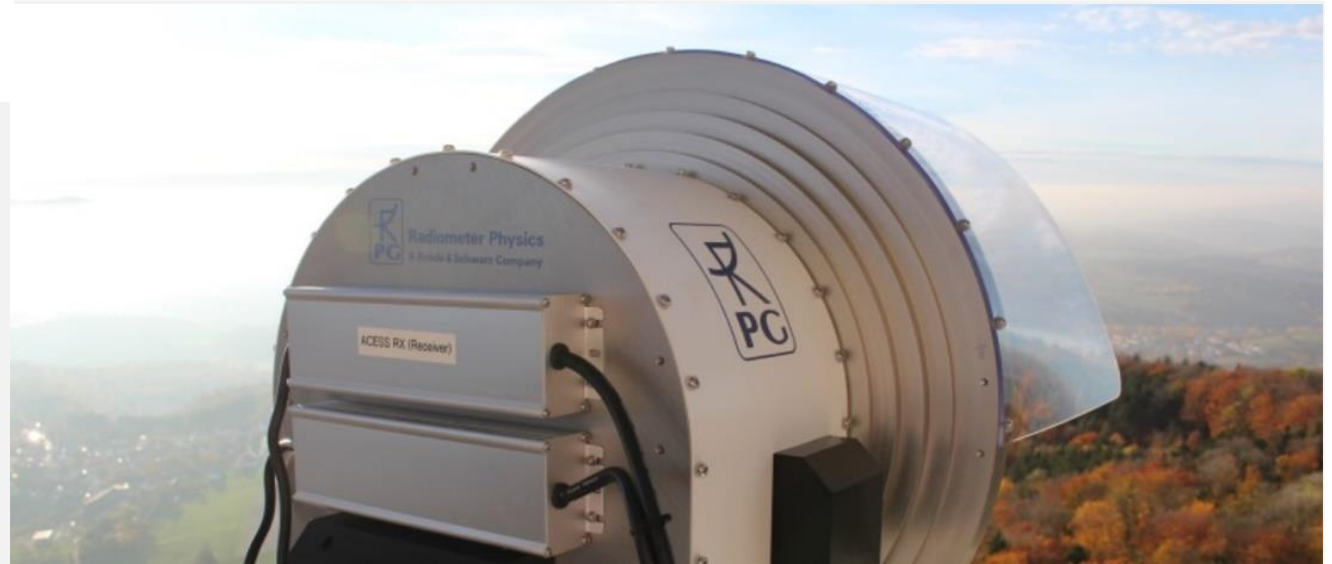


This project is co-funded by

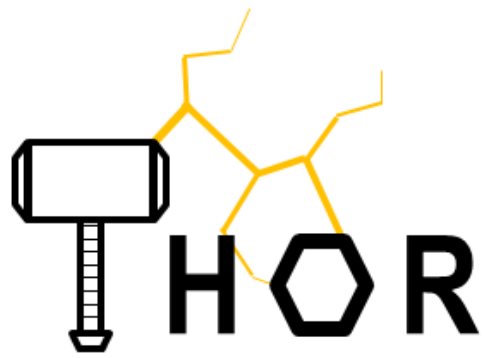
Horizon 2020



## 300 GHz transmission of E/V bands data-flows in the ThoR project

G. Ducournau, P. Szriftgiser, S. Hisatake, I. Kallfass, D. Wrana, L. John, R.P. Braun, Y. Leiba, K. Kondou, S. Sasaki., T. Kawanishi

EuCAP 2021 SW03



This project is co-funded by

Horizon 2020

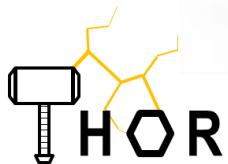


G. Ducournau, P. Szriftgiser, Univ Lille, FR  
S. Hisatake, Gifu Univ, JP  
I. Kallfass, D. Wrana, ILH Stuttgart, DE  
L. John Fraunhofer IAF, DE  
R.P. Braun, Deutsche Telekom, DE

Y. Leiba, Siklu, IL  
K. Kondou, HRCP, JP  
E. Sasaki, NEC, JP  
T. Kawanishi, Waseda Univ, JP

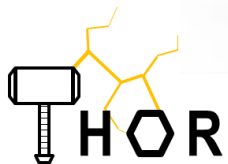
# Outline

1. Overview/concept of the Thor system
2. Building blocks demonstrated so far
3. Perspective



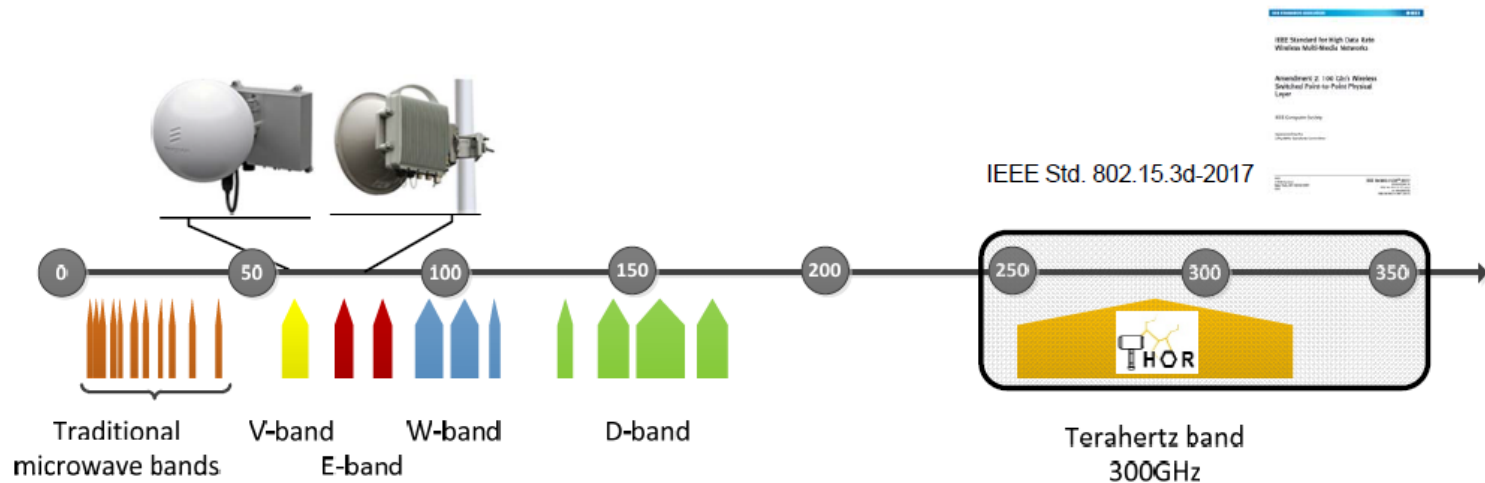
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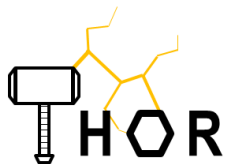


# 1. Overview/concept of the Thor system

- 5G access networks are already approaching data rate requirements of several Tbps/km<sup>2</sup>
- Beyond 5G (B5G) networks are expected to ramp this even further
- Expected extension of wireless transport links to W- and D-band only provide mid-term alleviation
- The sub-mm-wave band beyond 300 GHz offers huge bandwidths in a spectral region without specific allocation made yet.



➔ THOR targets aggregation of E/V bands with up-conversion in the 300 GHz radio



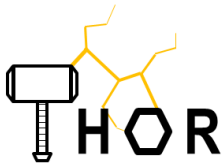
# 1. Overview/concept of the Thor system

Enabling THOR is leveraging on several key building blocks:

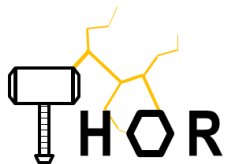
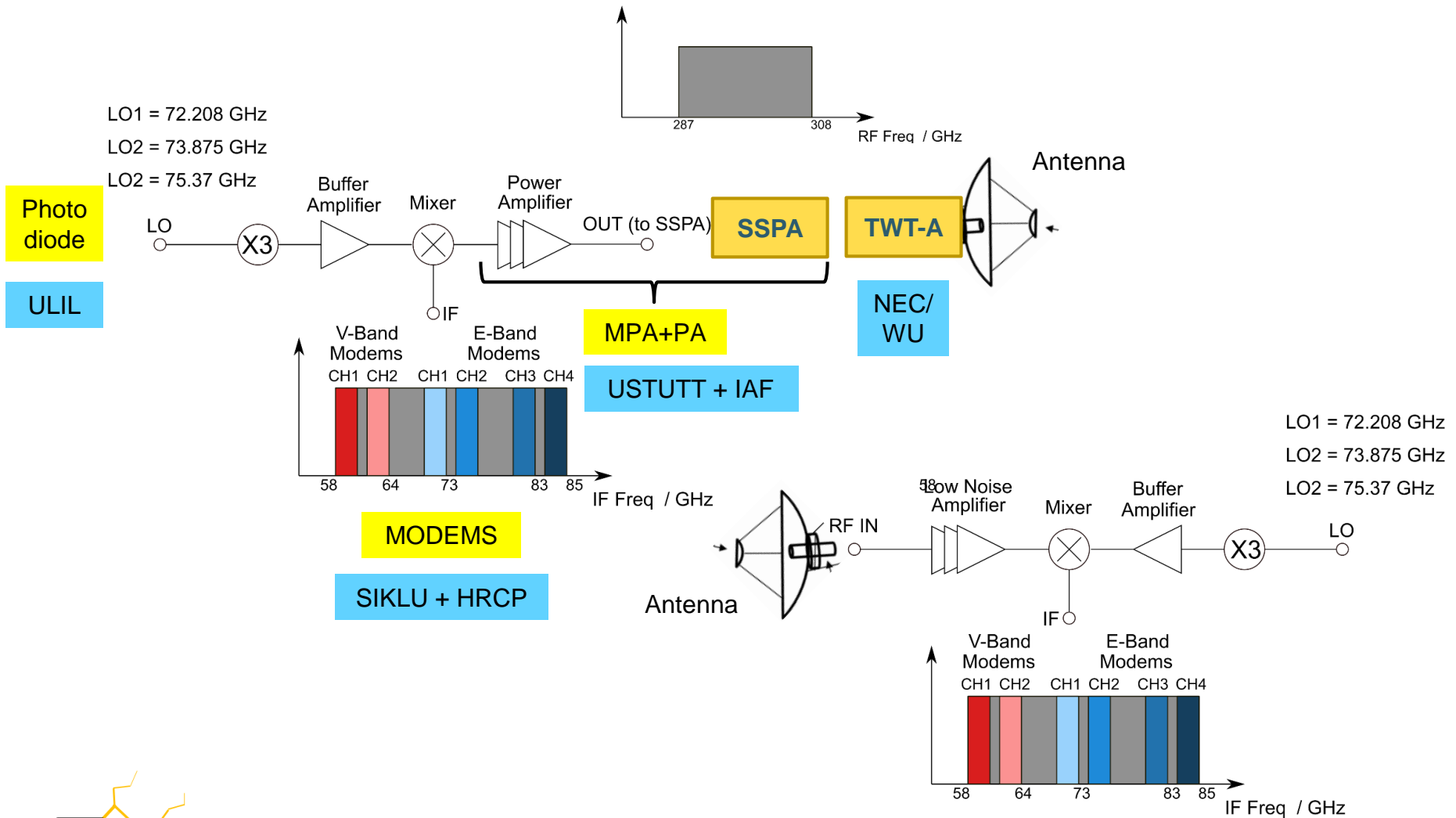
- High frequency LO without spurious around 77 GHz
- Industrial-grade MODEMS in E/V bands
- Solid-state III-V based up/down converters+MPA, driven by 77 GHz LO, and using MODEMS as IF data-flow
- Power amplifier (mHEMT technology), to reach 10 dBm to feed HPA (vacuum amp)
- High-power tube amplifier to at 300 GHz.



Such association is SoTA in the THz datacoms



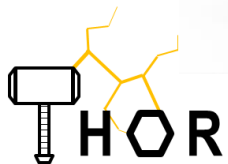
# 1. Overview/concept of the Thor system





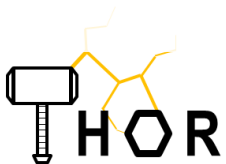
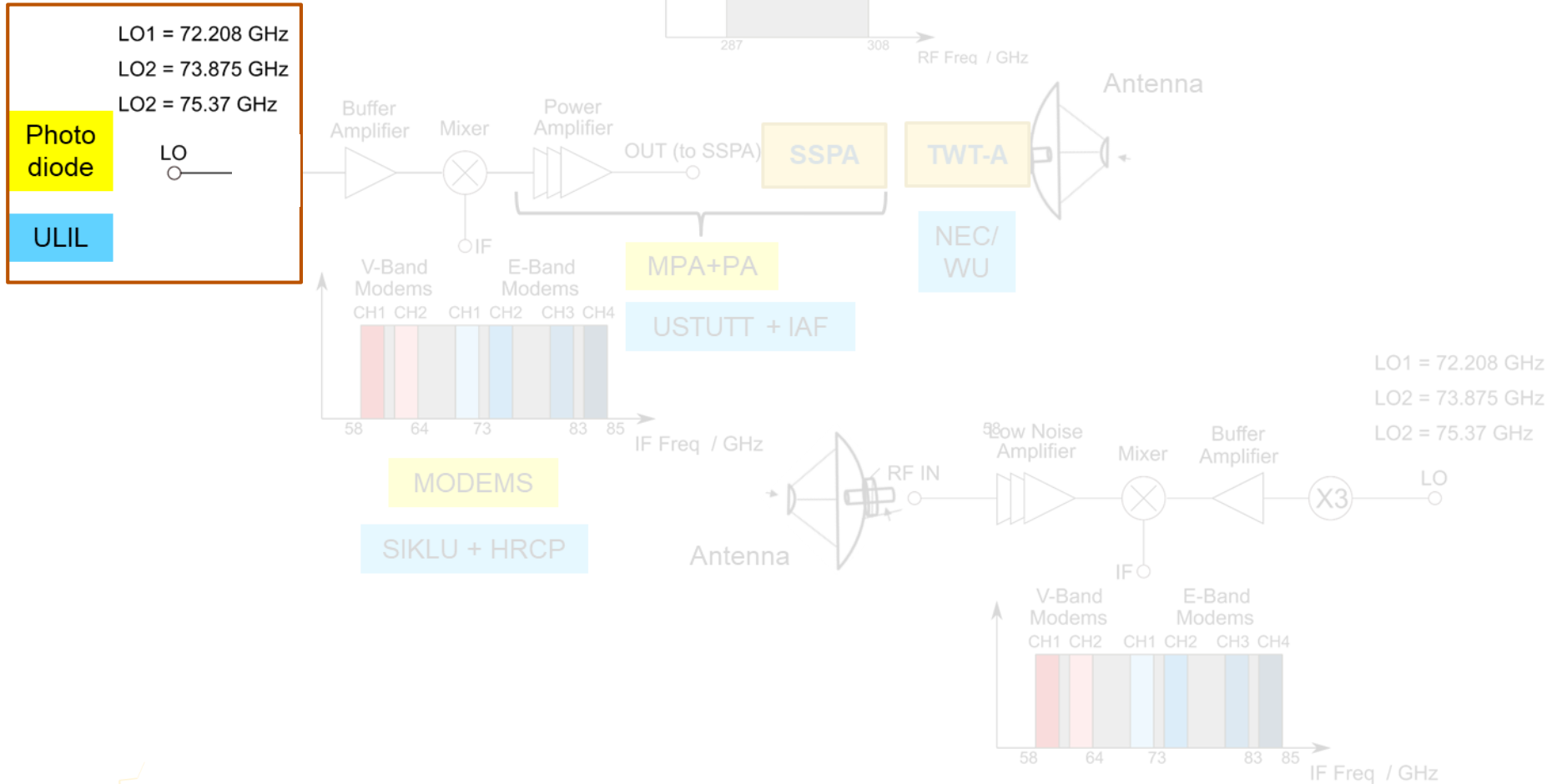
# Outline

1. Overview/concept of the Thor system
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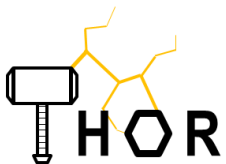
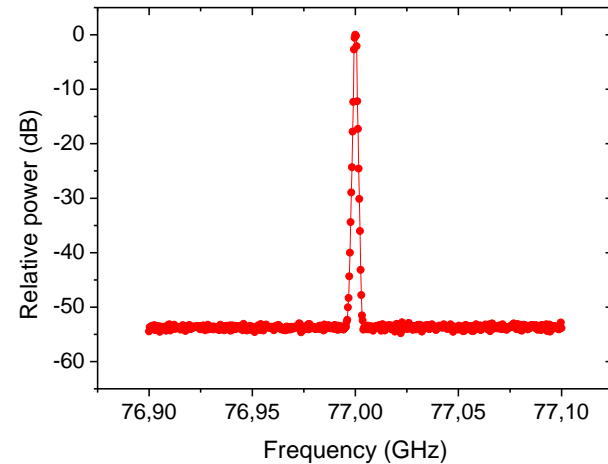
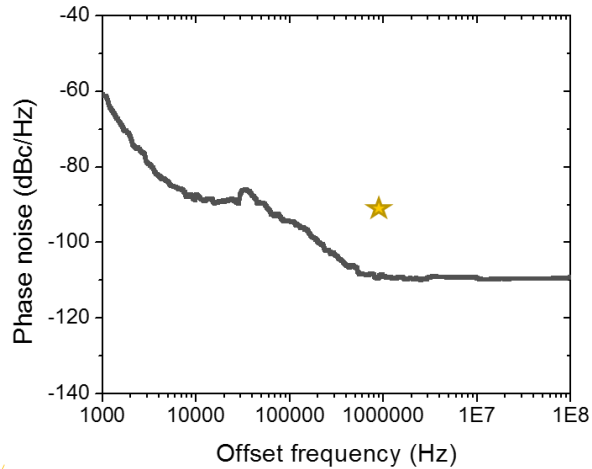
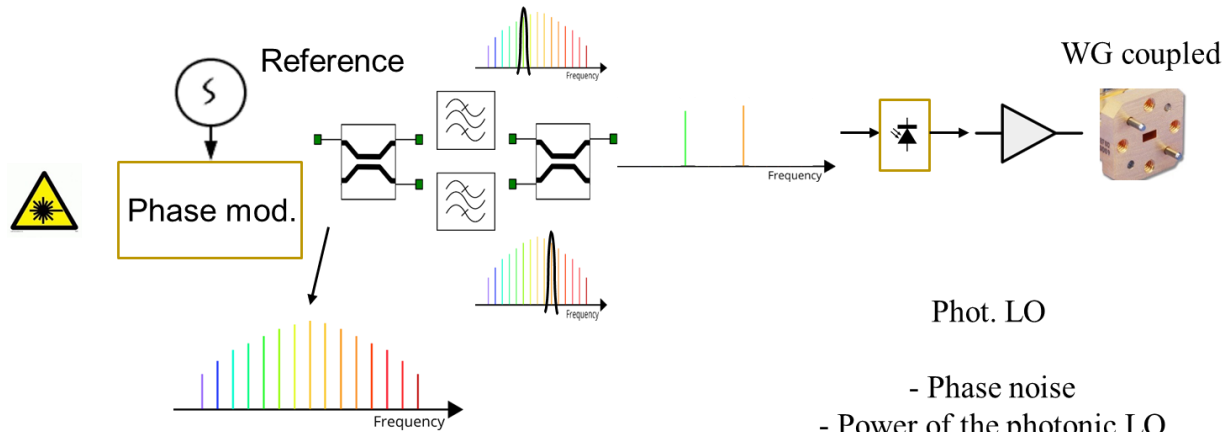




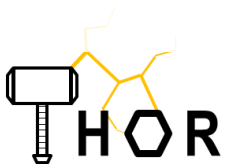
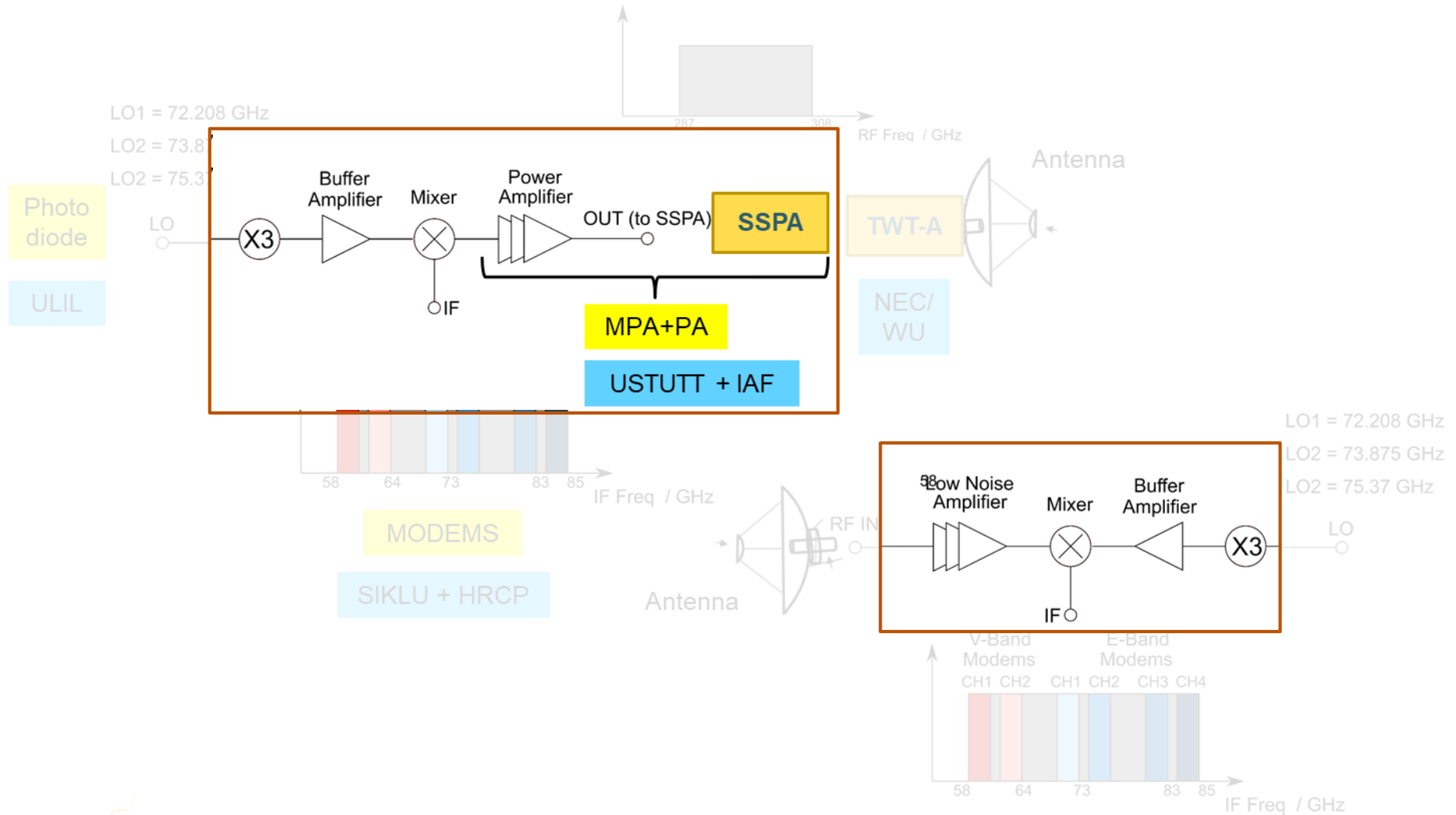
## 2. Building blocks demonstrated so far: LO



# 2. Photonic LO



## 2. Building blocks demonstrated so far: up/down conv. / PAs

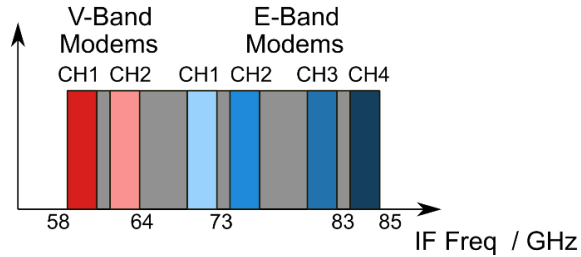
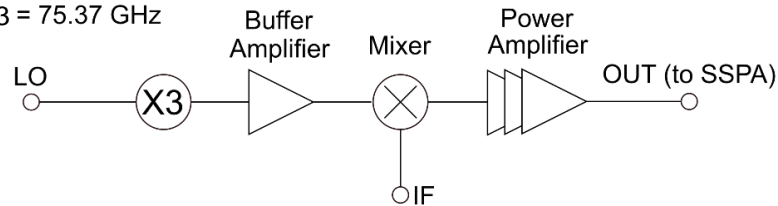


## 2. Up-down converters (1)

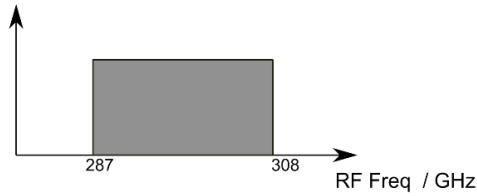
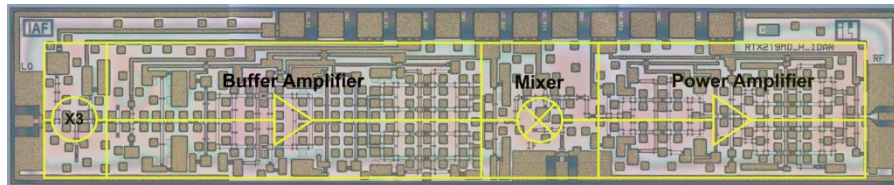
LO1 = 72.208 GHz

LO2 = 73.875 GHz

LO3 = 75.37 GHz



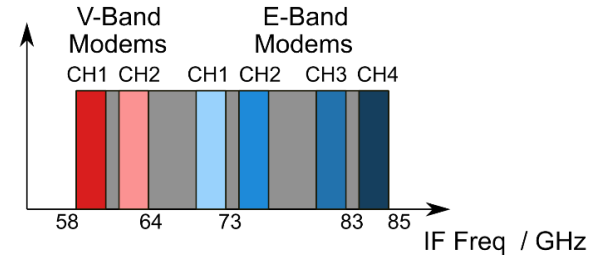
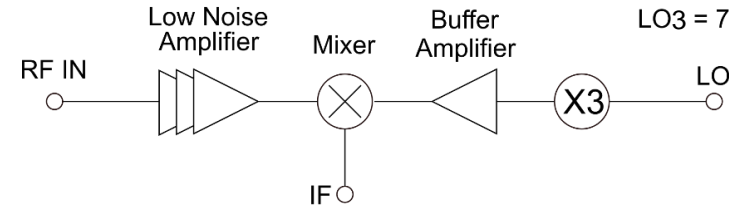
**Transmitter RTX219**



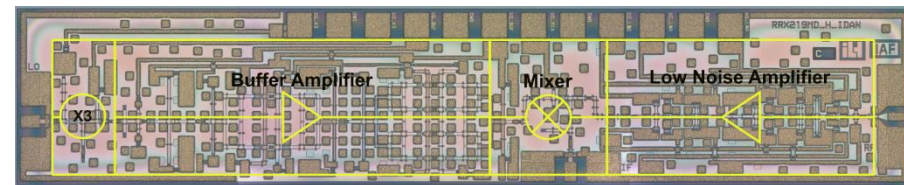
LO1 = 72.208 GHz

LO2 = 73.875 GHz

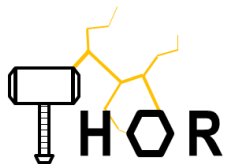
LO3 = 75.37 GHz



**Receiver RRX219**

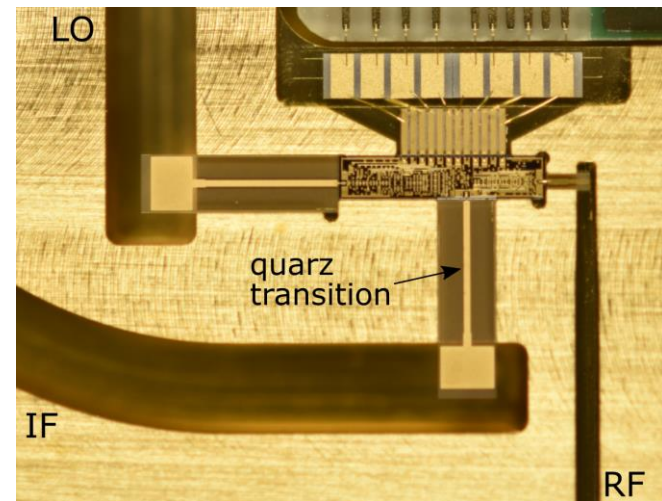
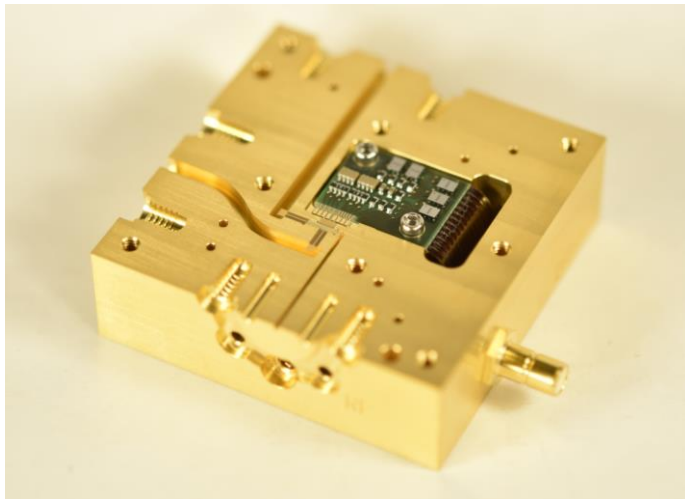


Design by ILH (USTUTT), Fab by Fraunhofer IAF



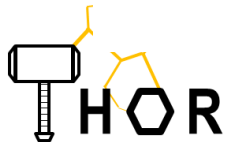
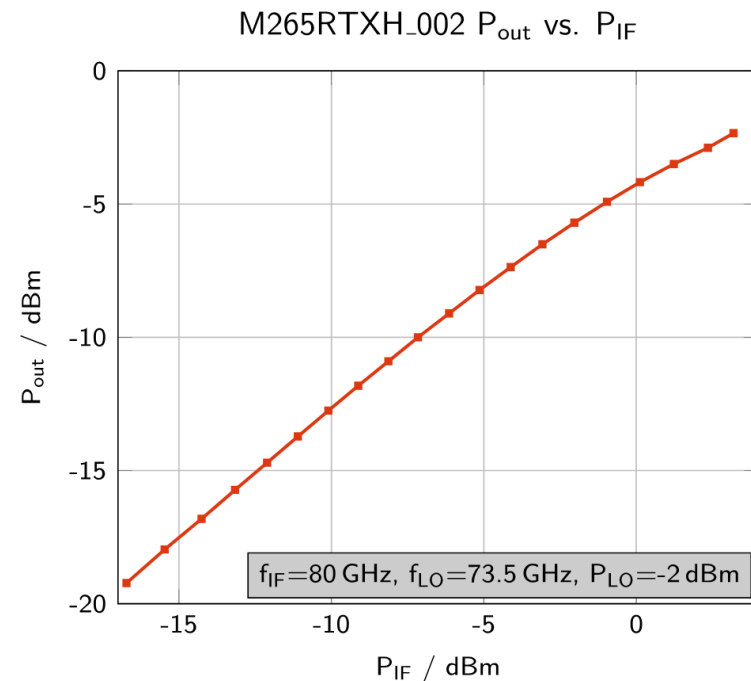
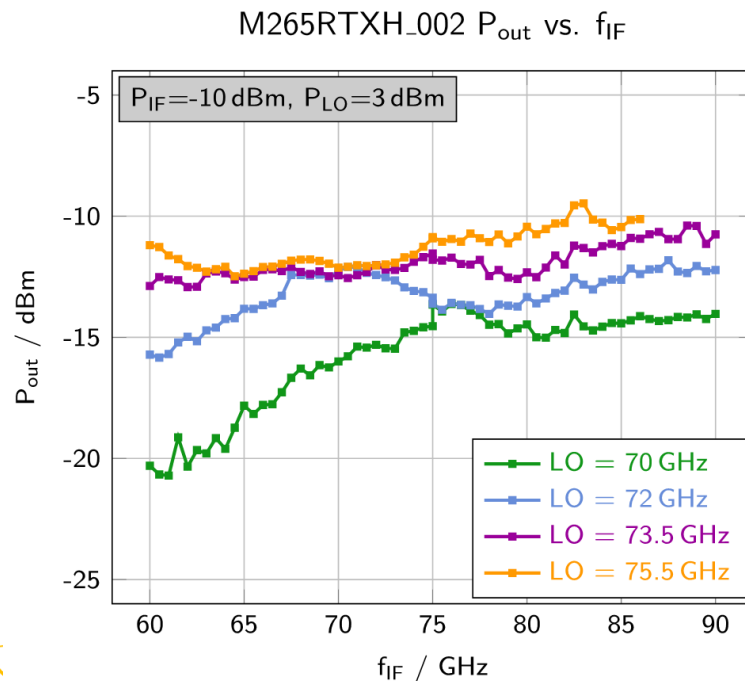
## 2. Up-down converters (2) packaging

- Quartz transitions are used for the MMIC to waveguide transitions
- E-band transition were developed (insertion loss  $< 1$  dB, return loss  $> 20$  dB)
- Insertion loss of the 300-GHz transition: 1–2 dB



## 2. Up-down converters (3): Transmitter RTX219

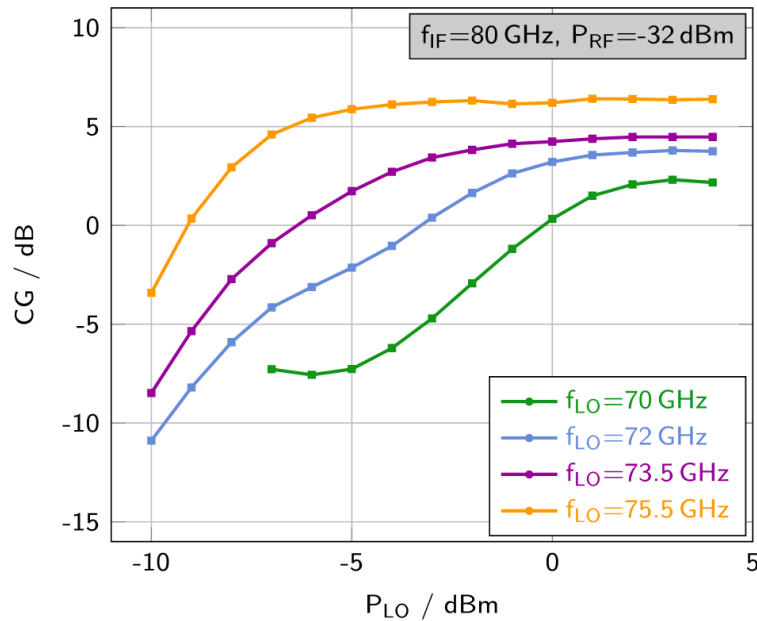
- ThoR target frequency ranges covered  
IF: 64 - 85 GHz ( $\rightarrow$  RF: 287 - 308 GHz)  
LO: 72 - 76 GHz
- $OCP_{1dB}$  of -6 dBm
- Slightly reduced conversion gain and output power at lower LO frequencies



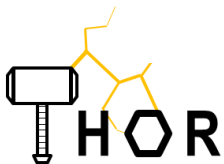
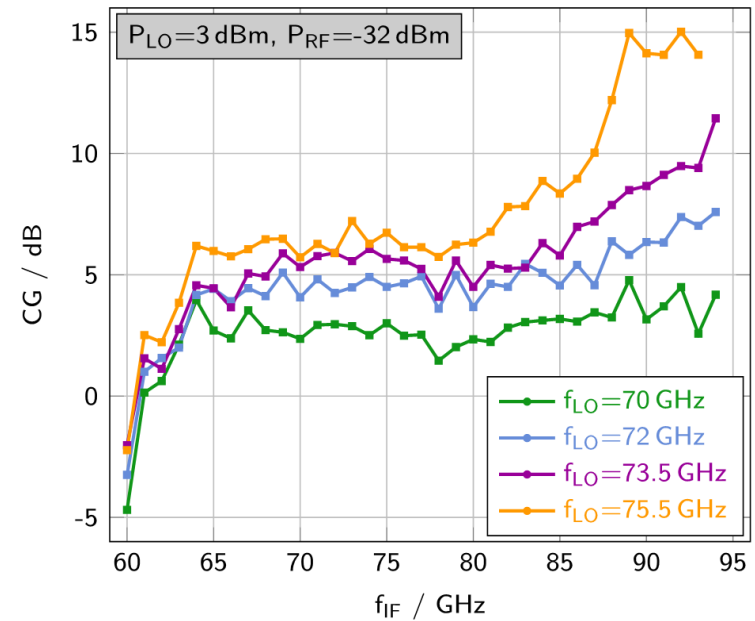
## 2. Up-down converters (4): Receiver RRX219

- ThoR target frequency ranges covered  
IF: 64 - 85 GHz (→ 3 dB IF and RF bandwidth of 30 GHz achieved)  
LO: 72 - 76 GHz
- CG of 4 - 7 dB for targeted IF frequencies and LO frequencies above 70 GHz
- $ICP_{1dB}$  around -23 dBm RF input power
- Slightly reduced conversion gain and output power at lower LO frequencies

M265RRXH.001 CG vs.  $P_{LO}$



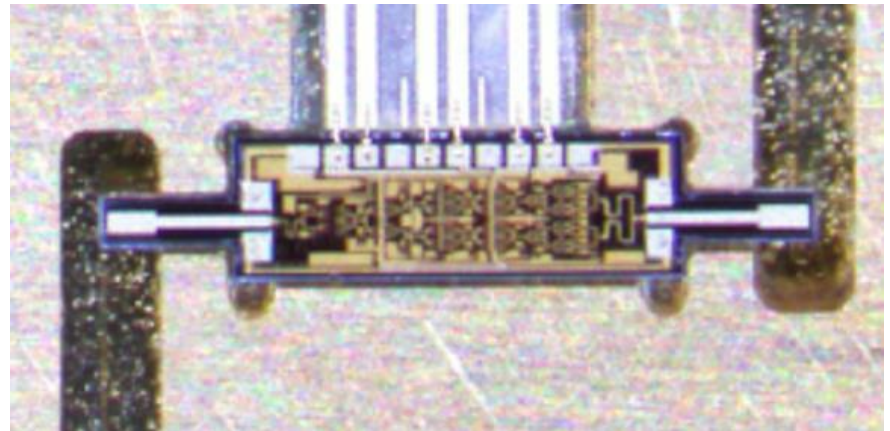
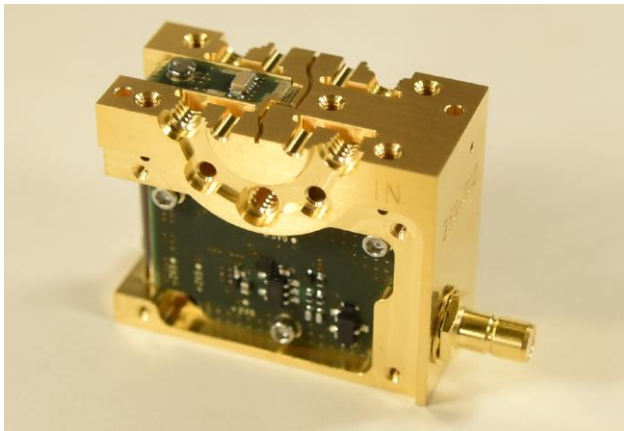
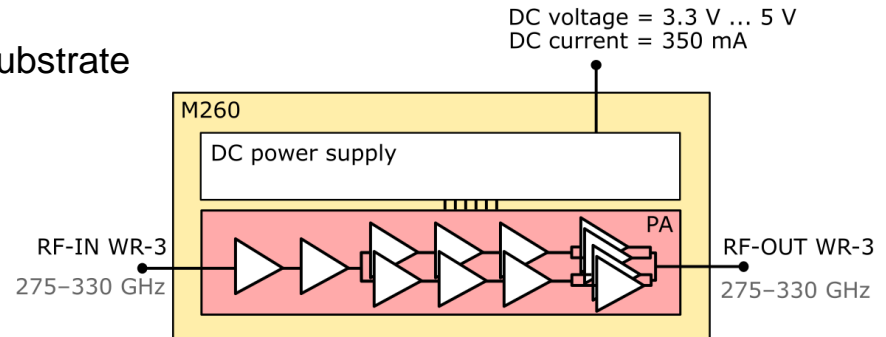
M265RRXH.001 CG vs.  $f_{IF}$





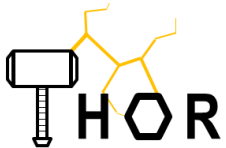
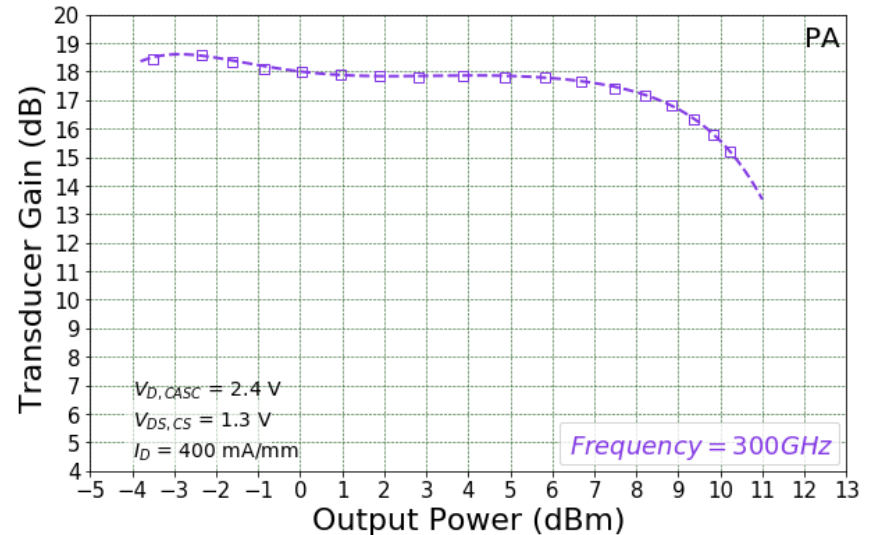
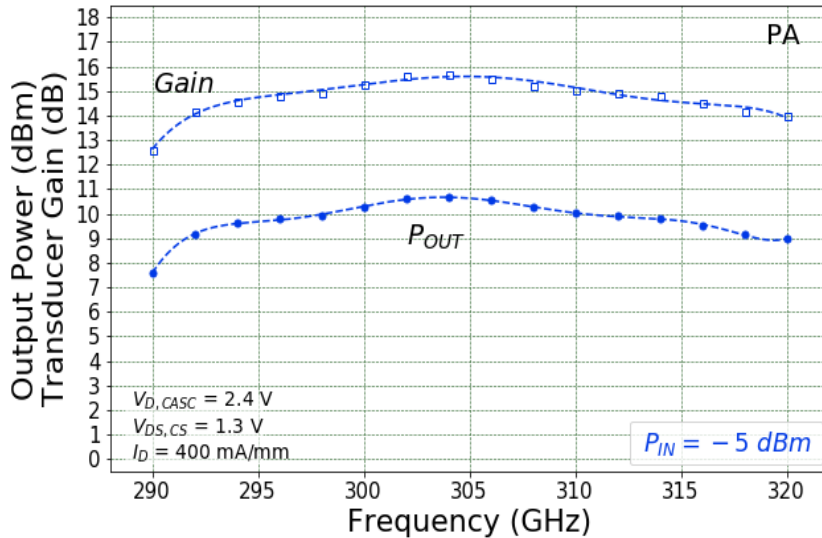
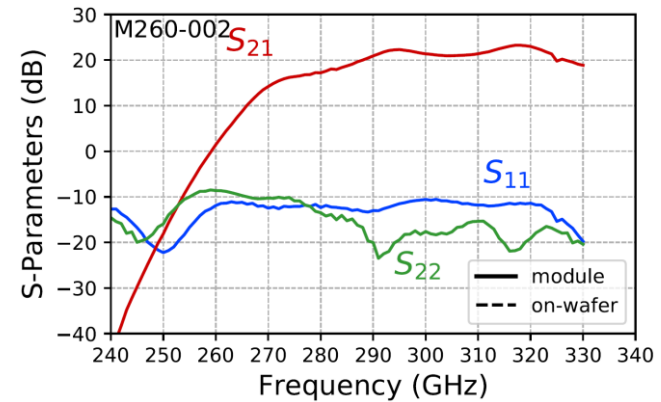
## 2. SSPA (1)

- ThoR targets to use a TWTA HPA at Tx output
- Requires a driving power of about 10 dBm (to reach Watt level at TWTA output)
- Integrated MMIC to waveguide transitions on GaAs substrate are used
- Transition loss should be around 1 dB

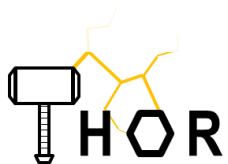
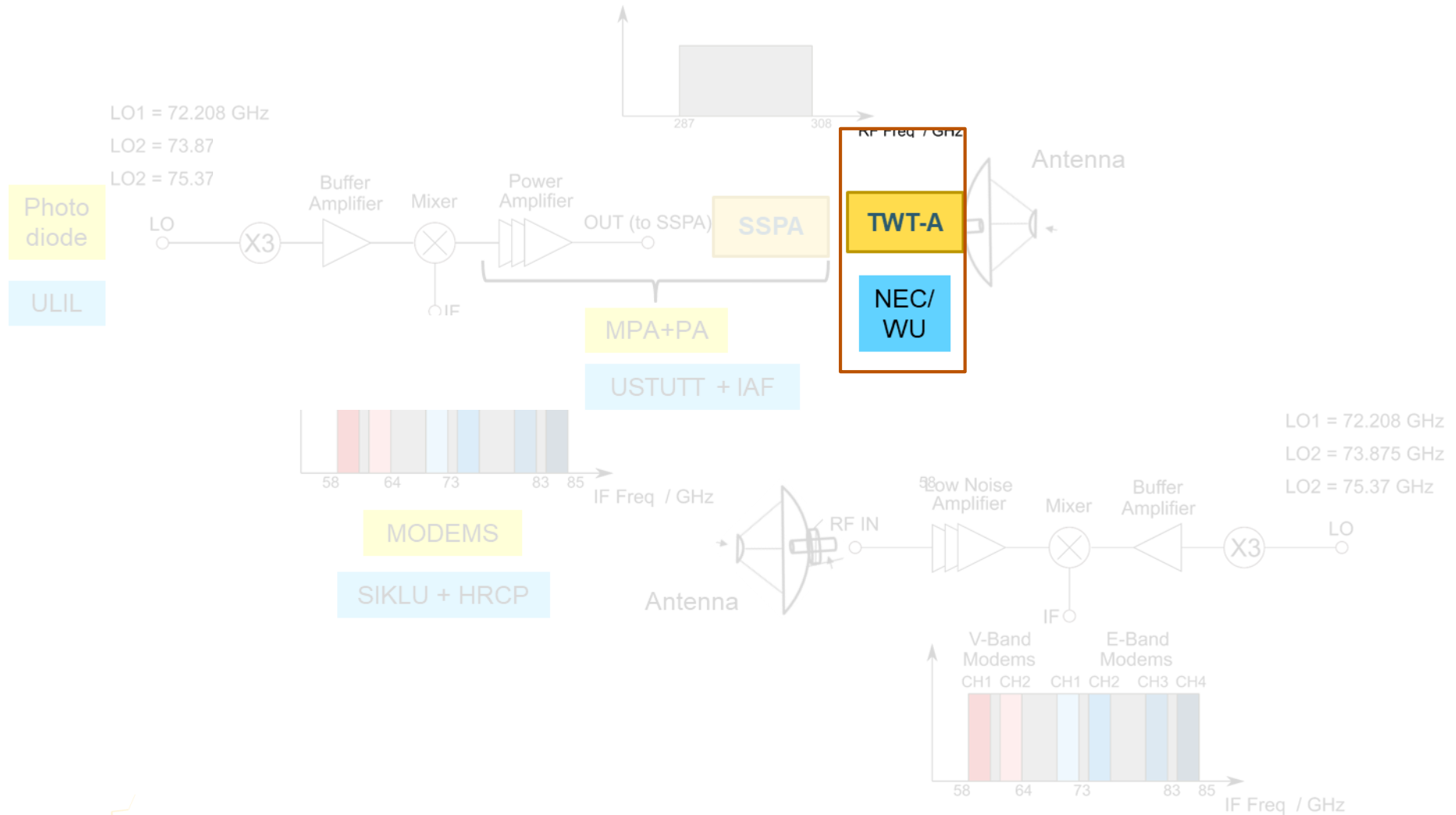


## 2. SSPA (2)

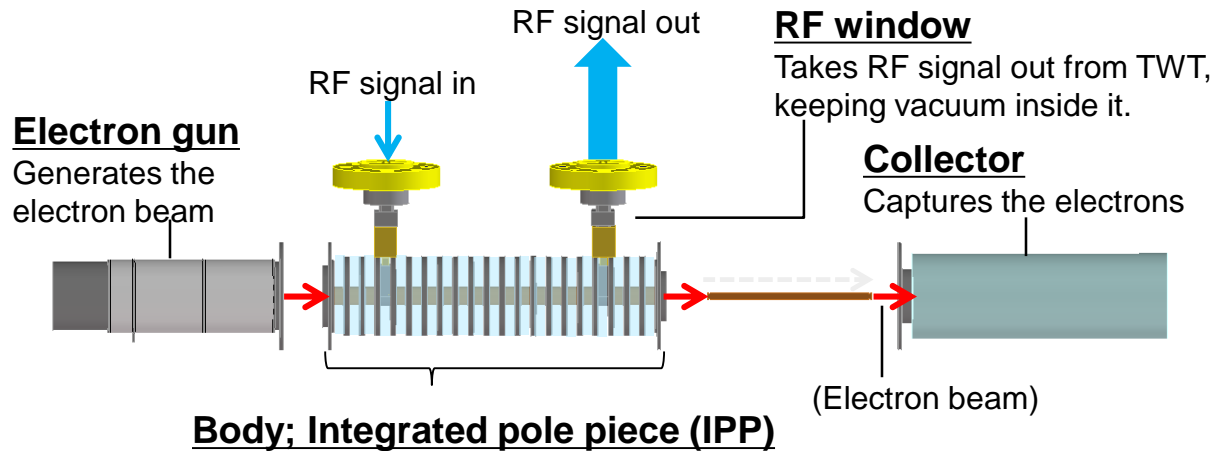
- Saturated output > 10 dBm (300 GHz)
- Wide bandwidth



## 2. Building blocks demonstrated so far: TWTA



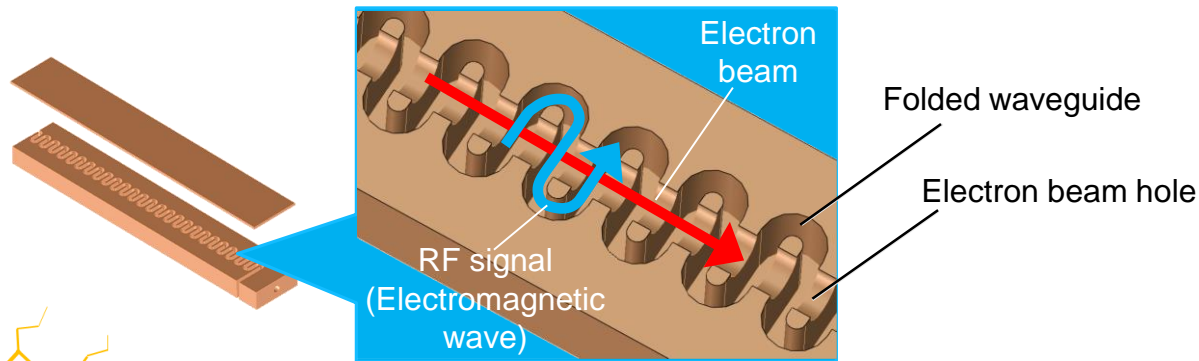
## 2. Building blocks demonstrated so far: TWTA



Permanent magnets and pole pieces are arranged periodically for focusing the electron beam to a small cross section. **FWG-SWS is built into the IPP.**

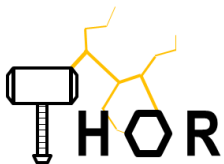
### **Folded waveguide slow wave circuit structure (FWG-SWS)**

Amplifies the RF signal by the interaction of the electromagnetic wave (modulated wave by RF signal) with the electron beam.

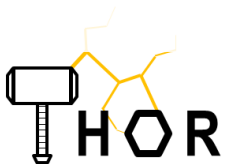
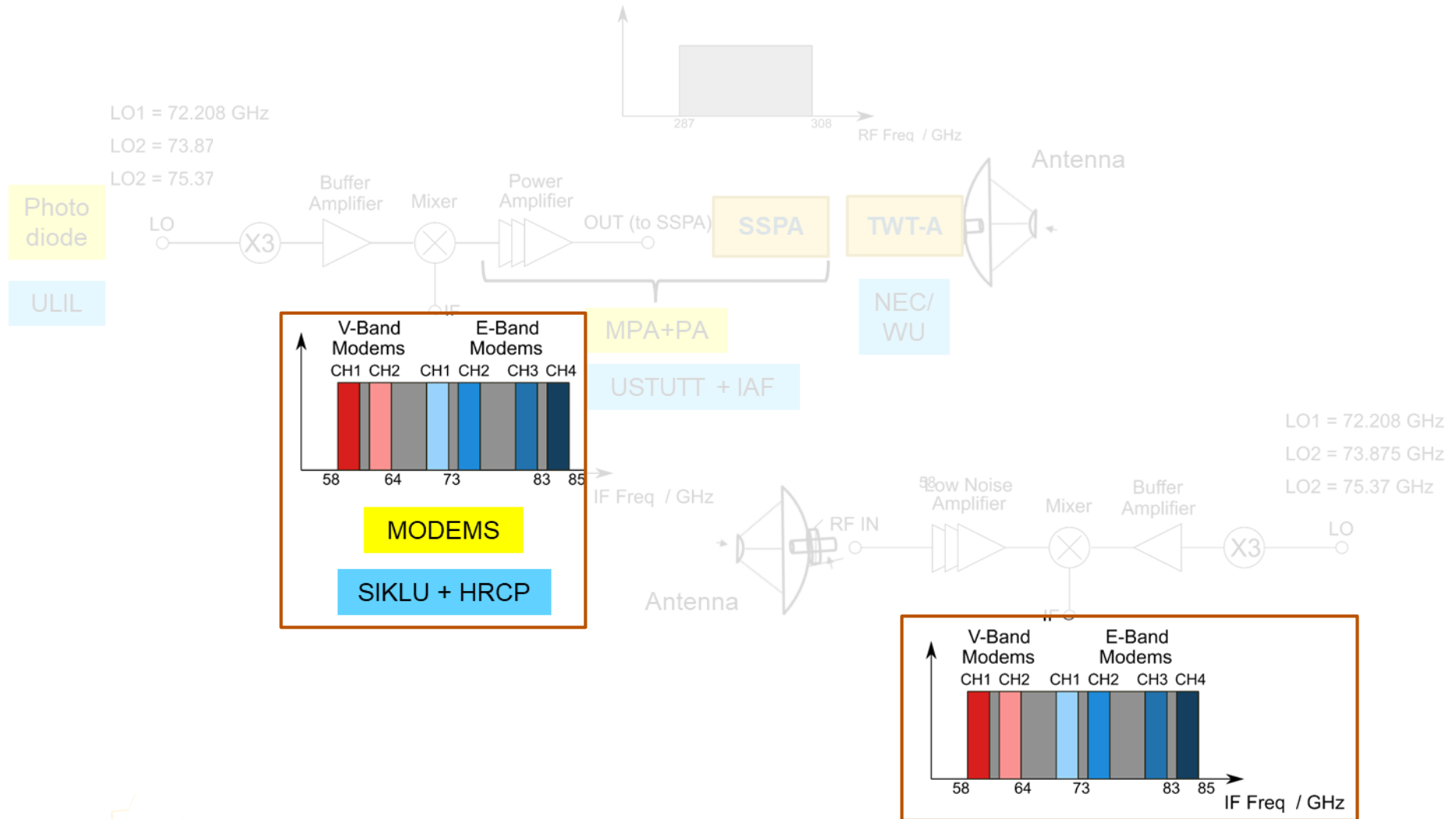


## 2. Building blocks demonstrated so far: TWTA

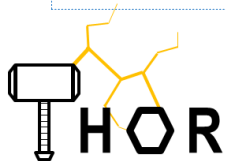
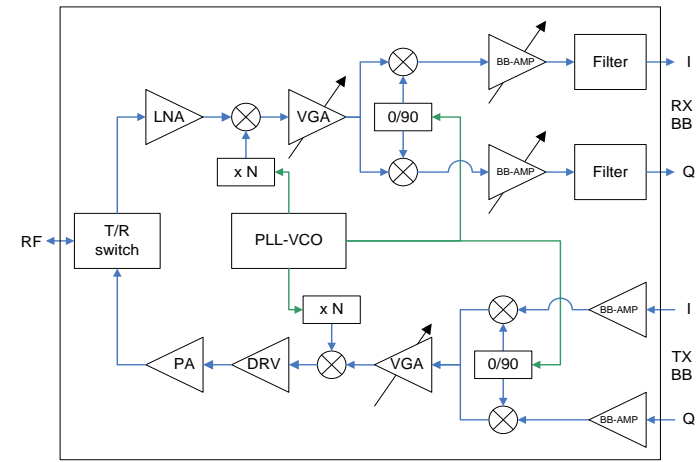
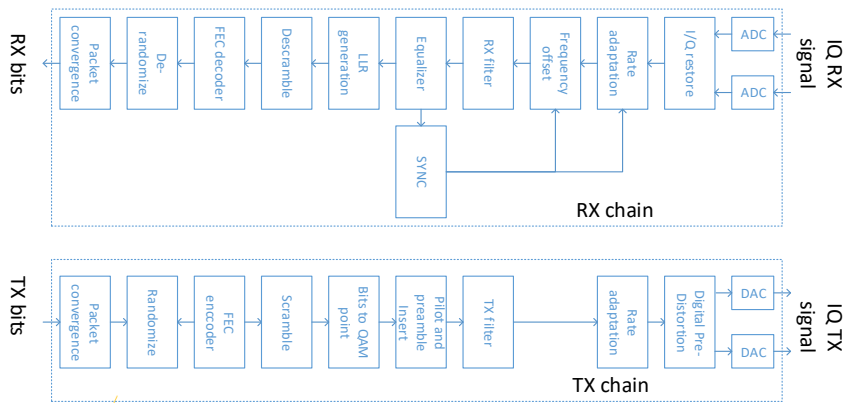
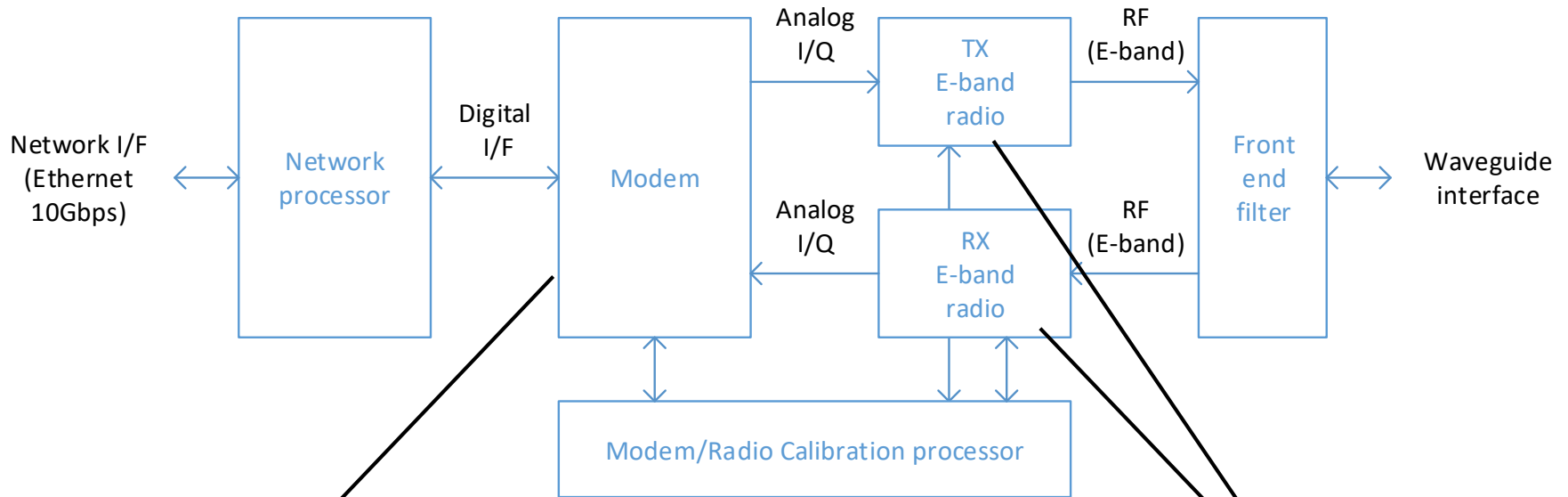
Item	Target / Spec
Input Level	10 mW
Gain	20 dB (at 290 GHz)
Output Level (saturation)	0.1W or 1W
Center frequency	290 GHz
Bandwidth	5 GHz
I/O Interface (Waveguide)	WR-3 (WR-3.4) : 220 to 330 GHz, 0.864 mm × 0.432 mm



## 2. Building blocks demonstrated so far: TWTA



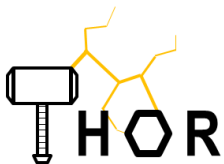
# 2. Building blocks demonstrated so far: MODEMS 70/80G (1)





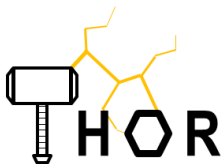
## 2. Building blocks demonstrated so far: MODEMS 70/80G (2)

Bandwidth (MHz)	Modulation	FEC Rate	Pout (dBm)	Receiver Threshold (dBm @ BER=10 <sup>-6</sup> )	Bit rate (Mbps)	CINR at threshold (dB)	System Gain (dB)
2000	QAM128	0.87	14	-50	9550	23.6	64
2000	QAM64	0.87	14	-53	8180	20.3	67
2000	QAM32	0.87	15	-56	6820	17.3	71
2000	QAM16	0.87	16	-59	5460	14.3	75
2000	8PSK	0.87	17	-62	4090	11.3	81
2000	QPSK	0.87	18	-66	2730	7.3	84



## 2. Building blocks demonstrated so far: MODEMS 70/80G (3)

- The operations of combining several IF channels, up-conversion and down-conversion pose challenges to the flawless operation of the entire chain
  - Frequency offsets
  - Extra phase noise
  - TX power mismatch and non linearity
  - RX level mismatch and NF degradation
  - Interference between channels
- Considerations to ensure the matching between the IF and the RF were done in the context of WP2
- Transceiver characterization specifically verifies some relevant parameters



## 2. Building blocks demonstrated so far: MODEMS 60 G (1)

### RF SPECIFICATIONS

**Table 1. Supported Channel**

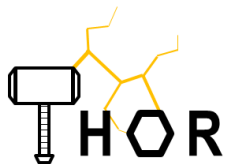
CHNL_ID	Start	Center	Stop
2	59.40 GHz	60.48 GHz	61.56 GHz
3	61.56 GHz	62.64 GHz	63.72 GHz

### SUPPORTED DATA RATE

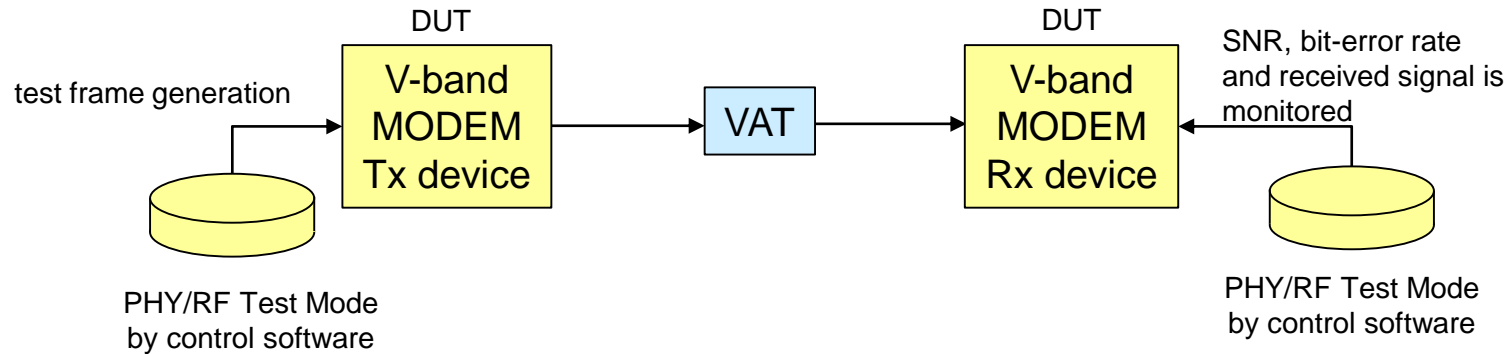
**Table 2. Modulation and Coding Scheme**

MCS ID	Modulation	FEC rate	Data rate (Gb/s)
0	QPSK	11/15	2.58
1	QPSK	14/15	3.29

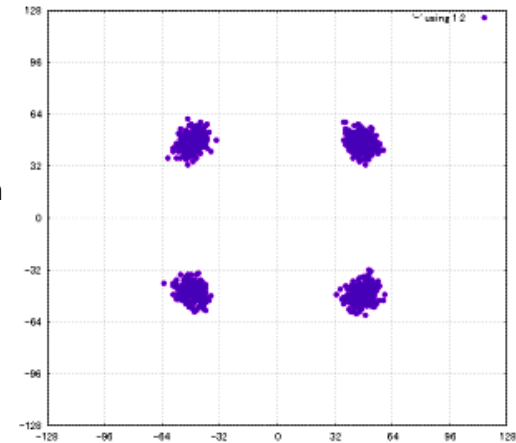
Evaluated on green marker part



## 2. Building blocks demonstrated so far: MODEMS 60 G (2)



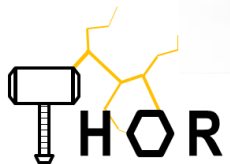
@ VAT: -20dBm



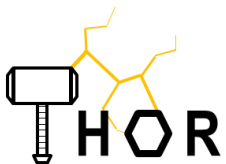
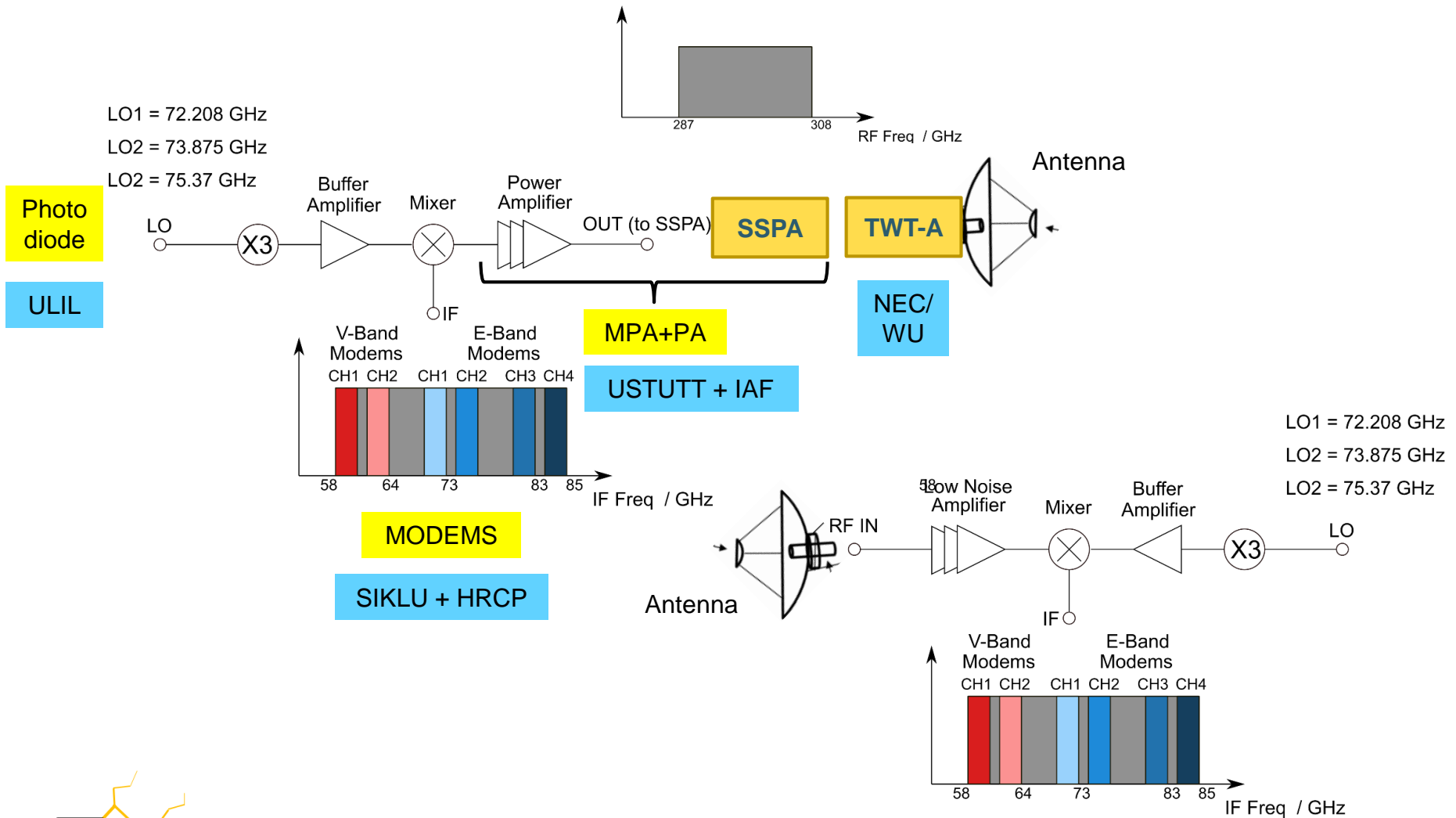
IQ constellation of MODEM output

# Outline

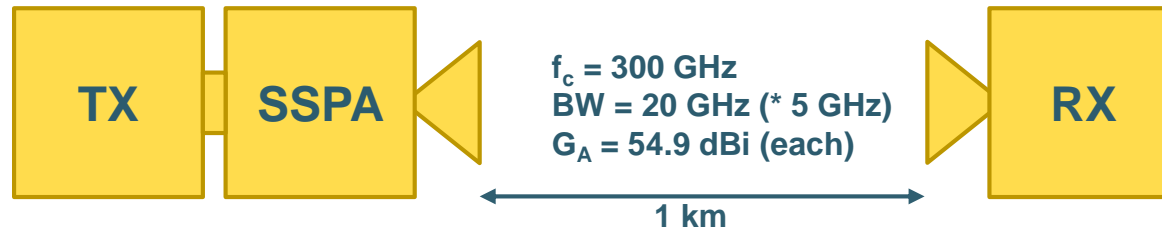
1. Overview/concept of the Thor system
2. Building blocks demonstrated so far
3. Perspective



# 3. Perspective: combination of all devices!



### 3. Perspective: example of link budget, wide BW



- Link Parameters

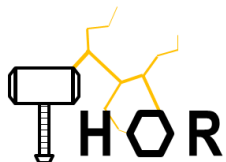
Component	Parameter	Value
TX	Gain	-3.5 dB
	OCP1dB	-7.5 dBm
RX	NF	10 dB
SSPA	Gain	20 dB
	OIP3	6 dBm

- Requirements

Parameter	Modulation scheme	Value
SNR	QPSK	13 dB
	16QAM	19 dB

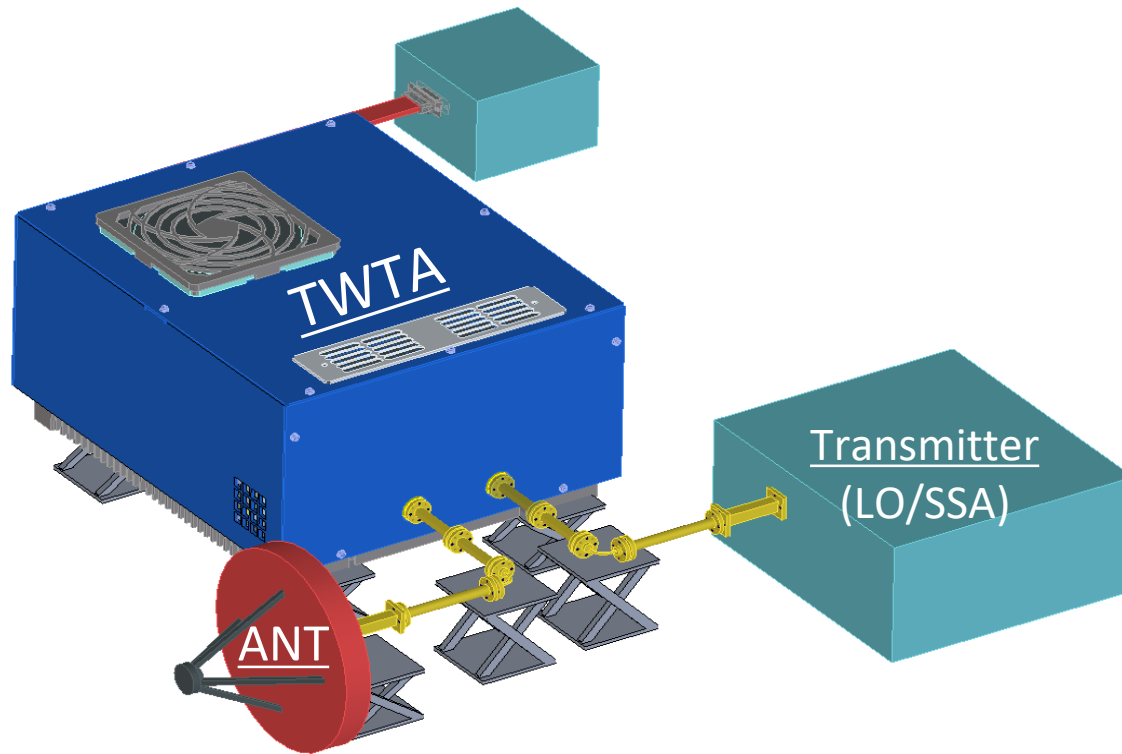
- Results

Parameter	Atmospheric Atten.	Value	
SNR @ 1 km distance	Mean (7 dB/km)	20.7 dB	[ QPSK 16QAM ]
	Best (2 dB/km)	25.7 dB	[ QPSK 16QAM ]
	Worst (20 dB/km)	7.8 dB	[ QPSK* 16QAM ]



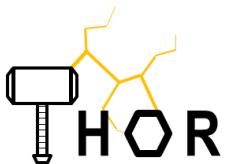


### 3. Perspective: Assembly (in progress)



Assembly is targetted for year 2021  
lab-demo (Stuttgart, Lille)

On-site demo in Germany in 2022! Stay connected to THOR H2020



# Thank you for your attention!

## ご清聴ありがとうございました

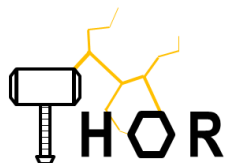


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[ThorProject.eu](http://ThorProject.eu)