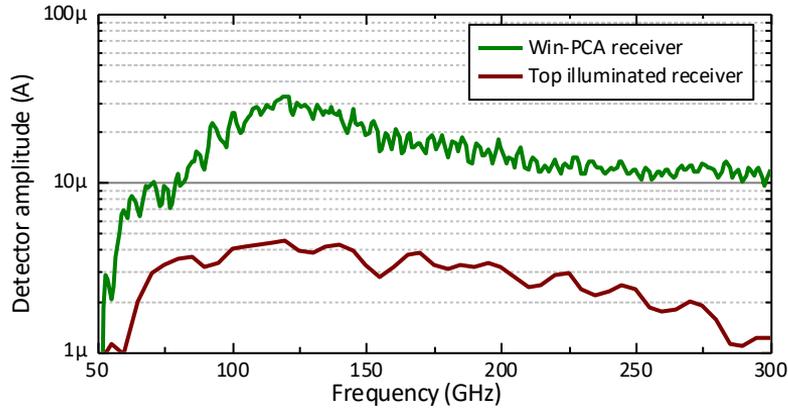
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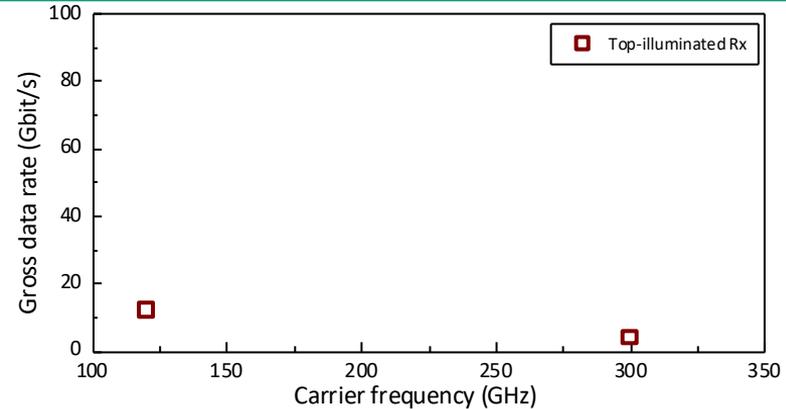
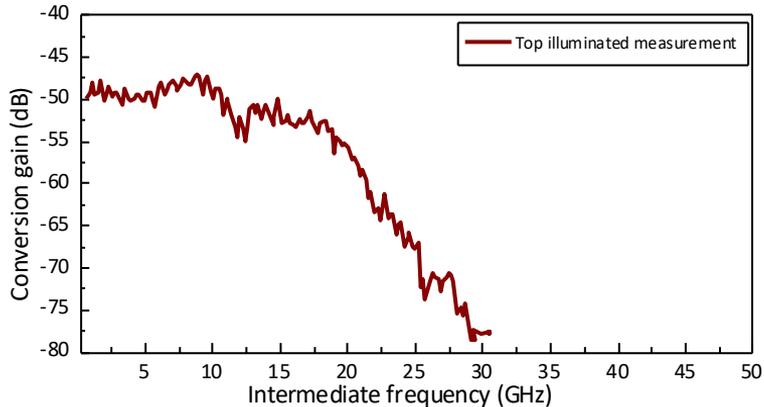
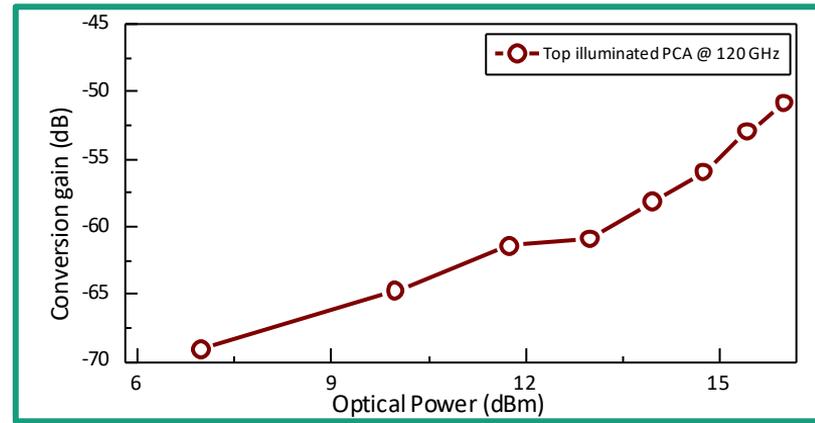
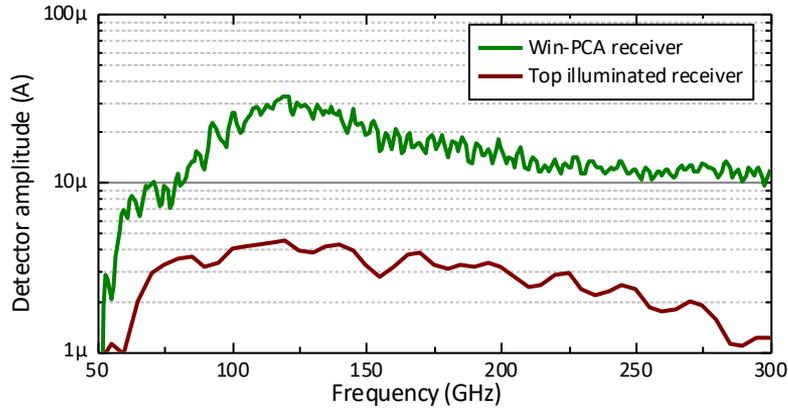
# New results



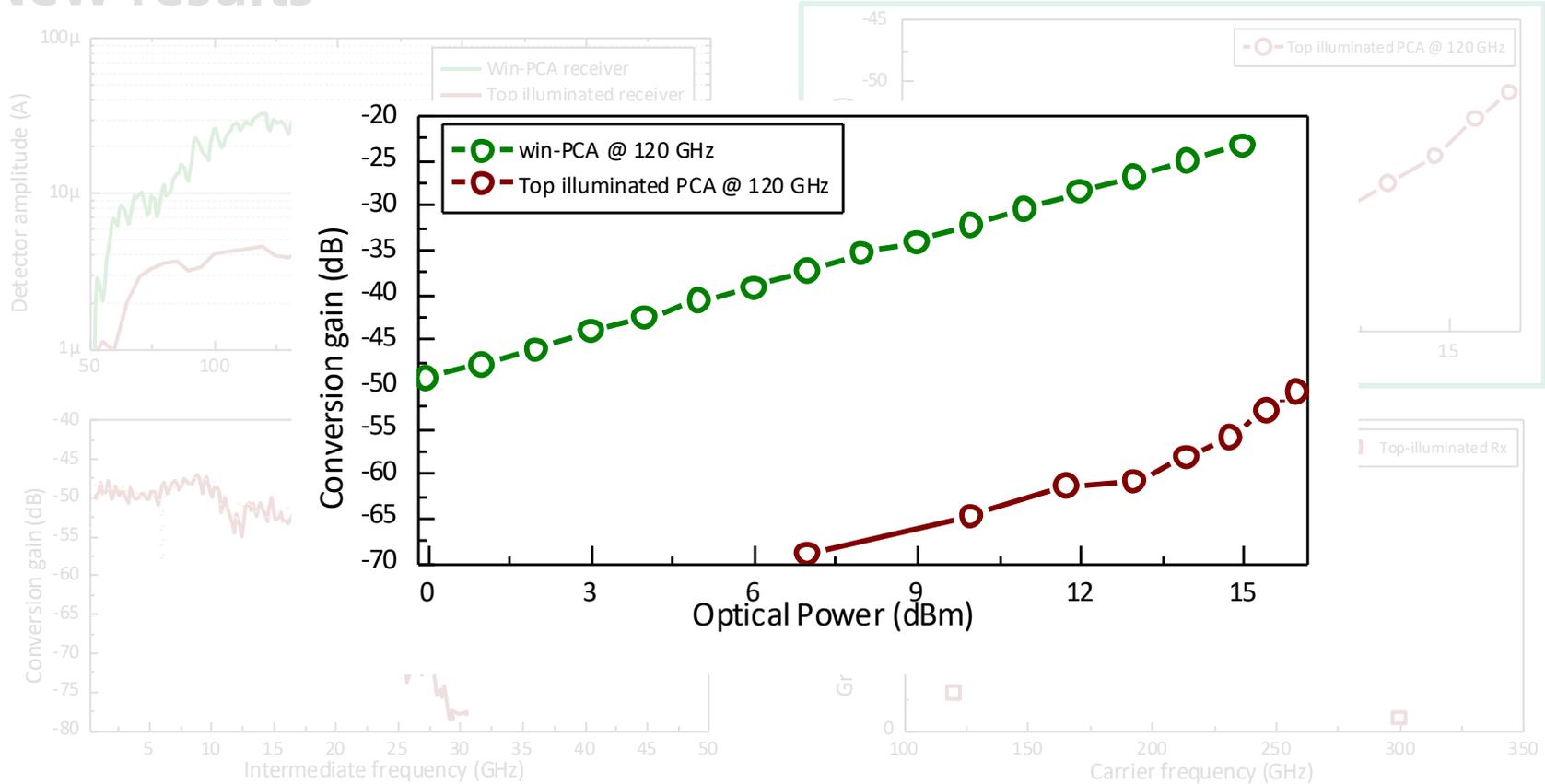
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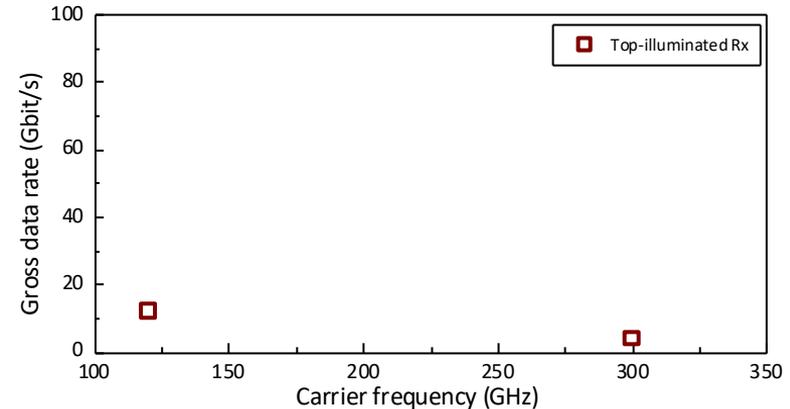
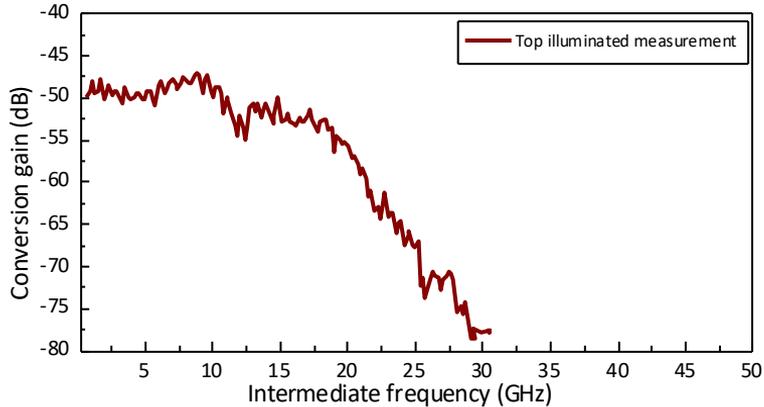
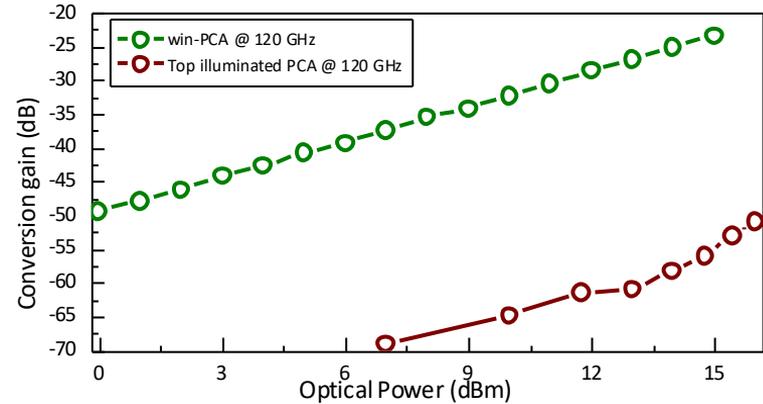
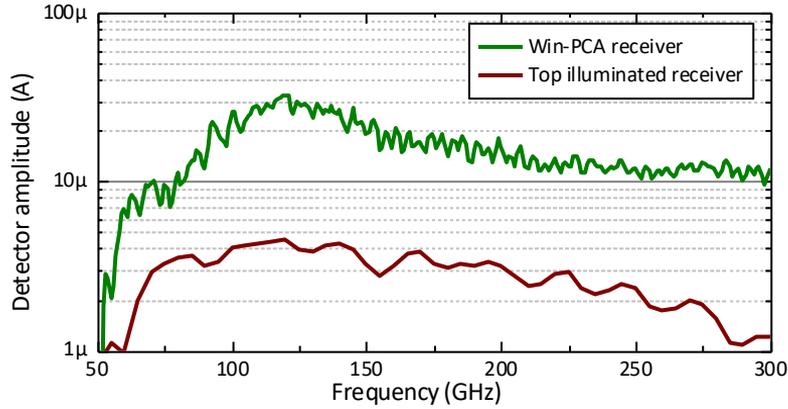
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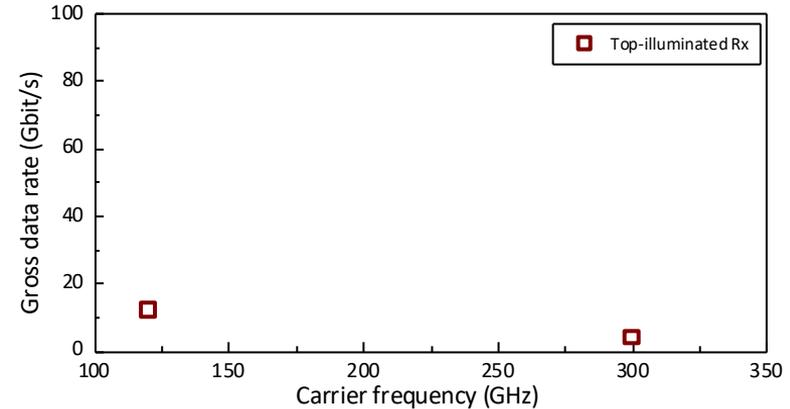
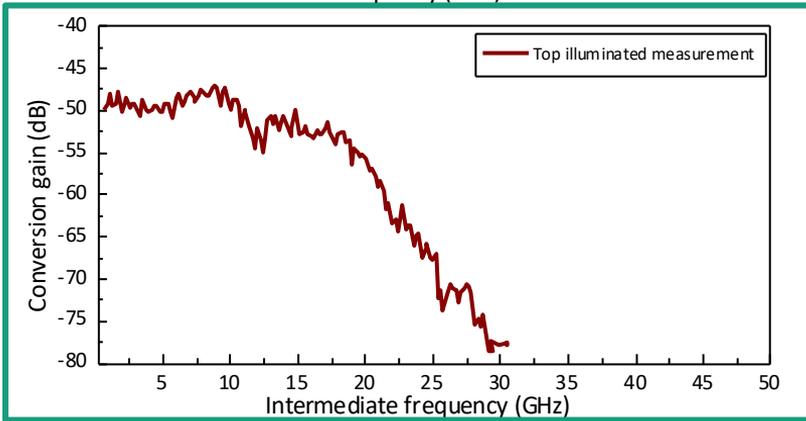
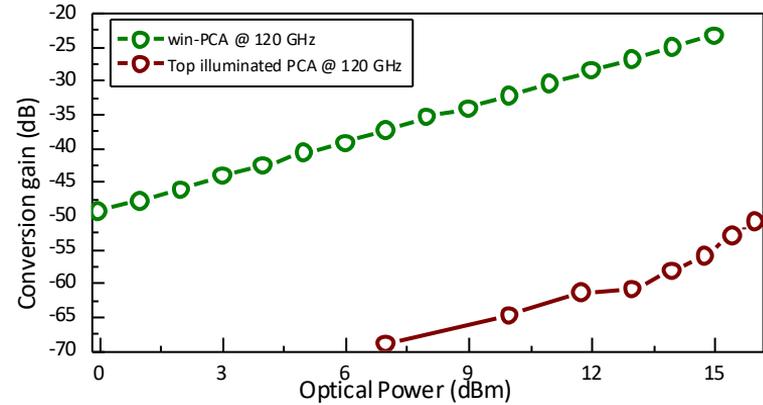
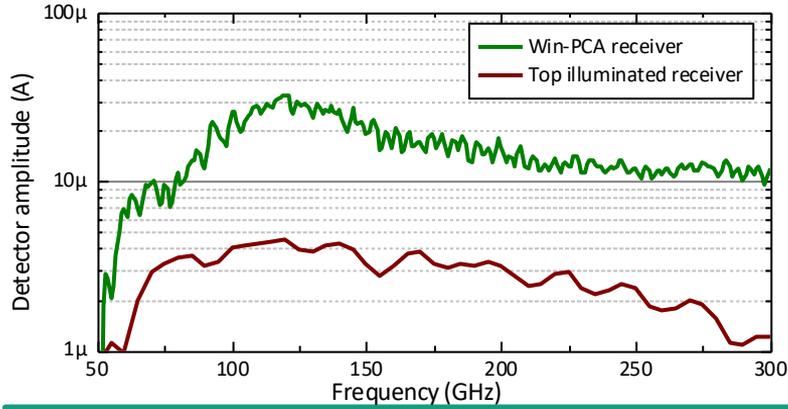
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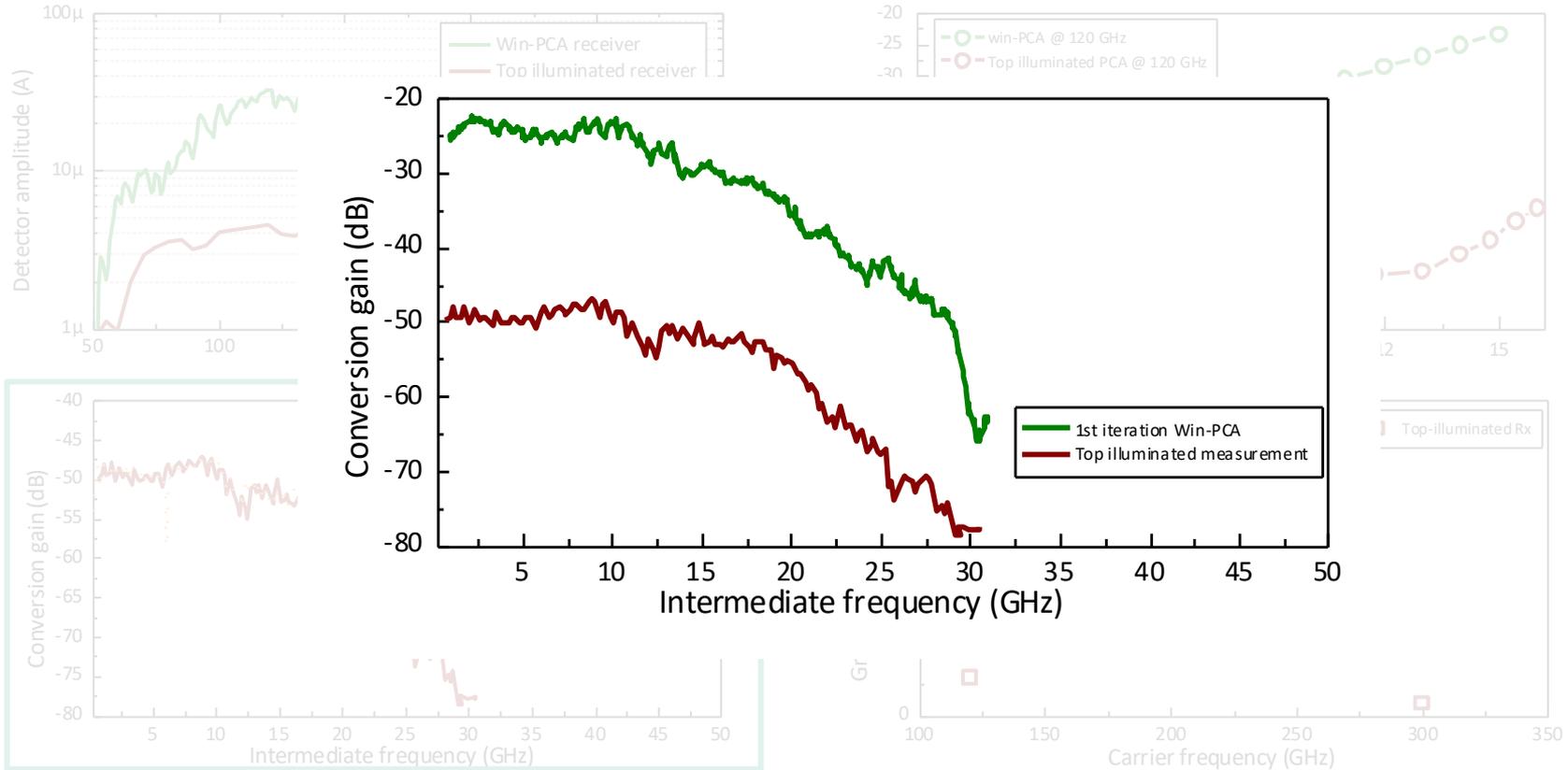
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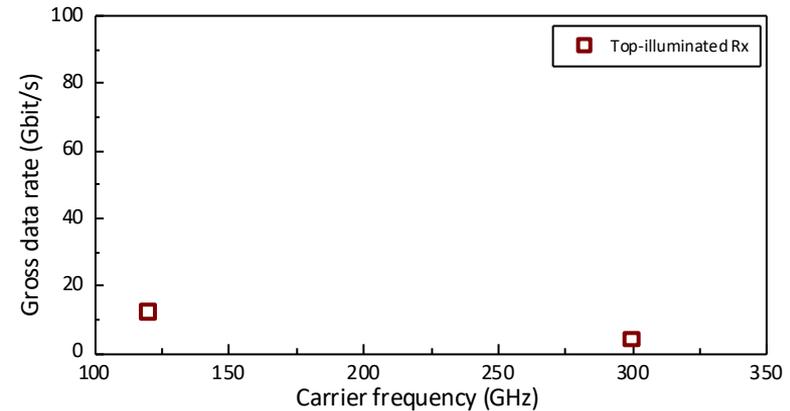
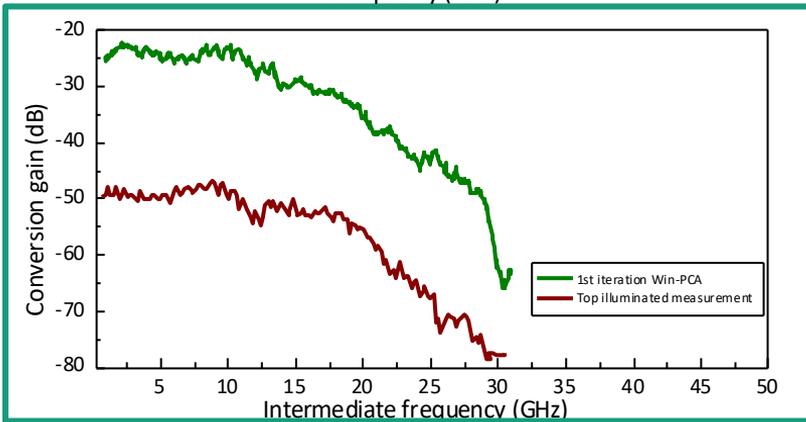
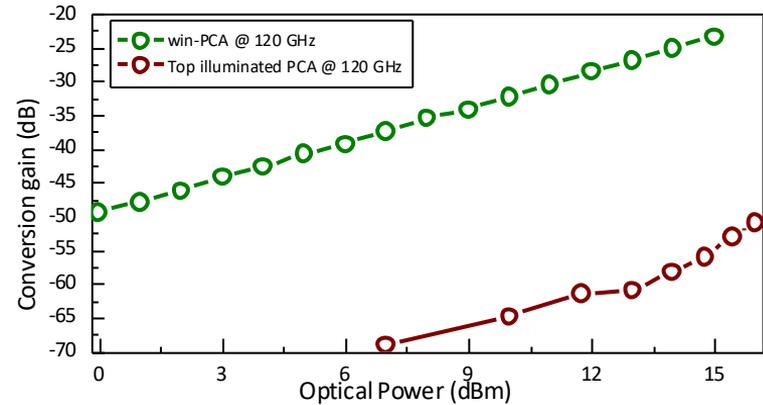
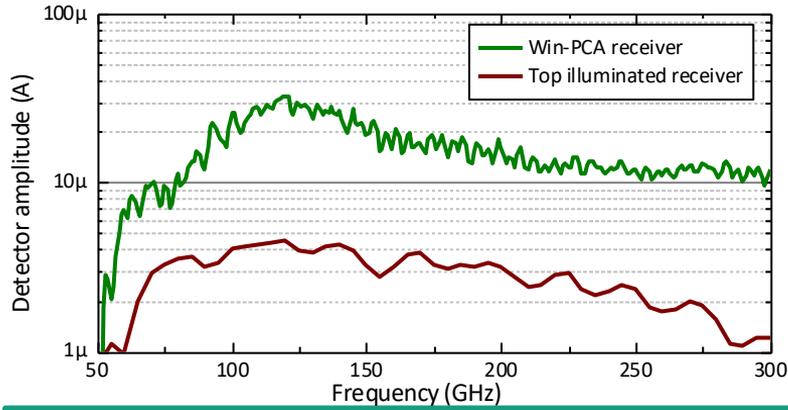
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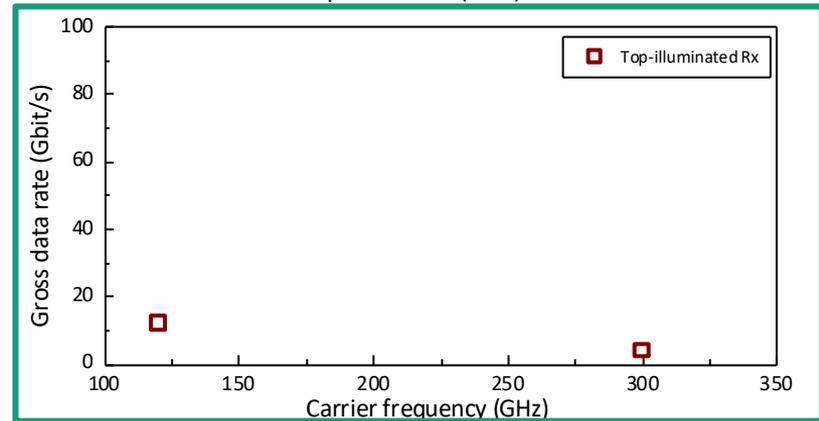
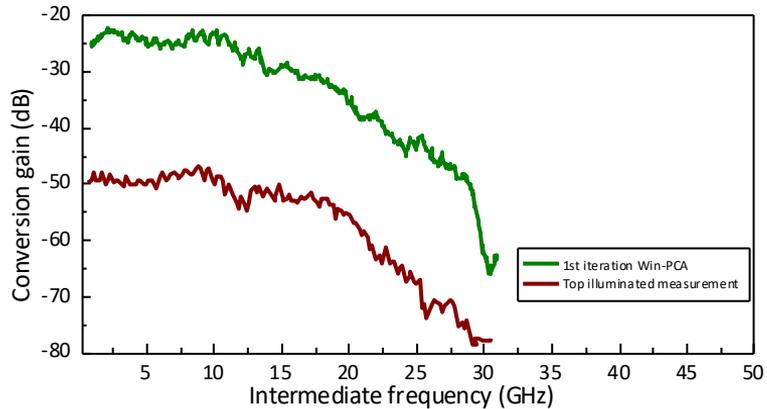
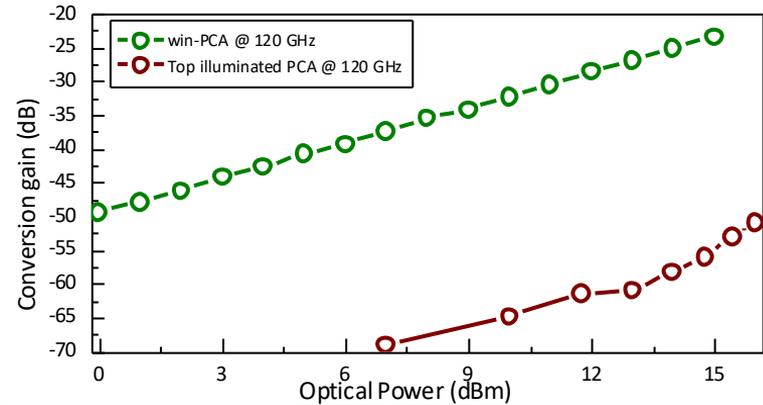
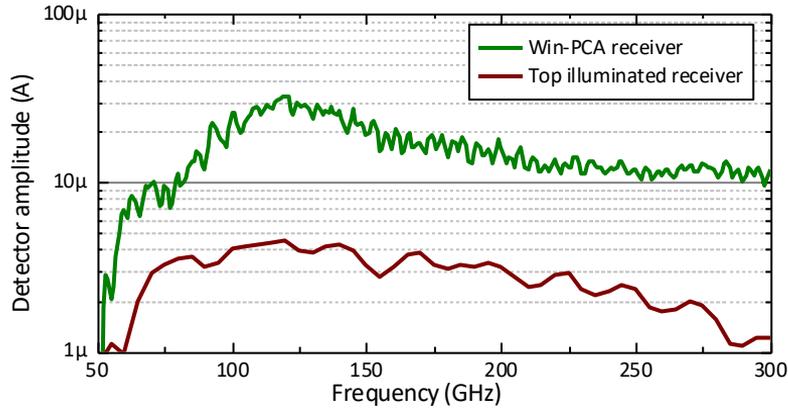
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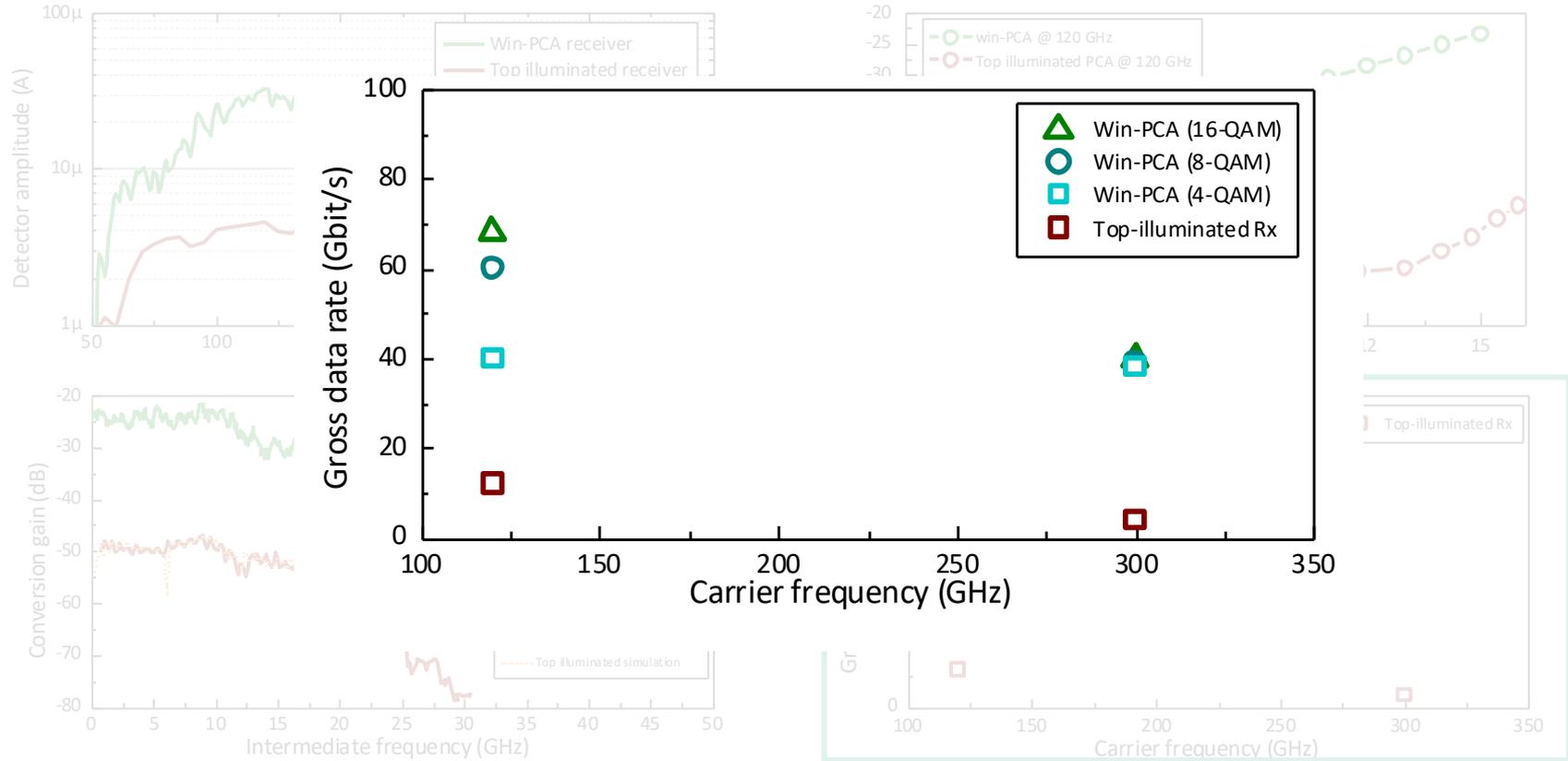
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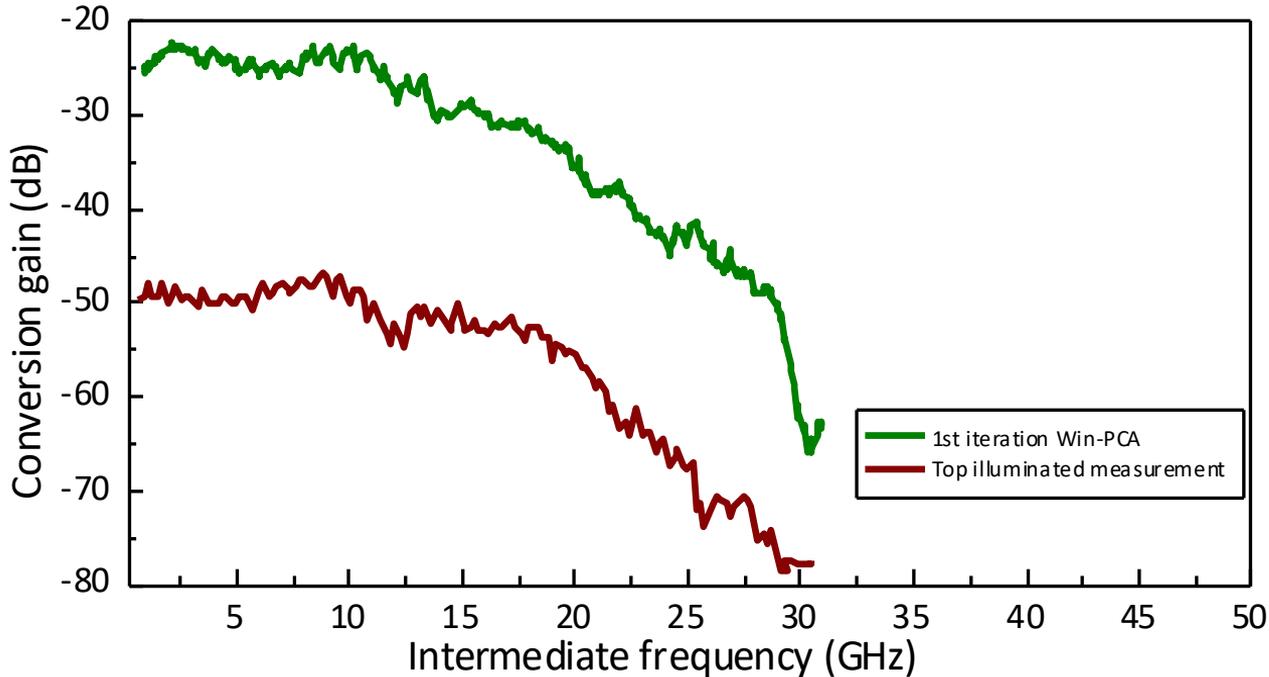
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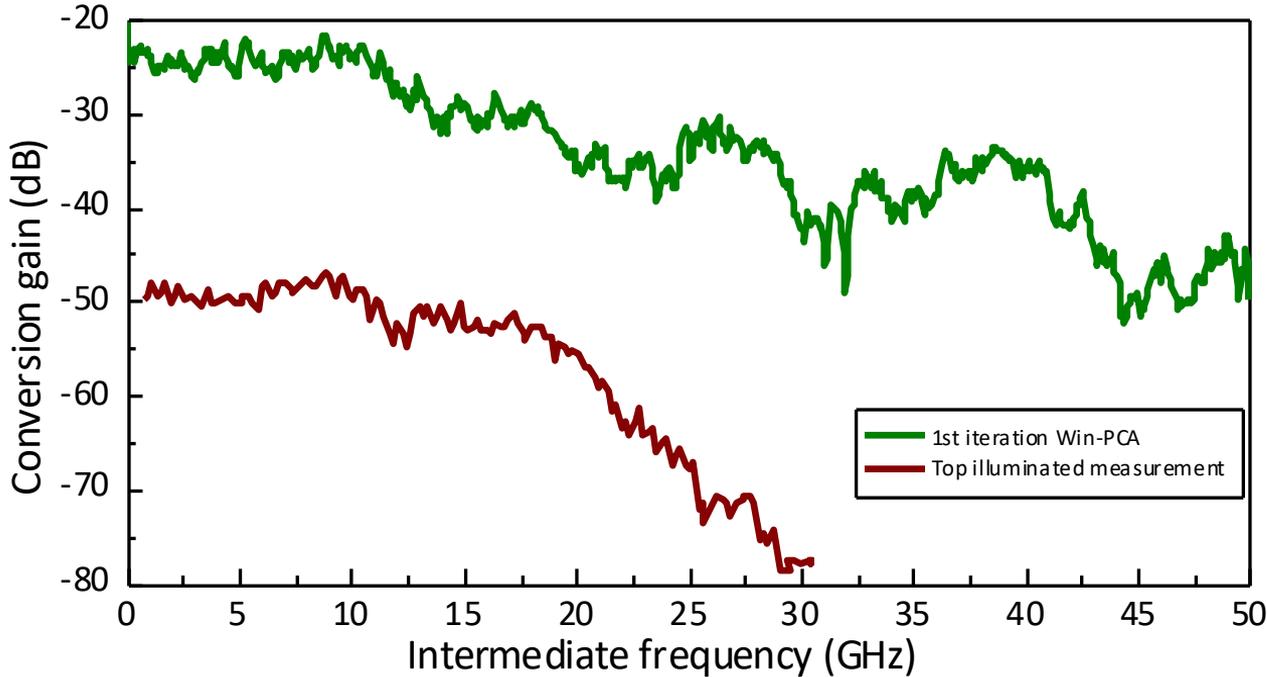


# Not enough IF bandwidth



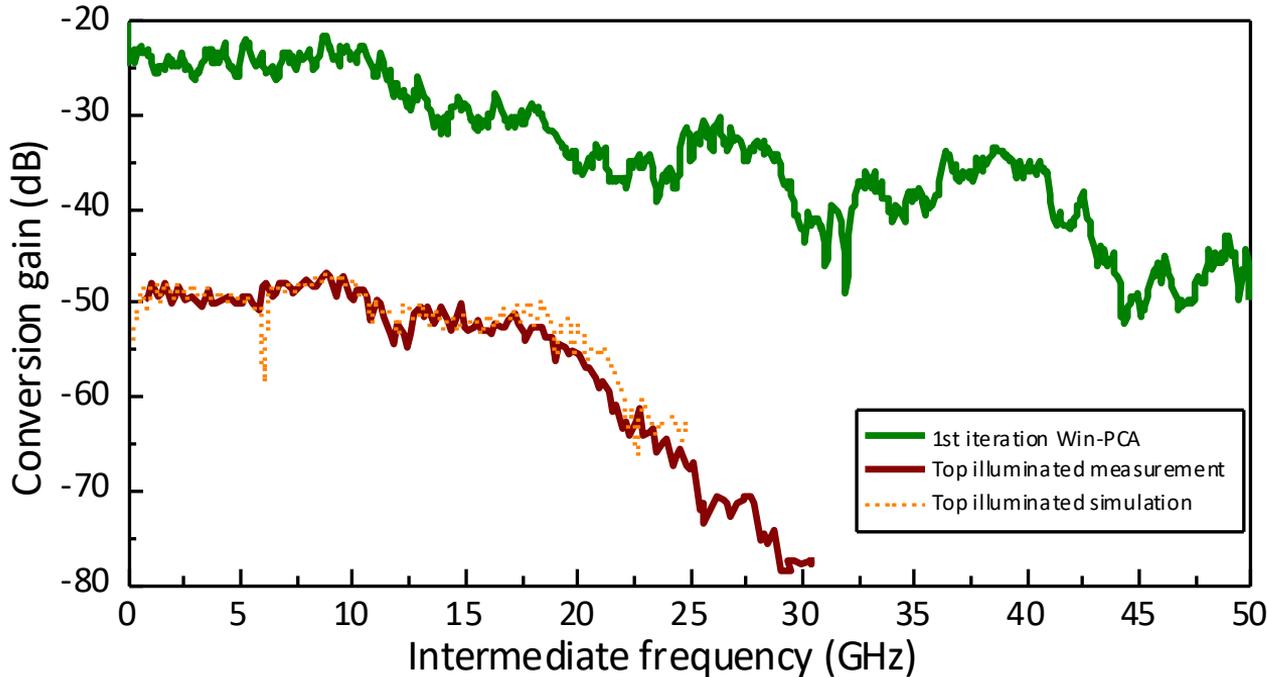
- Output amplifier has only 21 GHz bandwidth

# Better IF bandwidth



■ Output amplifier has only 21 GHz bandwidth

# Better IF bandwidth



- Output amplifier has only 21 GHz bandwidth
- Still room for improvement!

# WIN-PCA heterodyne detector – version 2.0

## Semiconductor

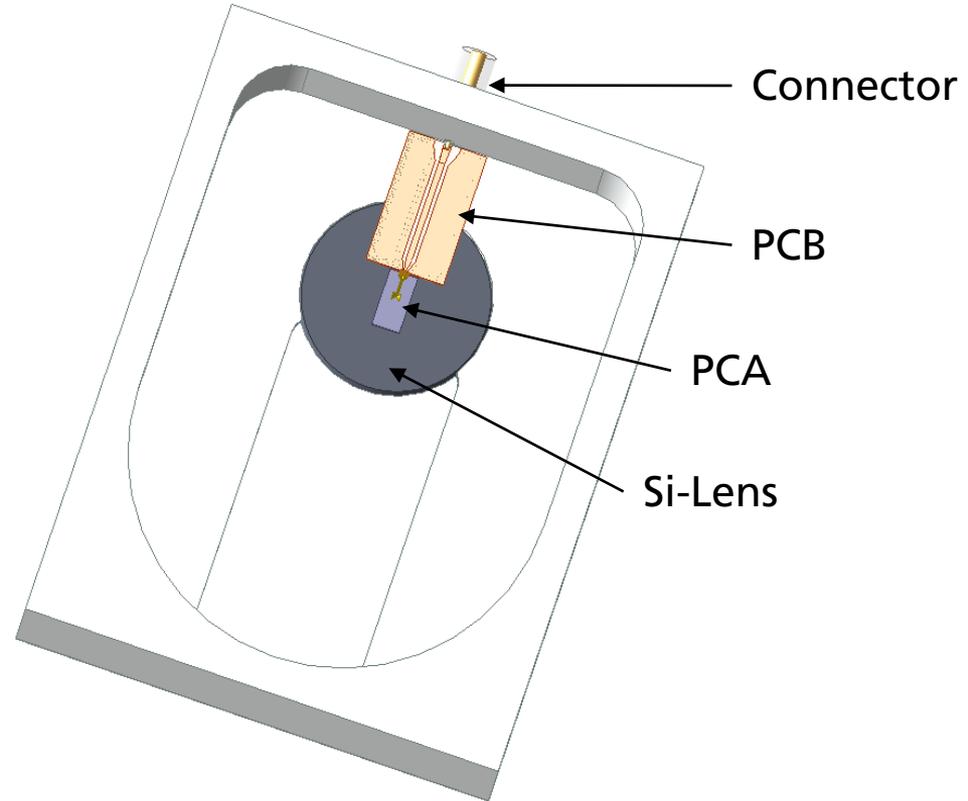
- InGaAs:Fe on optical waveguide
- 250  $\mu\text{m}$  InP:Fe substrate

## RF passive structures

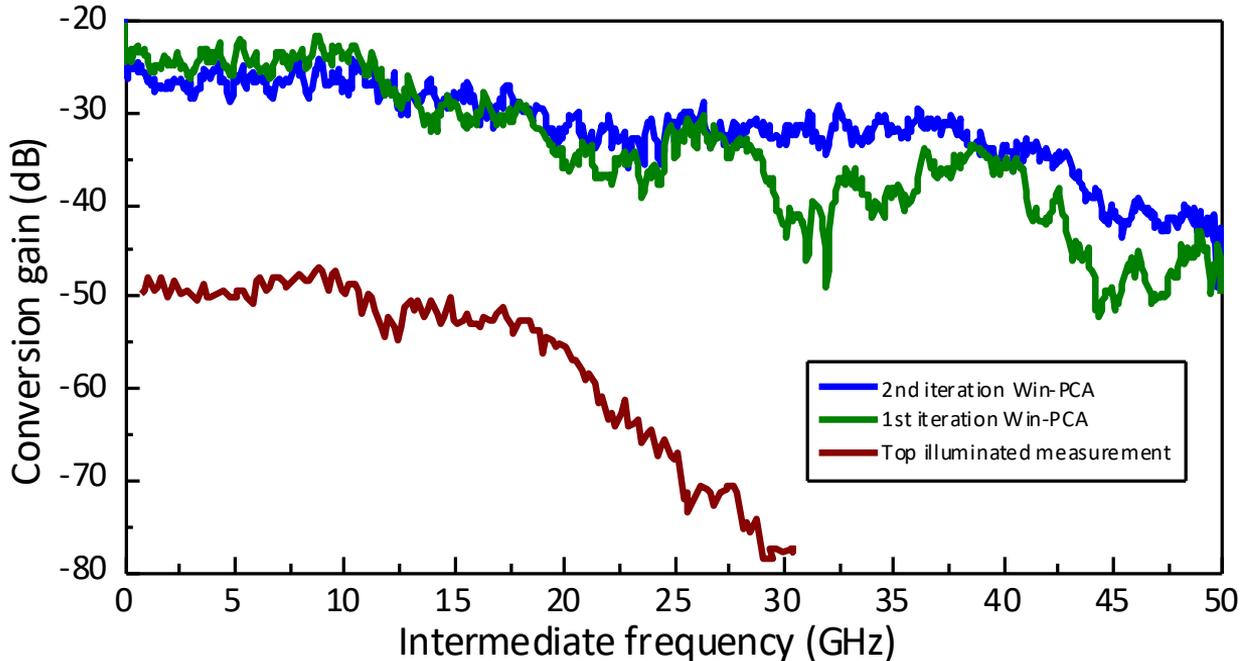
- Inductive lines as lowpass
- CPW line for Signal transmission

## Packaging

- Rogers interposer
- 1.85mm (V-) connector
- Edge coupled win-PCA
- Pig-tailed Module

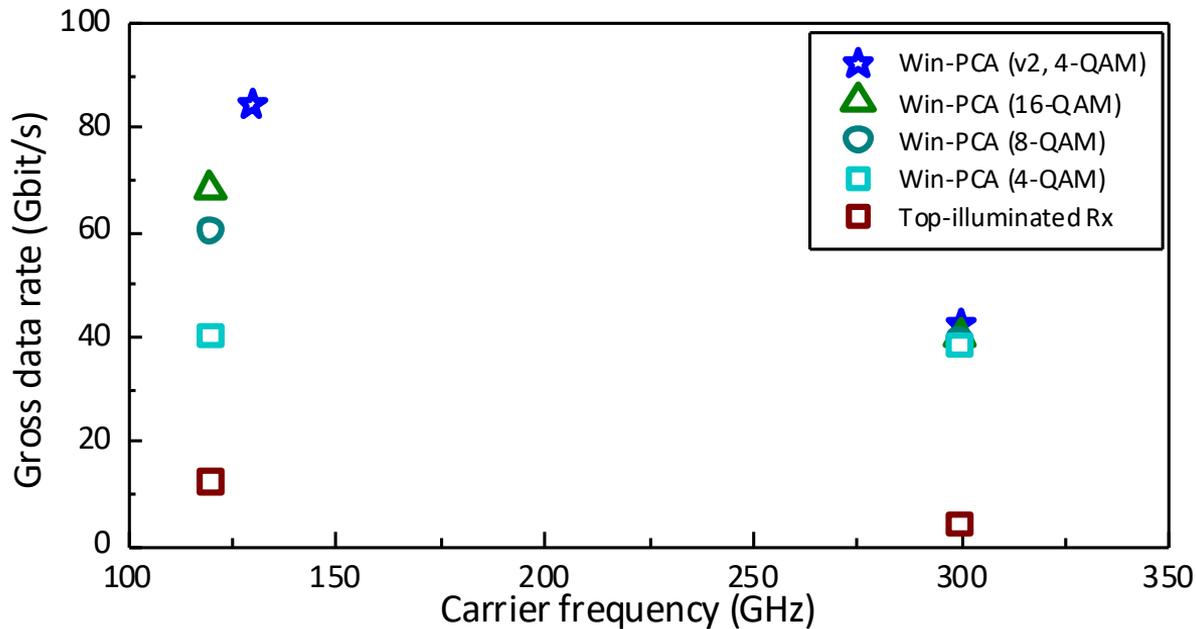


# Win-PCA receiver v2.0 – IF spectrum



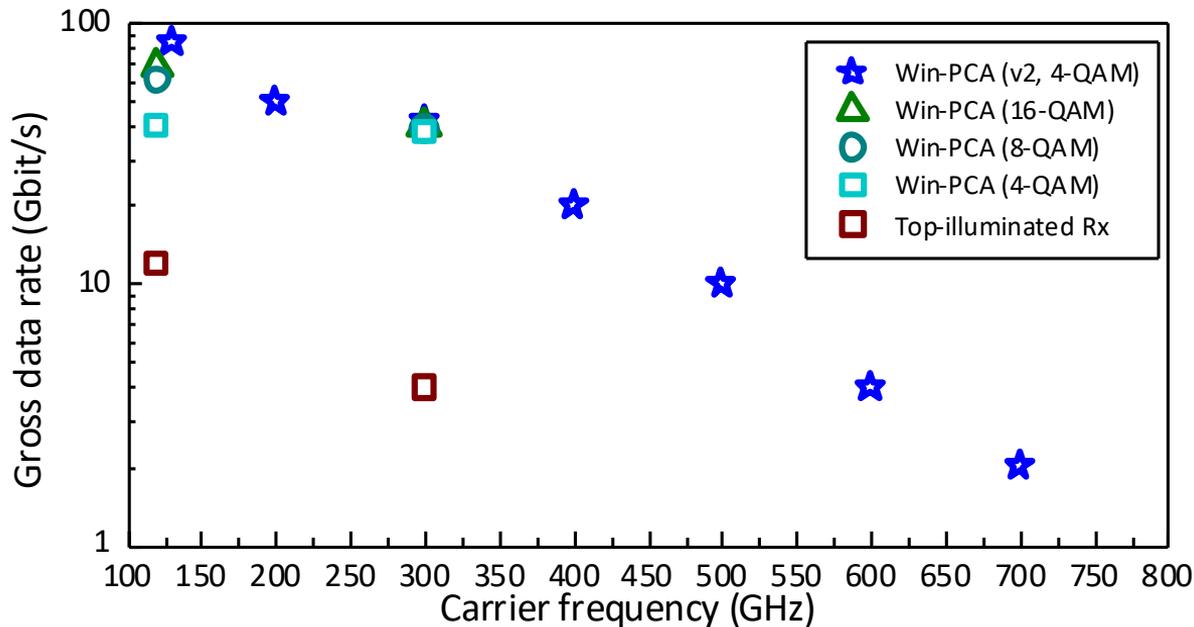
- More flat spectrum
- Still room for improvement

# Win-PCA receiver v2.0 – transmission results



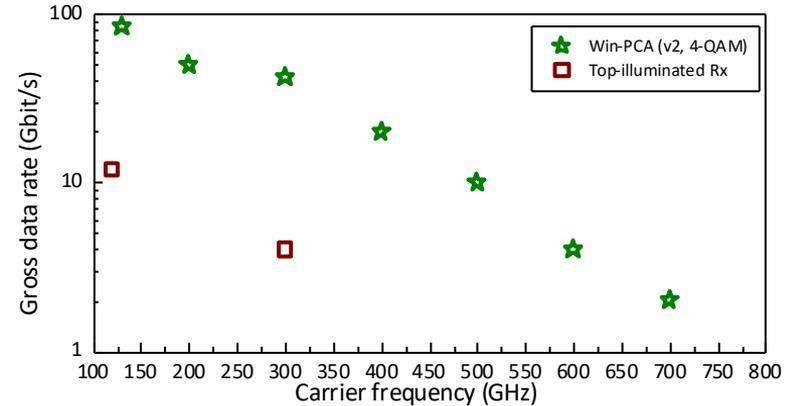
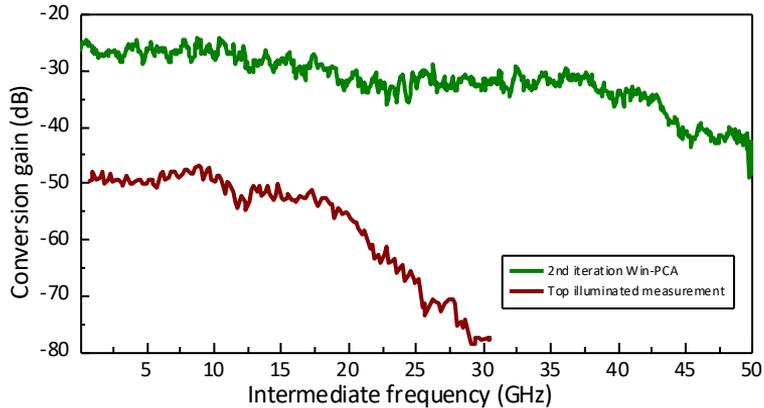
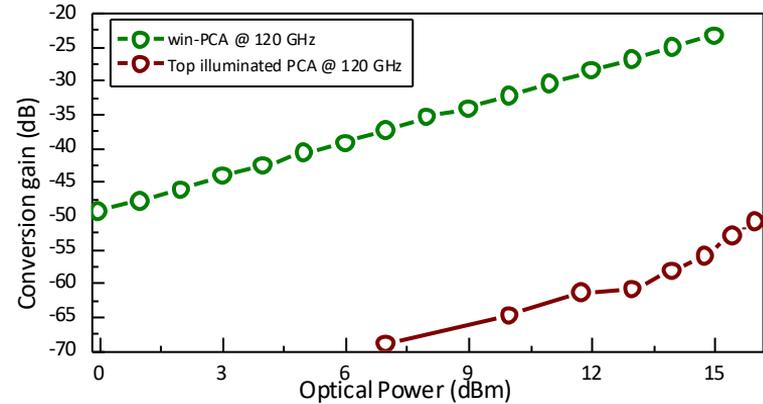
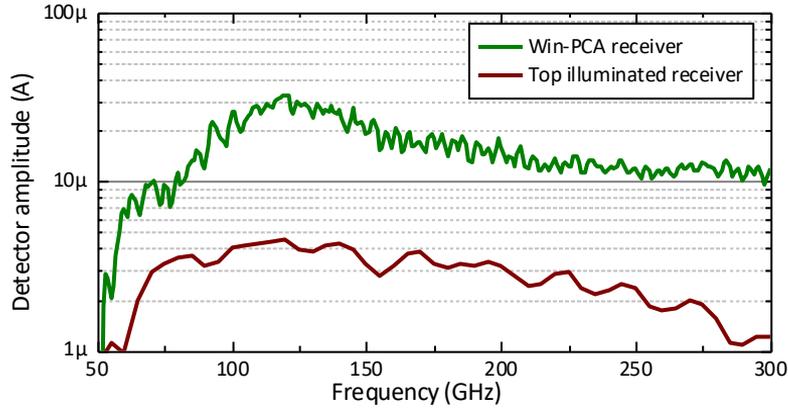
- 4-QAM now with the best results
- 84 Gbit/s @ 130 GHz
- 42 Gbit/s @ 300 GHz

# Win-PCA receiver v2.0 – transmission results



- Successful transmission up to 700 GHz
- Maximum data rate follows spectral roll-off

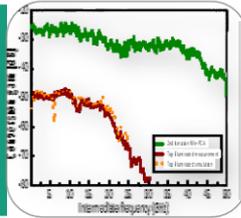
# Substantial improvements with win-PCAs



# Summary and Outlook

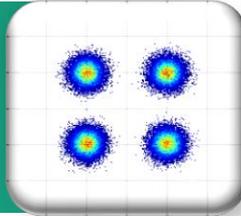
## Photoconductive antennas as heterodyne THz detectors

### Novelty



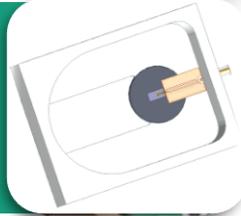
- First heterodyne win-PCA receiver
- +20 dB conversion gain; +20 GHz bandwidth
- 84 Gbit/s gross data rate at 130 GHz

### Impact



- Next step towards >100 Gbit/s full photonic THz links

### Outlook



- Further improvement of RF structures/package
- Improvement of photoconductive Material



Thank you very much for your  
attention!

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