

WE02B-2

# Terahertz Wireless Communications Using SiC-Substrate-Based Fermi-Level Managed Barrier Diode Receiver

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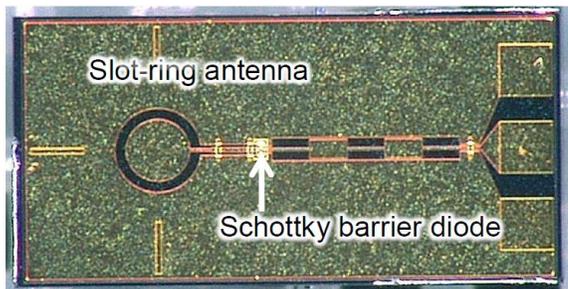
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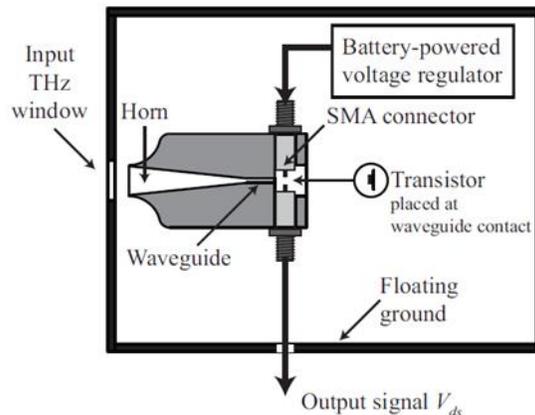
- **Background and motivation**
- **SiC-substrate-based FMBD module and communications**
- **Summary**

- Functions
  - Rectification for envelope detection
  - Mixing for coherent detection pumped by LO signal
- Devices



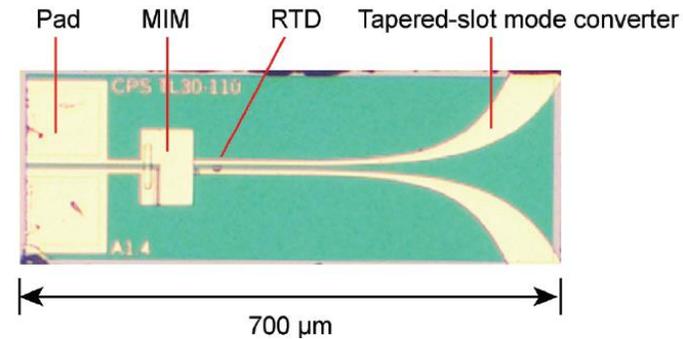
Schottky barrier diode (SBD)

[Hesler et al, *Pan Sandford Publishing*, pp. 104-131, 2015]



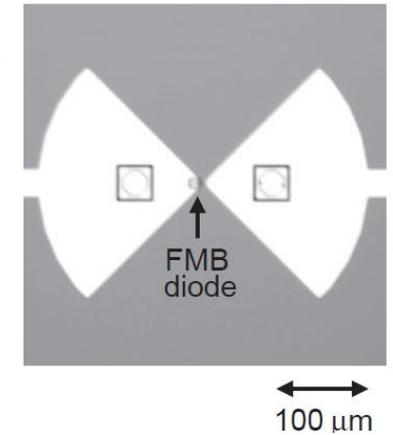
Field-effect transistor (FET)

[Blin et al, *Journal of Comm. & Net.*, 15(6), pp. 559-568, 2013]



Resonant tunneling diode (RTD)

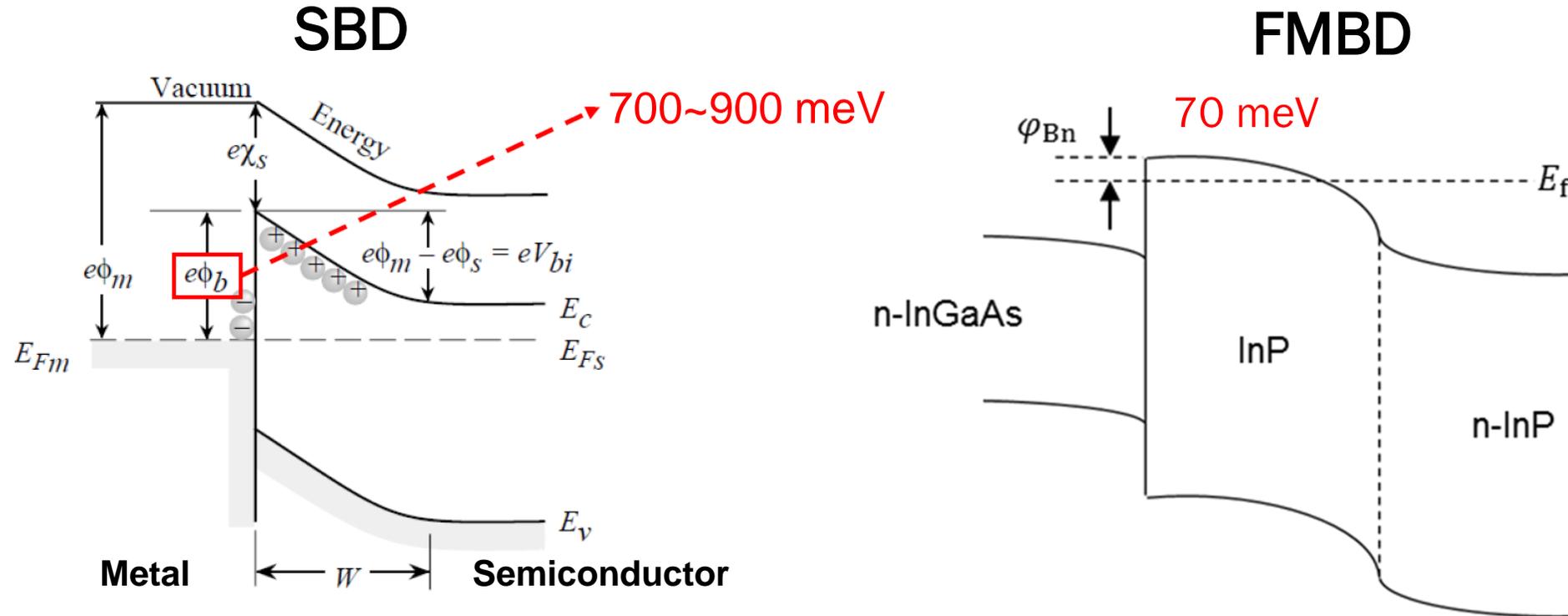
[Yu et al, *Opt. Express*, 27(20), pp. 28707-28721, 2019]



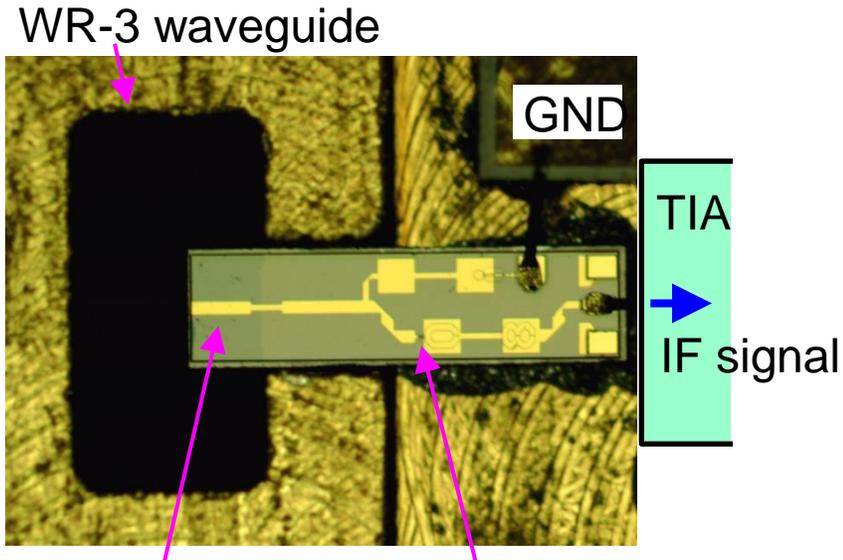
Fermi-level managed barrier diode (FMBD)

[Nagatsuma et al, in *Proc. IEEE MTT IMS*, 2019]

# SBD versus FMBD

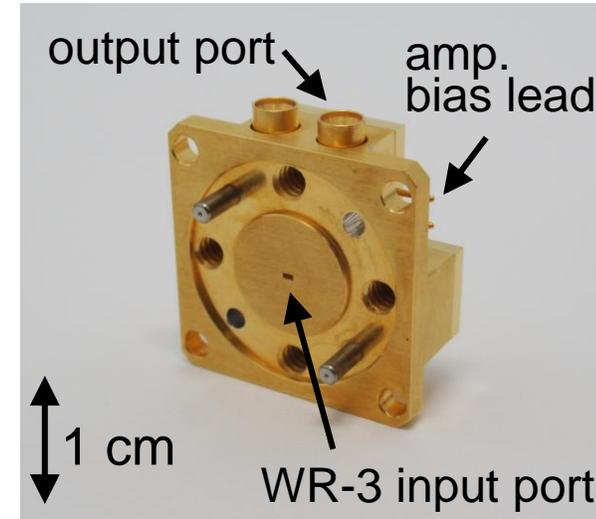


Device	Differential resistance	Impedance matching to the load	LO power required as mixers
SBD	High	No	High
FMBD	Low	Yes	Low



coupler FMB diode on SiC platform

Internal structure of fabricated FMB diode module



Waveguide-input FMB diode module

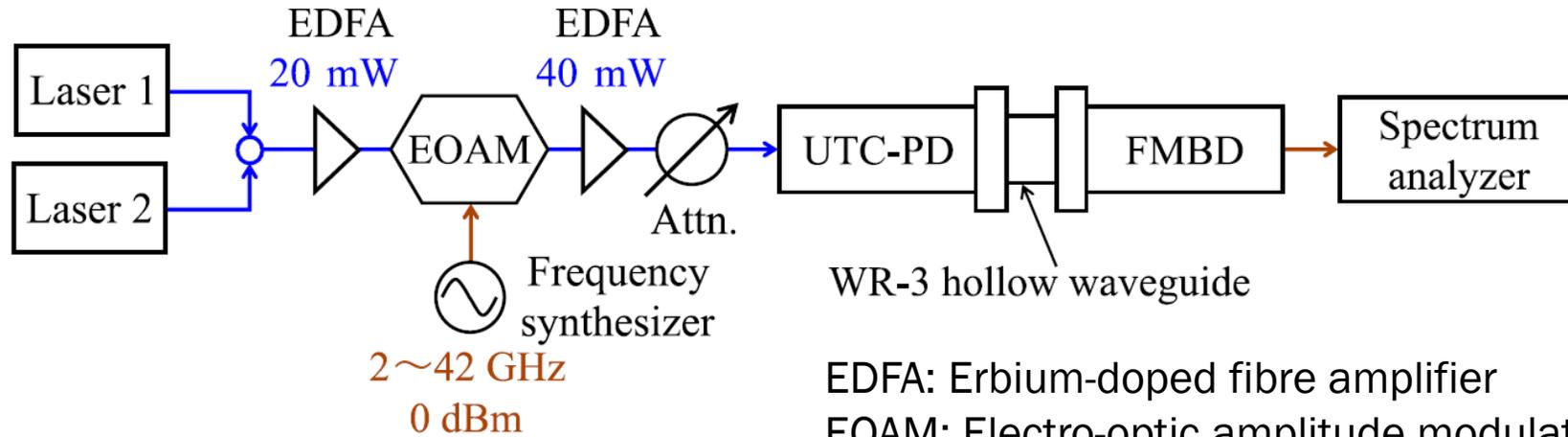
(size: 20 x 20 x 8 mm<sup>3</sup>)

- TIA\* integrated in package  
(\*Semtech, GN1800,  $f_{3dB}$ : 36 GHz)
- FMB diode: zero-biased
- Only DC bias for TIA (+3.3 V) supplied

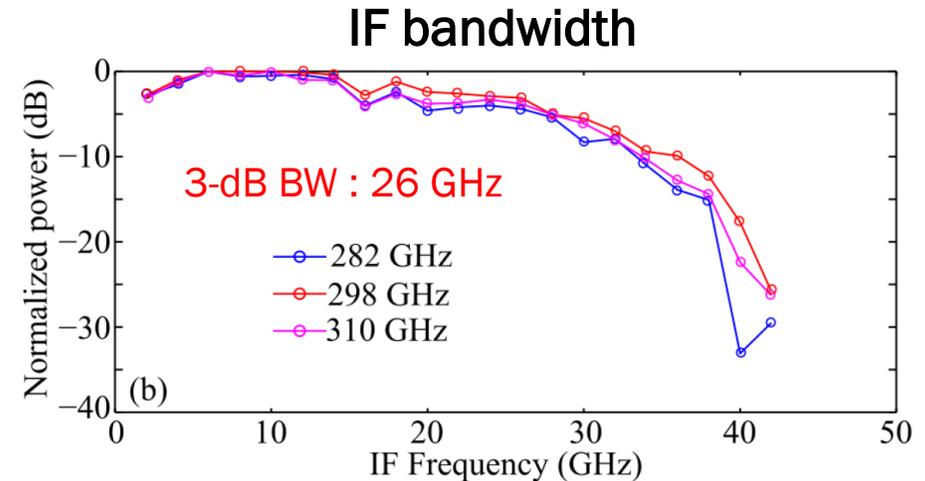
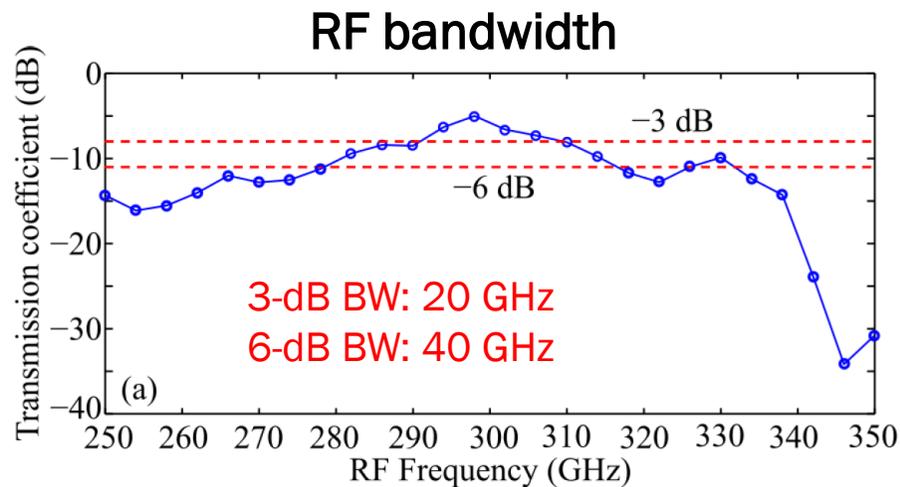
- Standard UG-387/U-M flange
- Standard SMPM connector for IF output port  
(bandwidth: 65 GHz)

[Ito et al. *Appl. Phys. Express* 15 (2022) 026501]

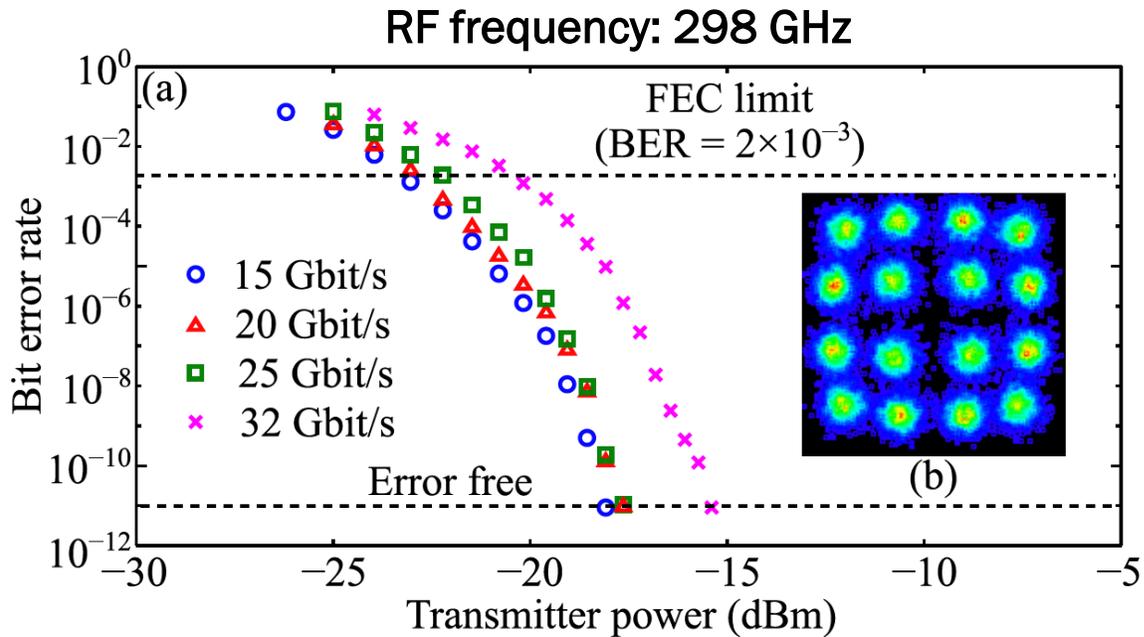
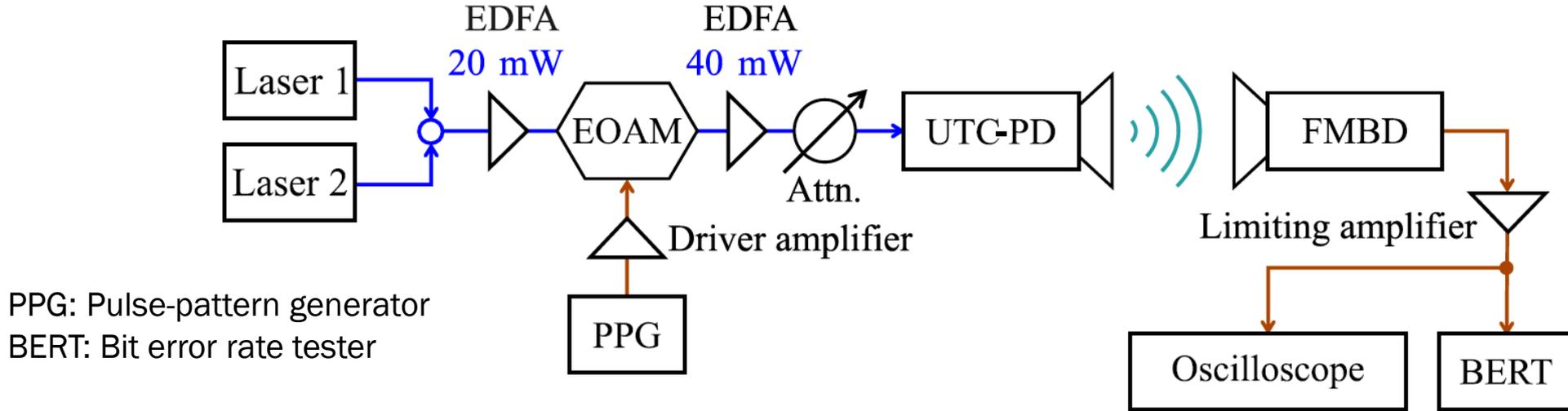
# FMBD bandwidth



EDFA: Erbium-doped fibre amplifier  
EOAM: Electro-optic amplitude modulator  
UTC-PD: Uni-traveling carrier diode  
Attn.: Attenuator

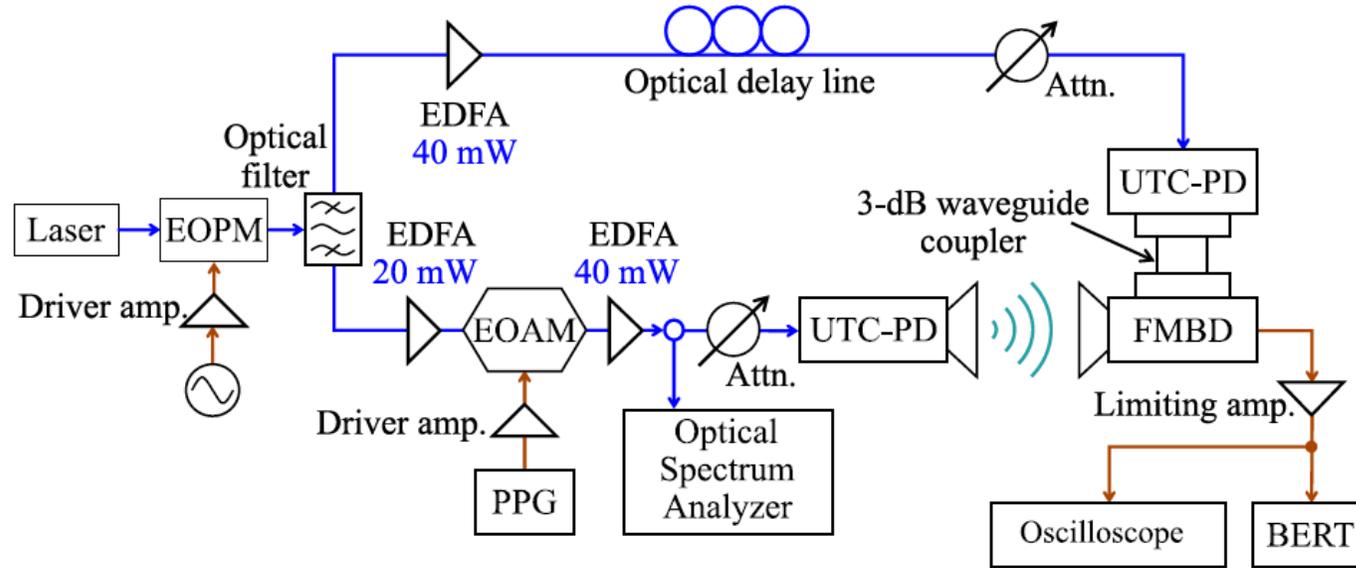


# Bit error rate test for direct detection

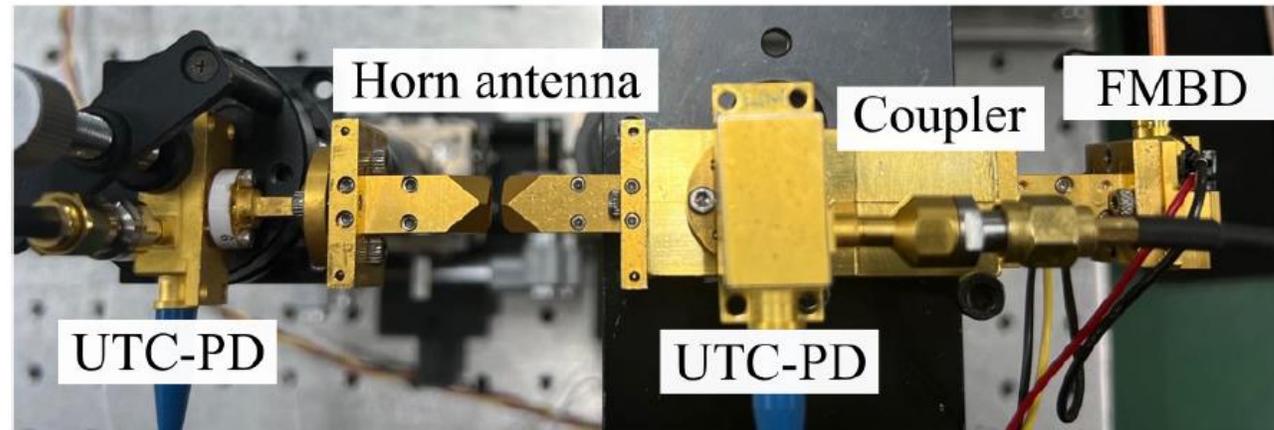


- OOK: 32 Gbit/s (Error free)
- 16-QAM: 48 Gbit/s (FEC-limit)
- Highest data rate
- 16-QAM: 120 Gbit/s and beyond (FEC-limit)

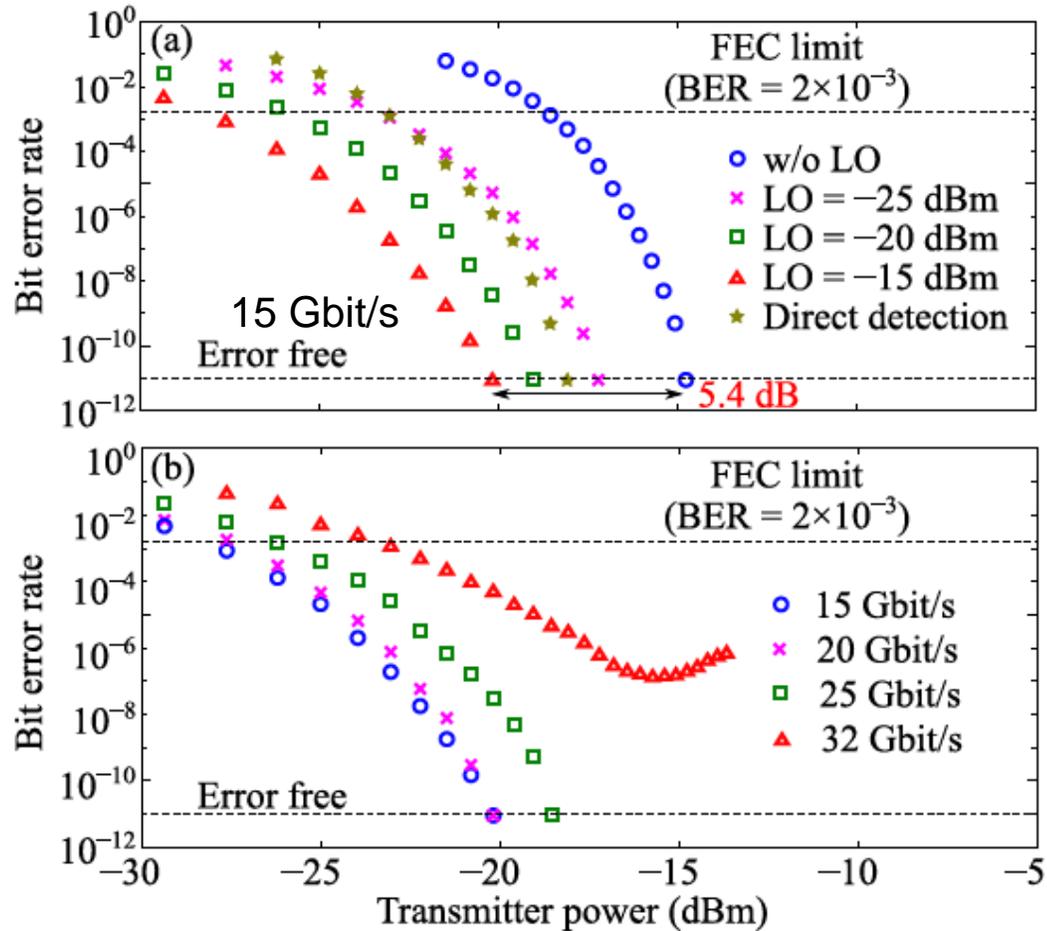
# Homodyne detection setup



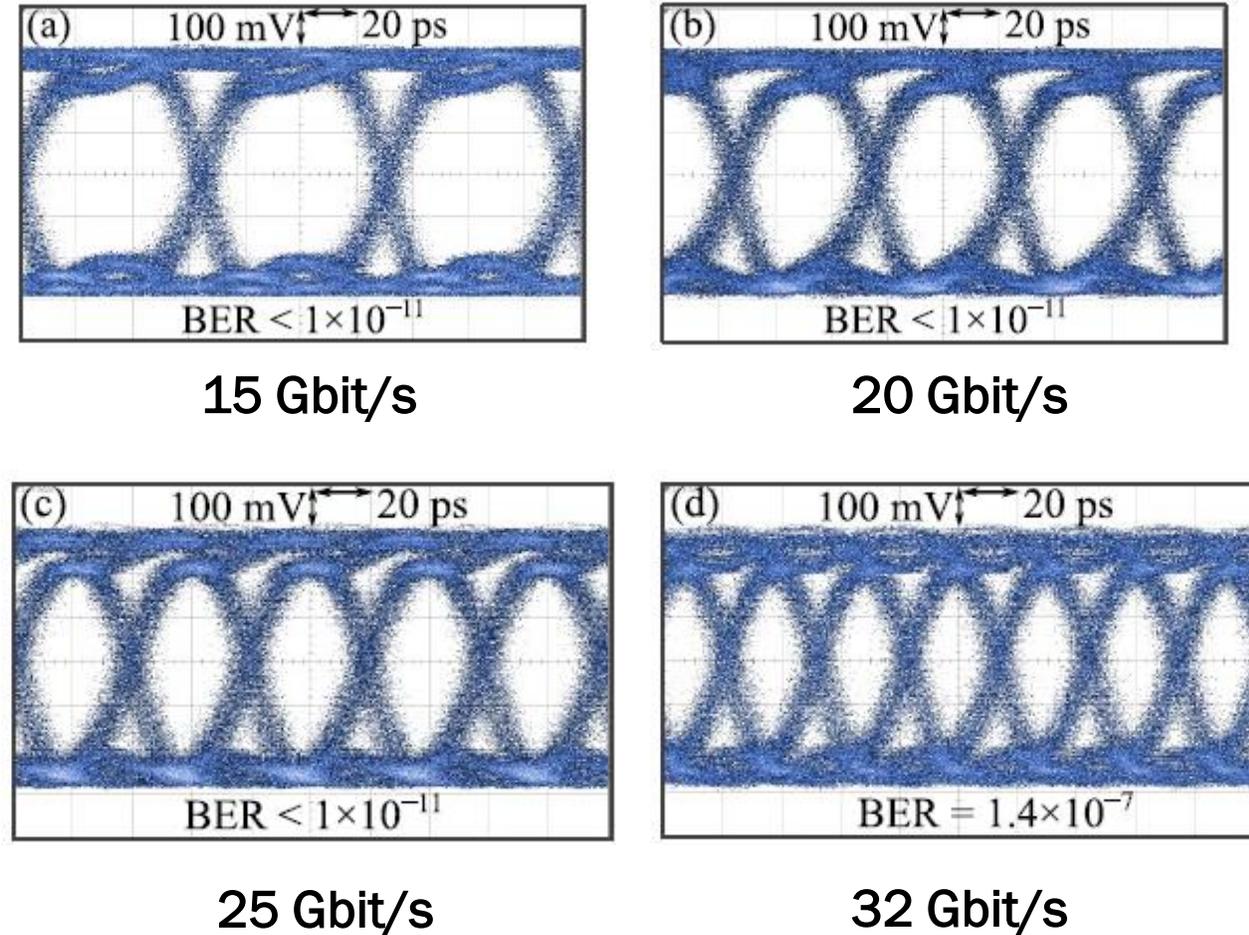
EOPM: Electro-optic phase modulator



## Bit error rate



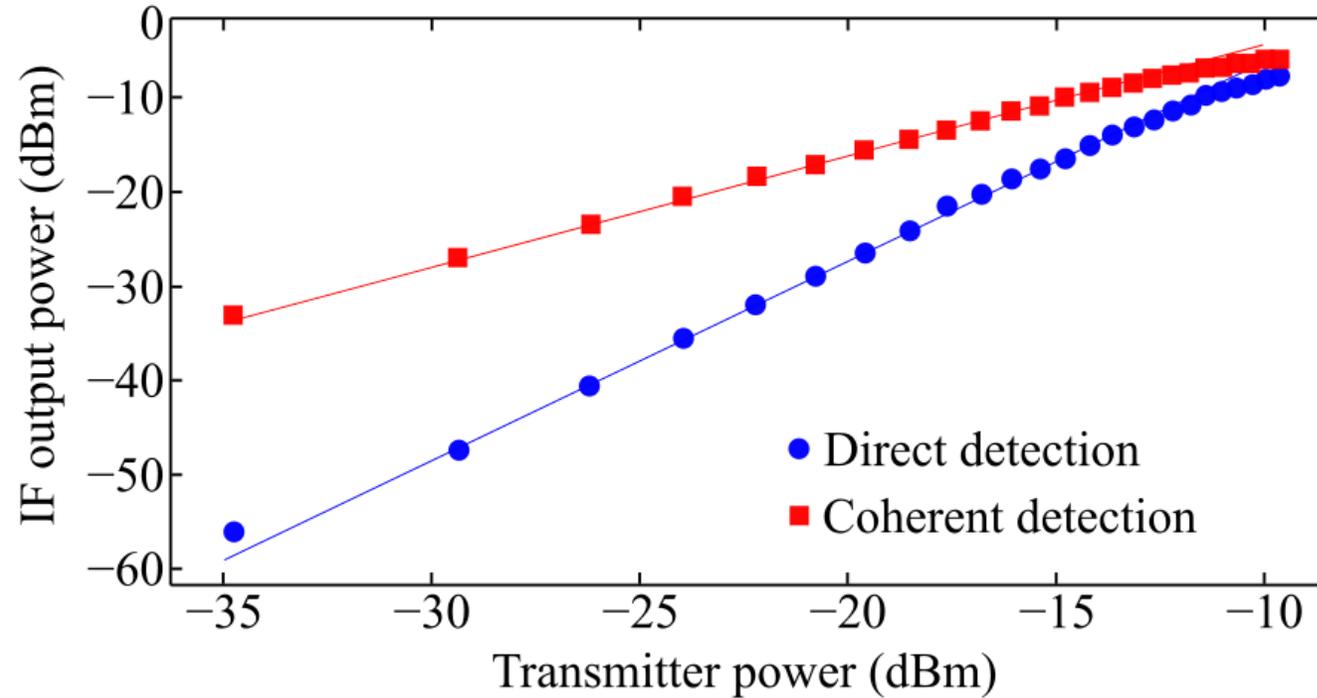
## Eye diagrams



RF frequency: 298 GHz; LO: -15 dBm

THz detector	OOK (Direct detection)	OOK (Coherent detection)	16-QAM (Direct detection)
SBD	12.5 Gbit/s (BER = $10^{-4}$ )	--	--
Quasi-optic FMBD	12.5 Gbit/s (BER = $10^{-9}$ )	12.5 Gbit/s (BER < $10^{-11}$ )	--
Waveguide-input FMBD (InP substrate)	32 Gbit/s (BER = $10^{-4}$ )	32 Gbit/s (BER = $2 \times 10^{-11}$ )	--
This Work	32 Gbit/s (BER = $10^{-11}$ )	32 Gbit/s (BER = $10^{-7}$ )	48 Gbit/s (BER < $2 \times 10^{-3}$ )

# Saturation



- The LO power is fixed as -15 dBm.
- The early saturation is mainly caused by the output limiting function of the internal TIA of the FMBD module.

- **SiC-substrate-based FMBD**
  - High sensitivity, low-noise, and broad bandwidth
- **FMBD characteristics**
  - RF bandwidth: 36 GHz ( $\pm 3$  dB)
  - IF bandwidth: 26 GHz at 300-GHz band
- **FMBD communications performance**
  - 00K error-free: 32 Gbit/s (direct), 25 Gbit/s (coherent)
  - 16-QAM below FEC-limit: 48 Gbit/s
- **Can benefit the beyond-5G communications**

# Acknowledgement

Part of this research result was obtained from the commissioned research (No.00901) by National Institute of Information and Communications Technology (NICT), Japan.