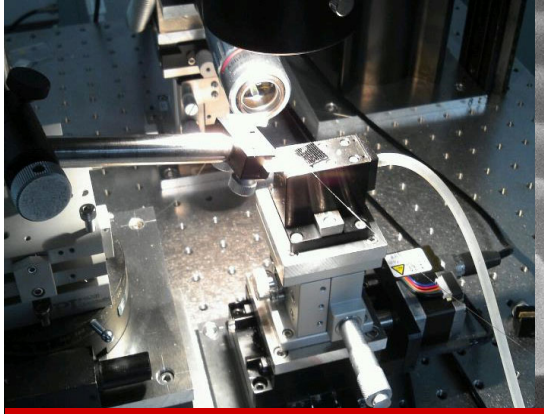
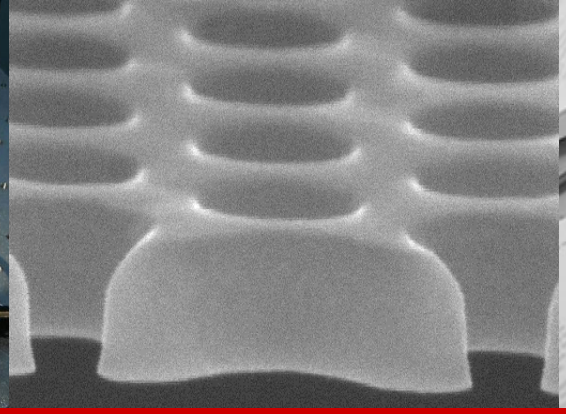

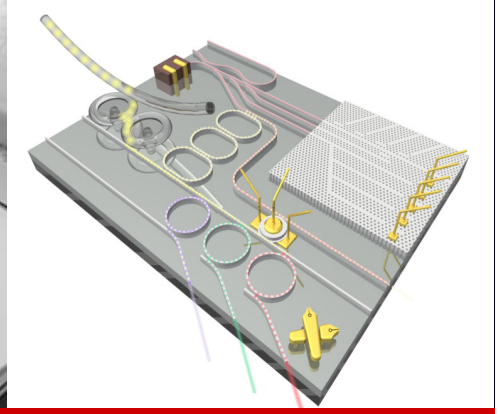

Photolithographically Fabricated Silicon Photonic Crystal Nanocavity Photoreceiver with a Laterally Integrated *pin* Diode

Nurul Ashikin Binti Daud, Tomohiro Tetsumoto and Takasumi Tanabe

Department of Electronics and Electrical Engineering, Keio University

Outline

1. Background
2. Device Design and Fabrication
   - Photolithographic fabrication
3. Photoreceiver properties
   - Leak current
   - Transmission and current spectrum at different input power
   - Responsivity
4. Photoreceiver operation
   - Time – domain measurement
5. Discussion & Summary

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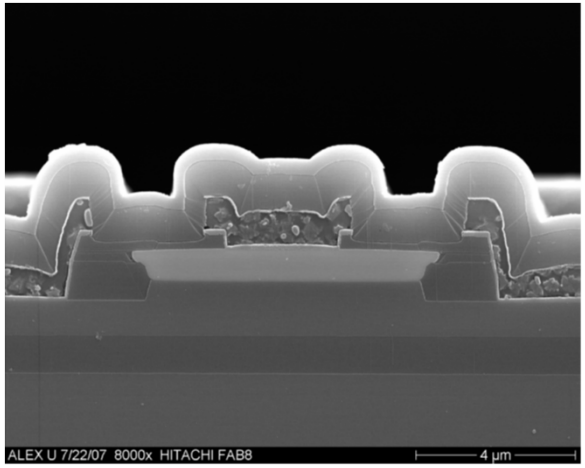
Previous Research

1. Ge integration on Si detector



T. Yin, et. al., Opt. Express **15**, 13965 (2007)

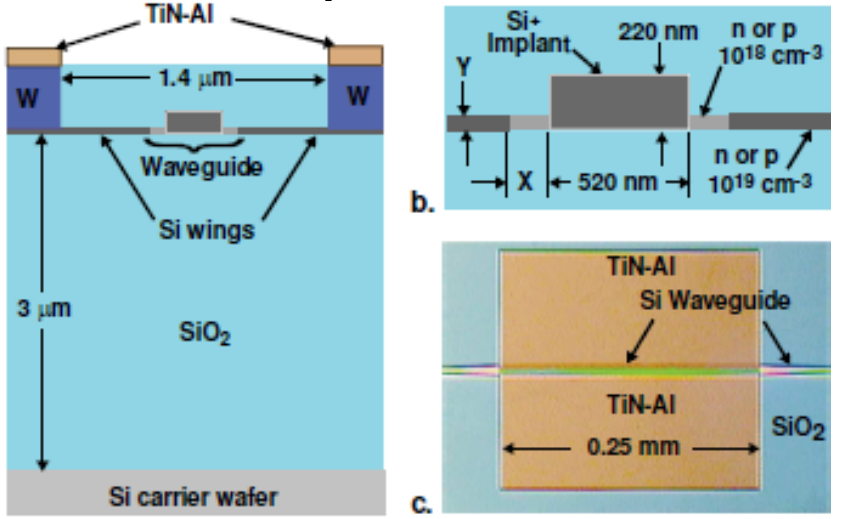
❑ **Advantages :**

- High speed (31 GHz)
- High sensitivity (QE~80%)
- Good responsivity (0.89 ~ 1.16 A/W)

❑ **Disadvantages :**

- Complicated in fabrication
- Large dark current due to defect (169 nA)

2. Ion-implanted Si detector



M. W. Geis, et. al., Opt. Express **17**, 5193 (2009)

❑ **Advantages :**

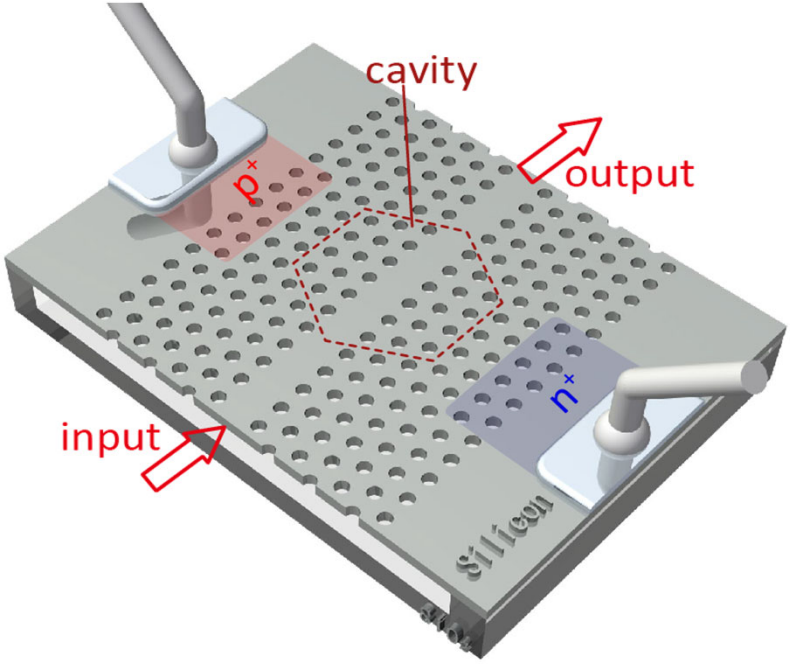
- CMOS compatible (all-silicon)
- Good sensitivity and speed
- Good responsivity : 0.5 ~ 10 A/W)

❑ **Disadvantages :**

- Unstable (large aging effect)
- Large dark current due to defect (0.5 nA to 0.5 μA)

All-Si Photoreceiver

Detect 1.5-μm telecom light using Si-chip integrated *p-i-n* diode



T. Tanabe, et. al., Opt. Lett. 23, 3895 (2010)

❑ Advantages :

- Low dark current
  - ➢ Because it is all-silicon
- High sensitivity
  - ➢ Due to high-*Q* cavity
- Requires low optical power

❑ Disadvantages :

- ➢ Requires air-bridge structure
  - Frangible and unstable
  - Incompatible with Si photonic devices
- ➢ Fabricated by EB lithography
  - High in accuracy but time consuming process

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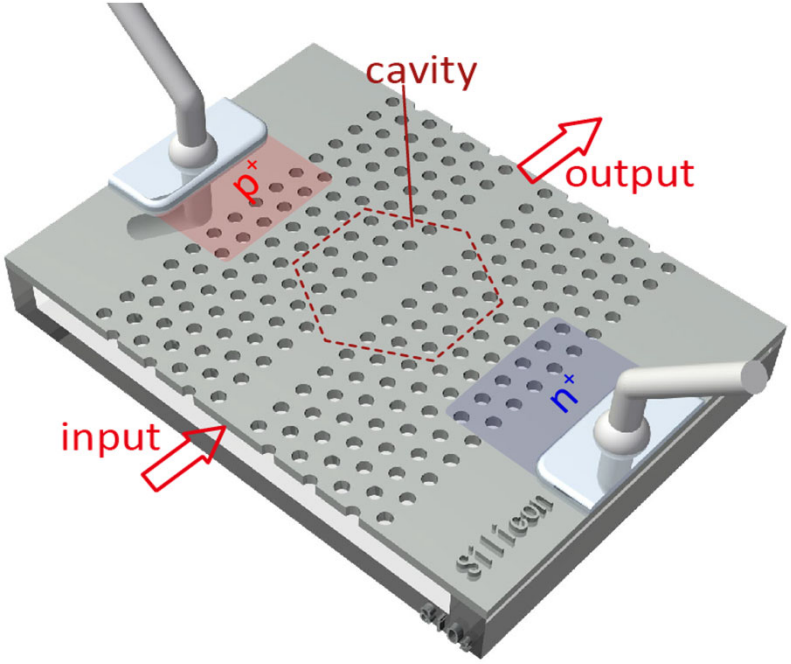

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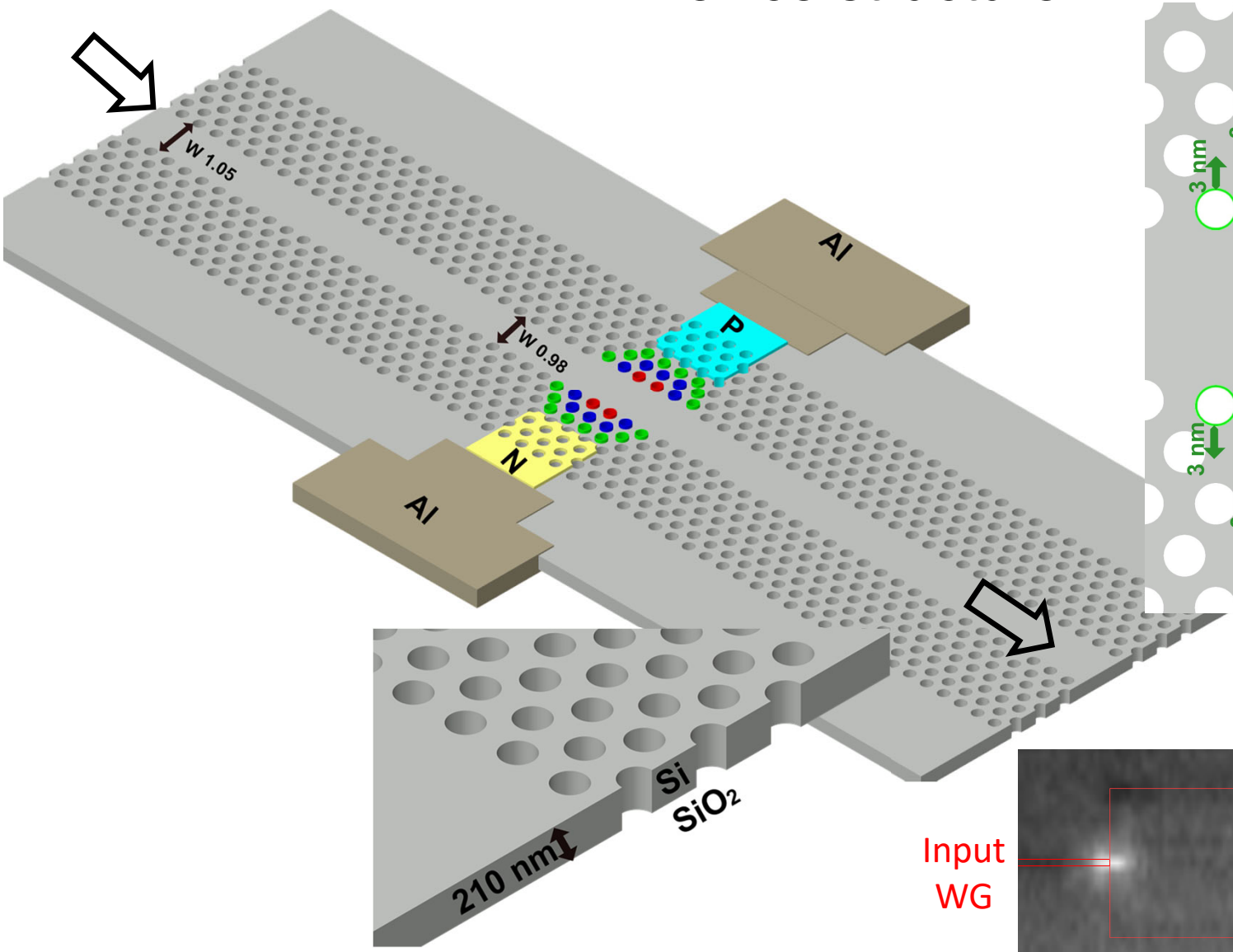
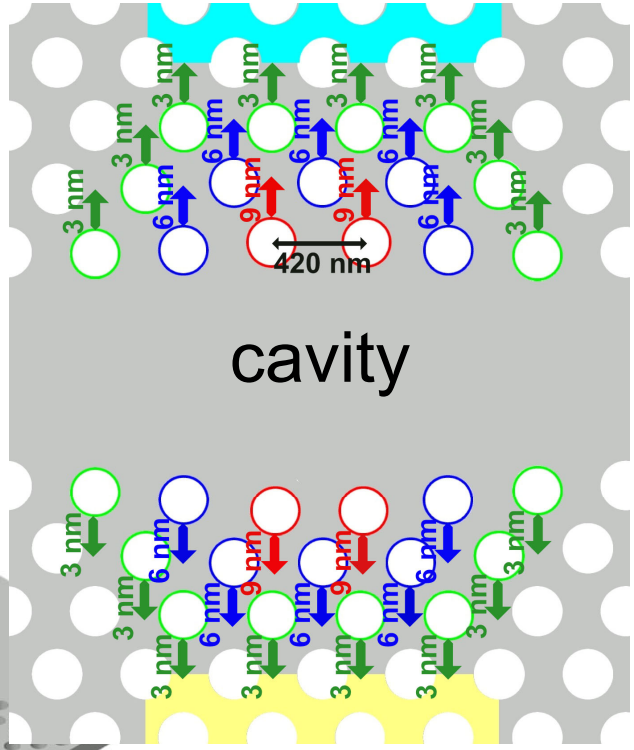
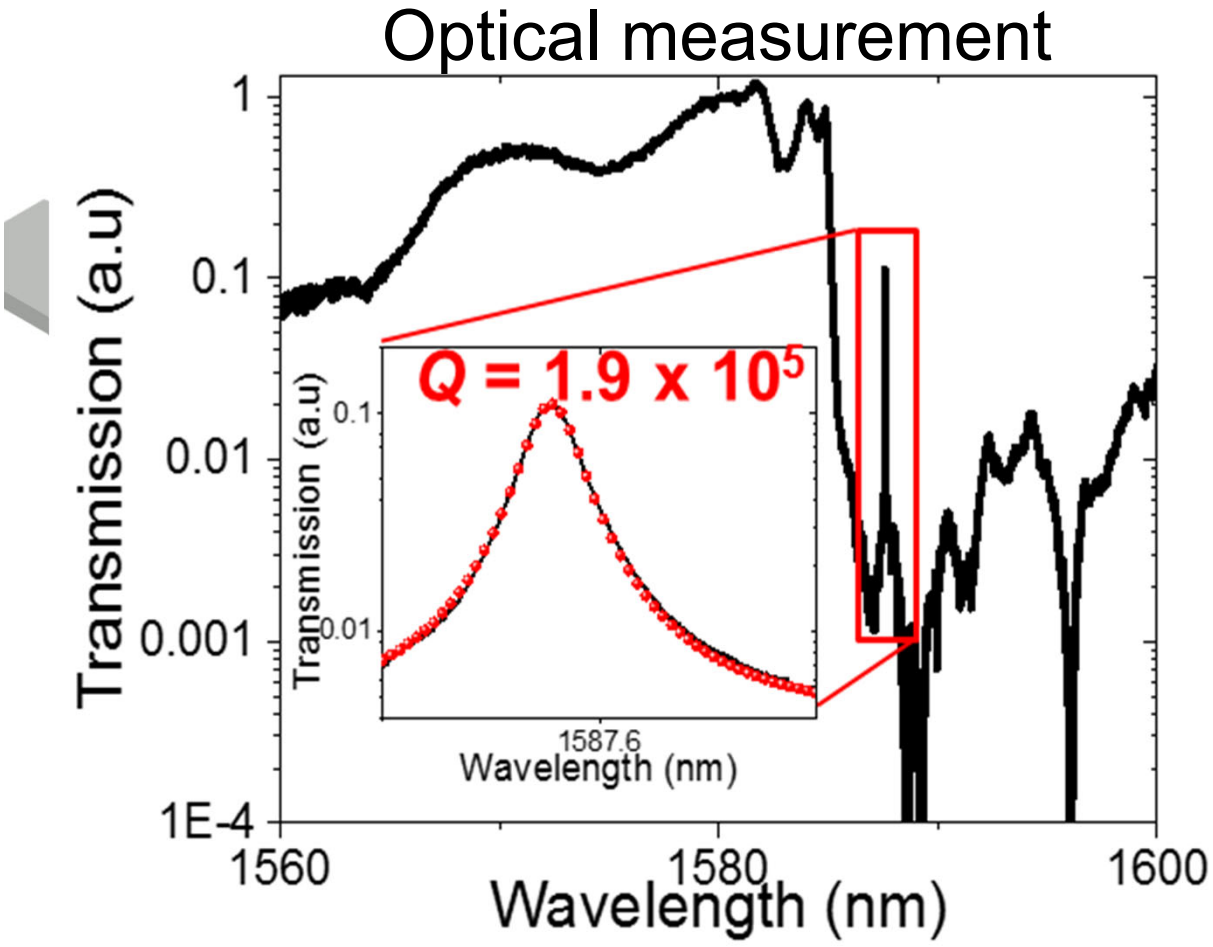
PhC nanocavity photoreceiver w/ pin diode

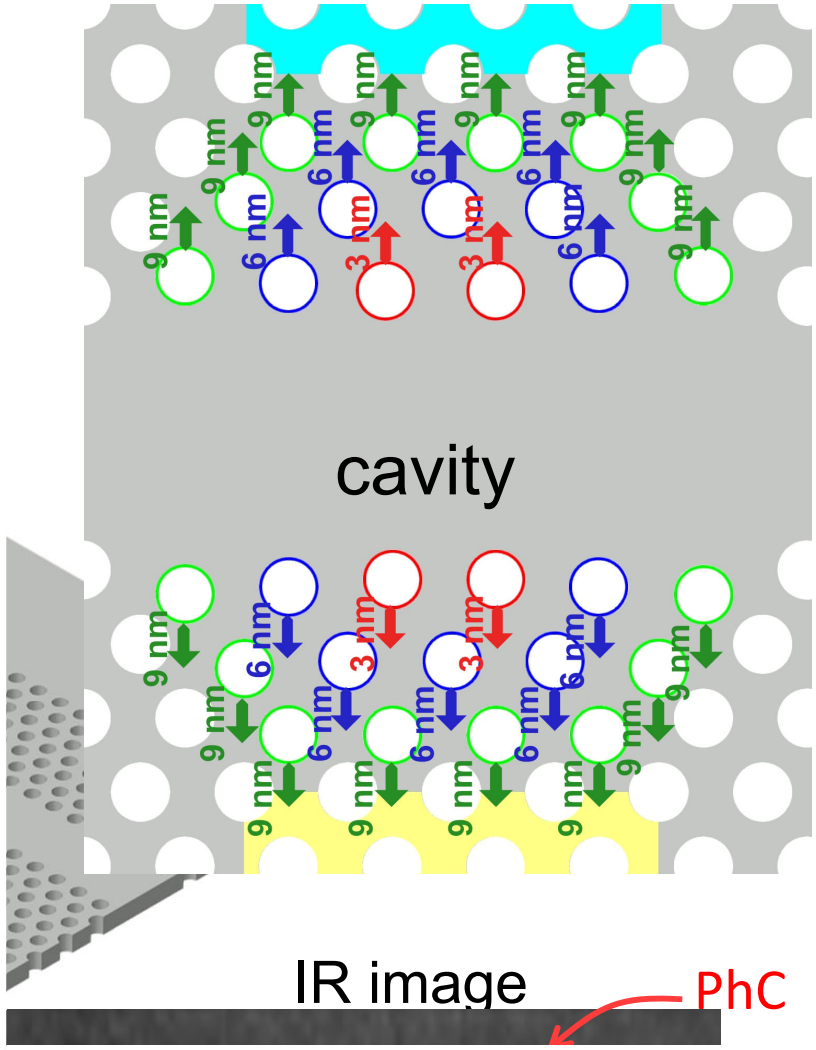
Device structure





PhC nanocavity photoreceiver w/ pin diode





Achieved high *Q* factor with photolithography & silica clad Y. Ooka, et al., Sci. Rep. 5, 11312 (2015)

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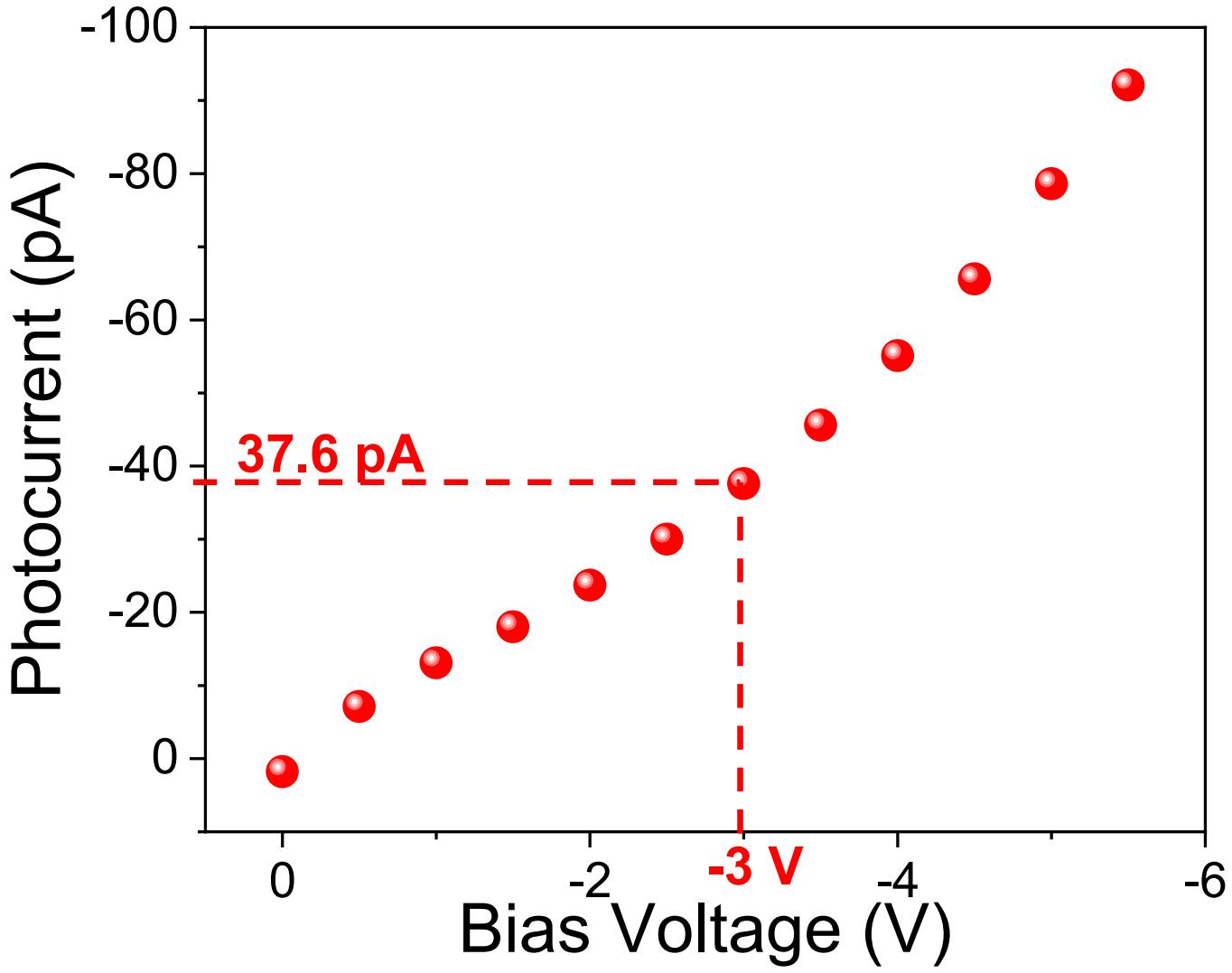
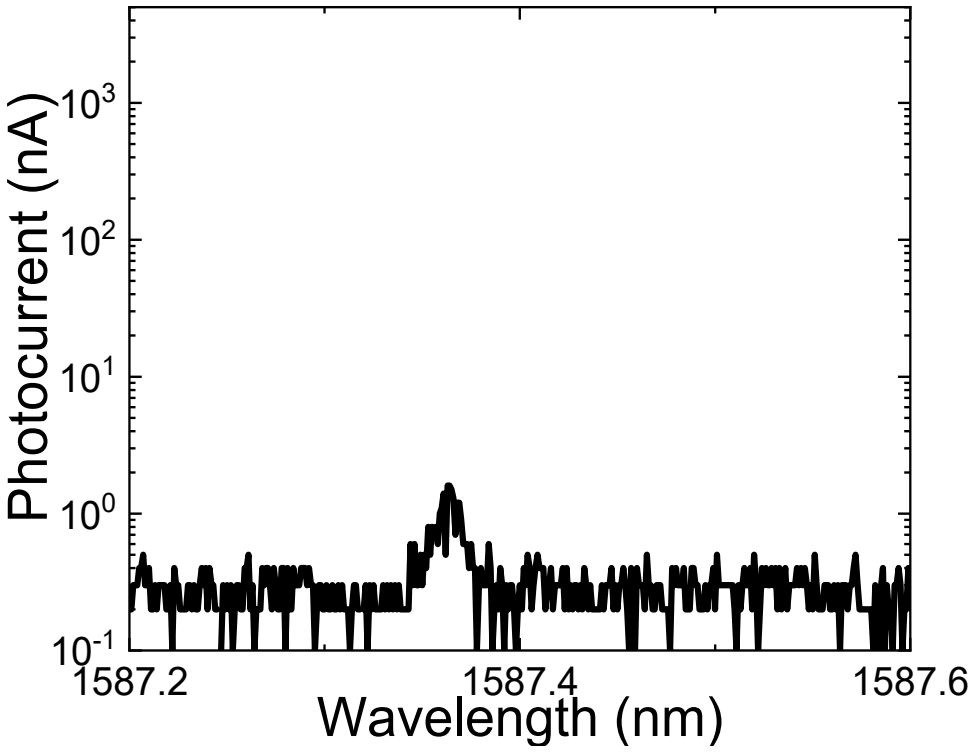
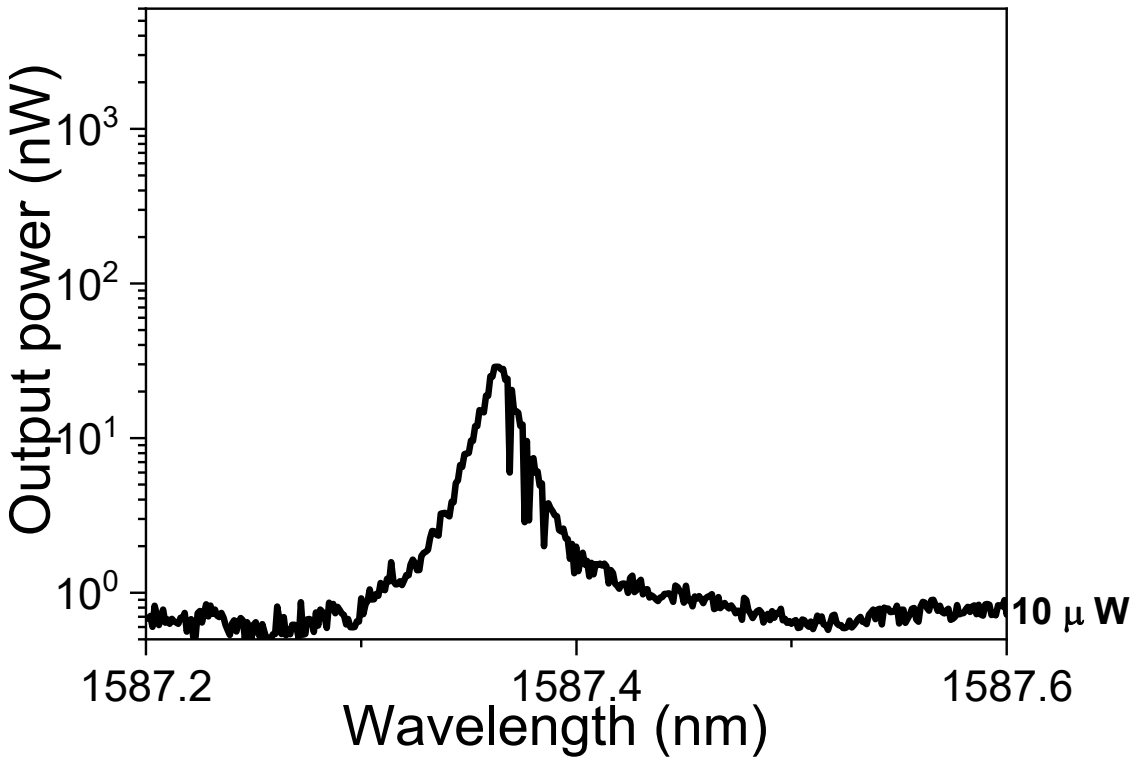
Dark (leak) current at RT



Value of leak current at -3 V is 37.6 pA

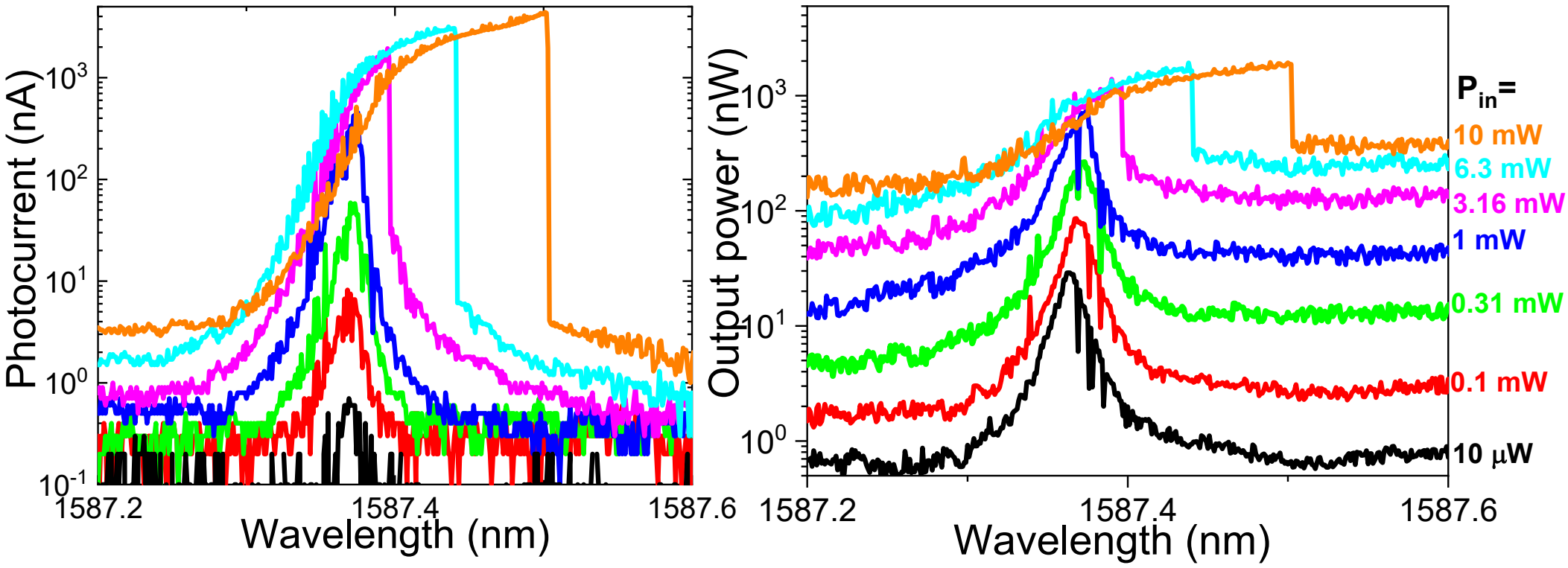
Transmission and current spectrum at different input power





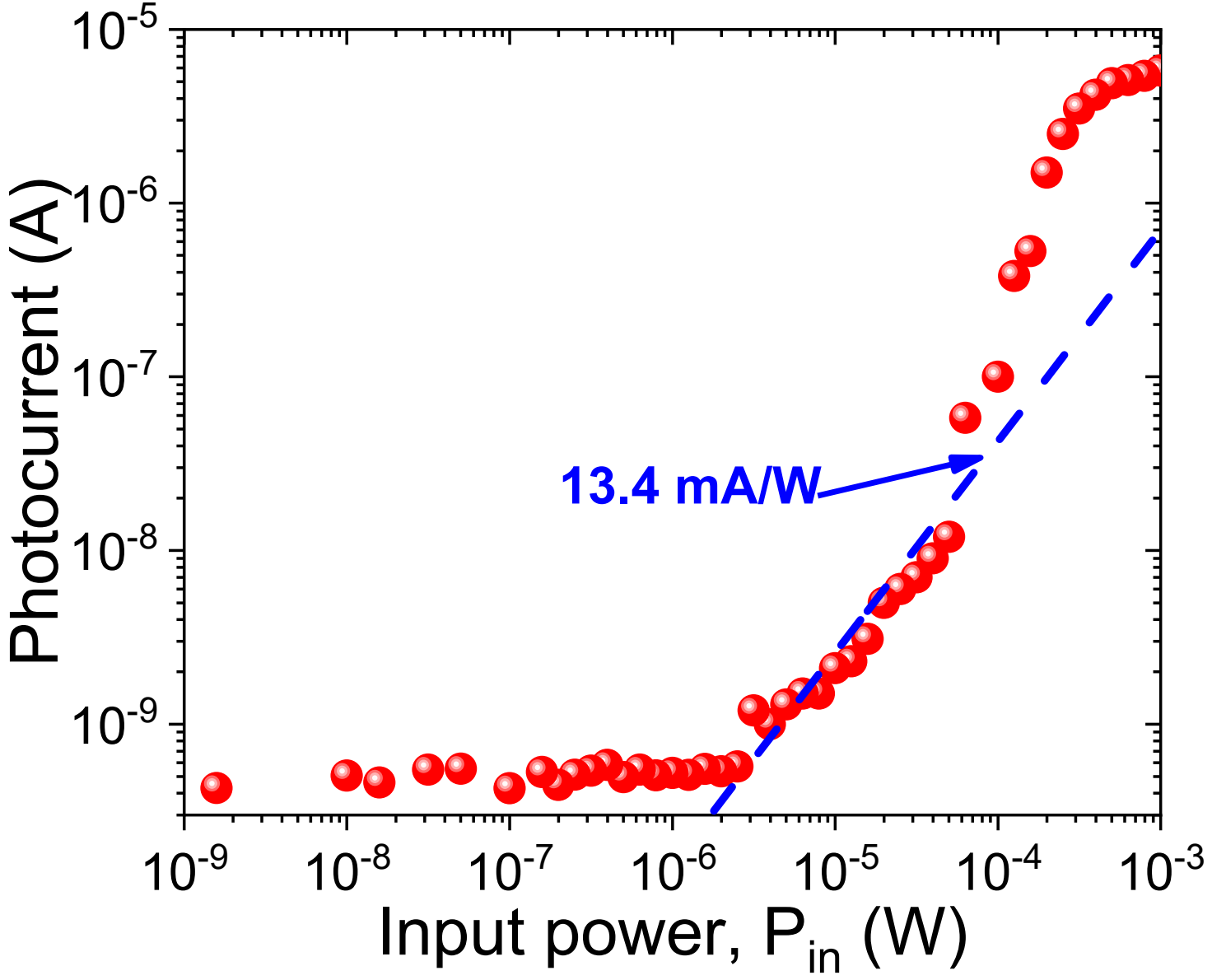
Resonance of cavity enhanced the photocurrent

Transmission and current spectrum at different input power



Thermo-bistability effect where carriers are generated by the two-photon absorption (TPA)

Responsivity of the device



Sensitivity of 0.89 % at 0.3 mW input power

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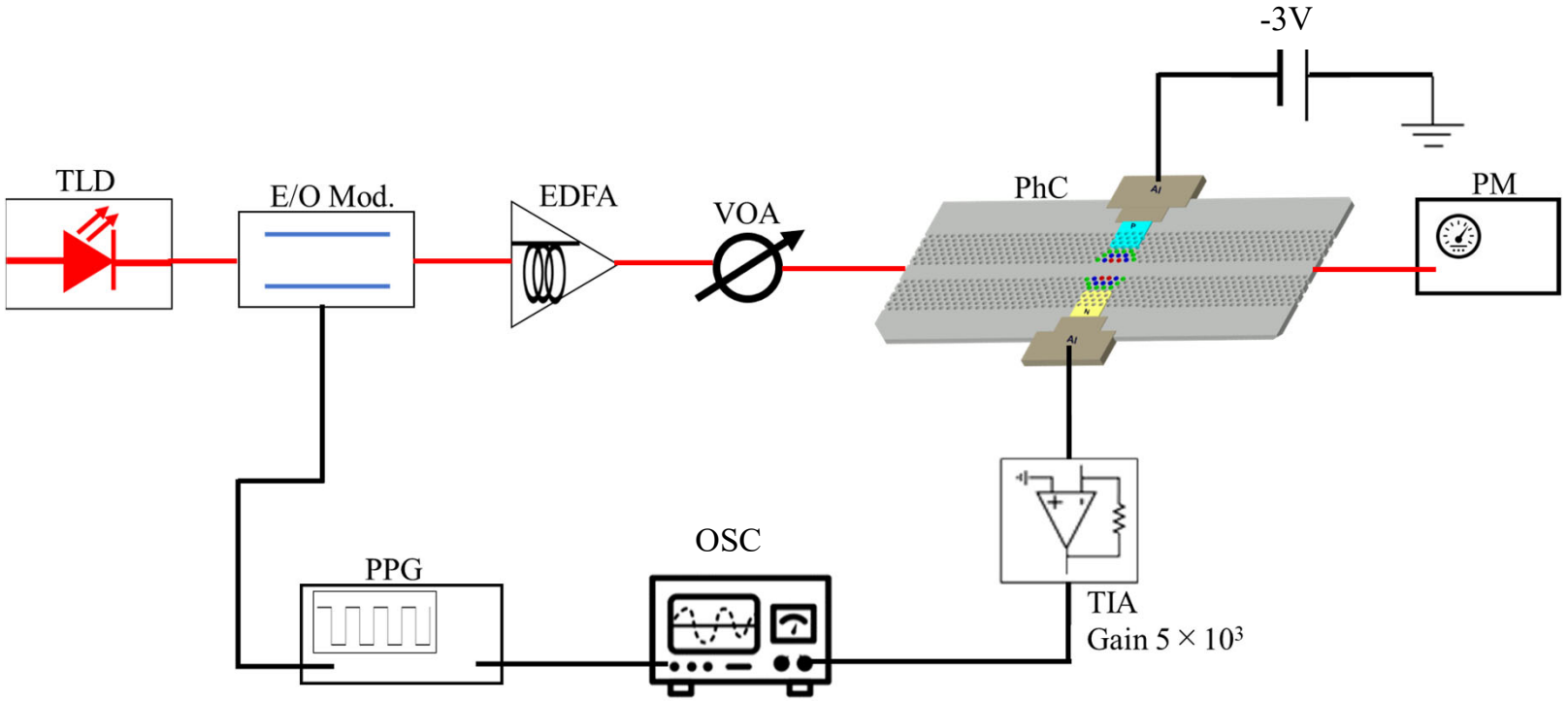
Time-domain measurement

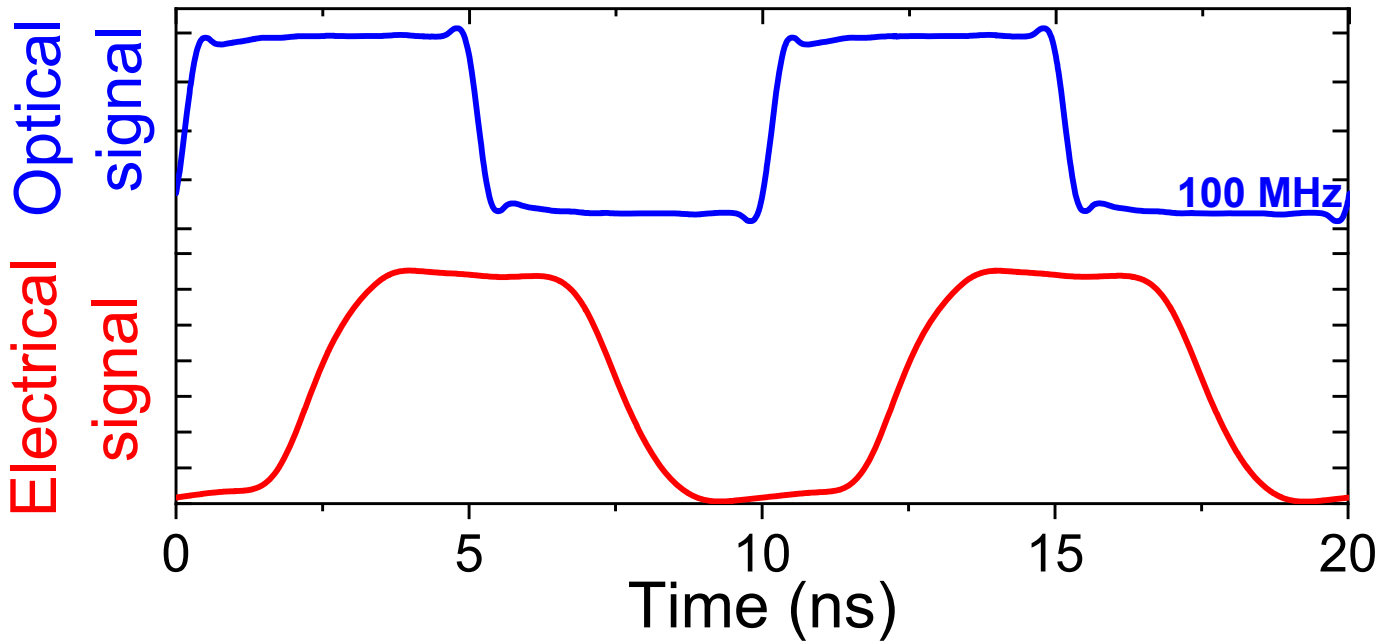
Experimental setup



TLD : Tunable Laser Diode
E/O Mod. : Electro-optic modulator
EDFA : Erbium doped frequency amplifier
VOA : Variable optical attenuator
PM : Power meter
PPG : Pulse pattern generator
OSC : Oscilloscope
TIA : Trans-impedance amplifier

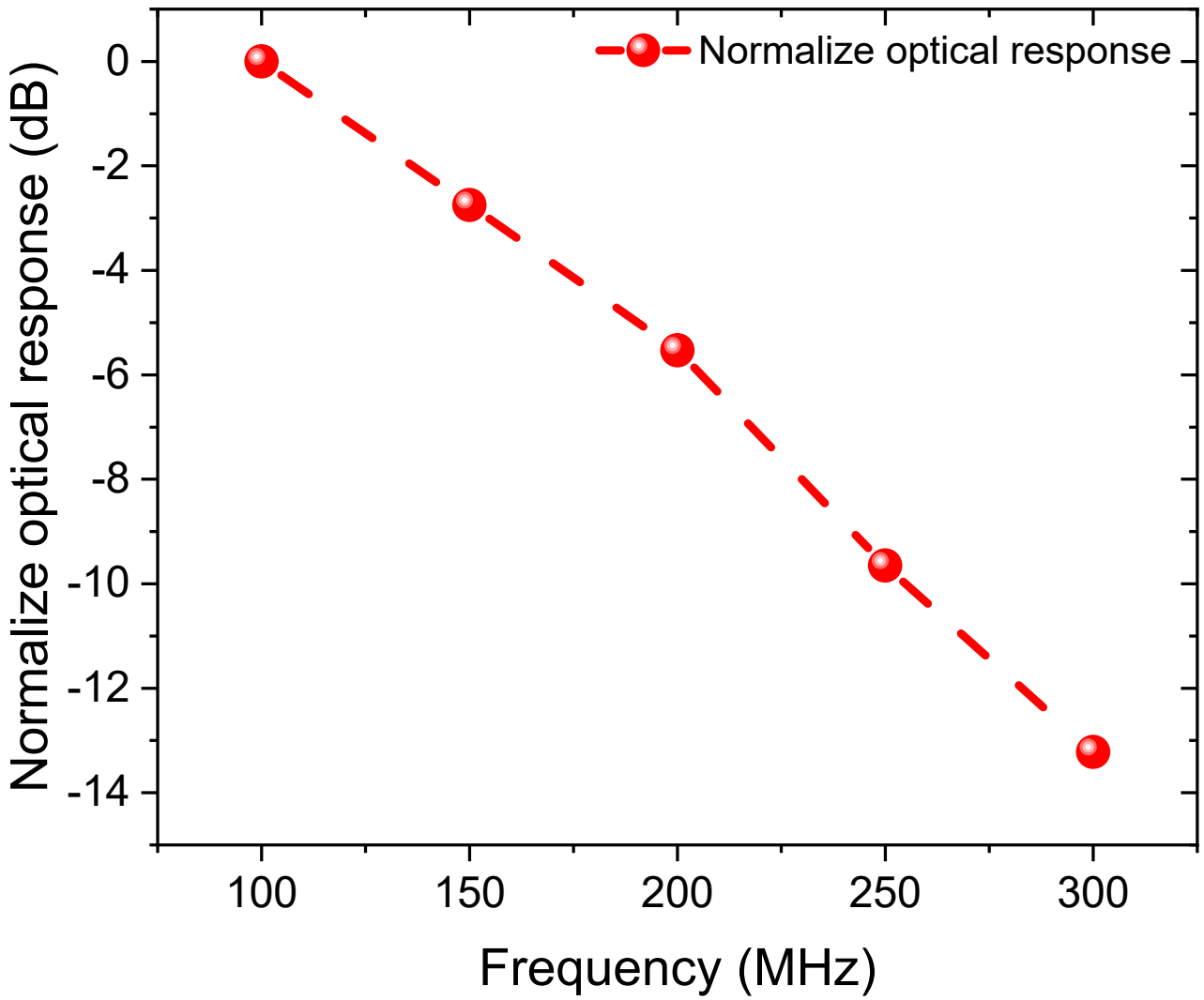
Time-domain measurement

Square pulse



0.1 GHz photoreceiver operation at the resonance cavity

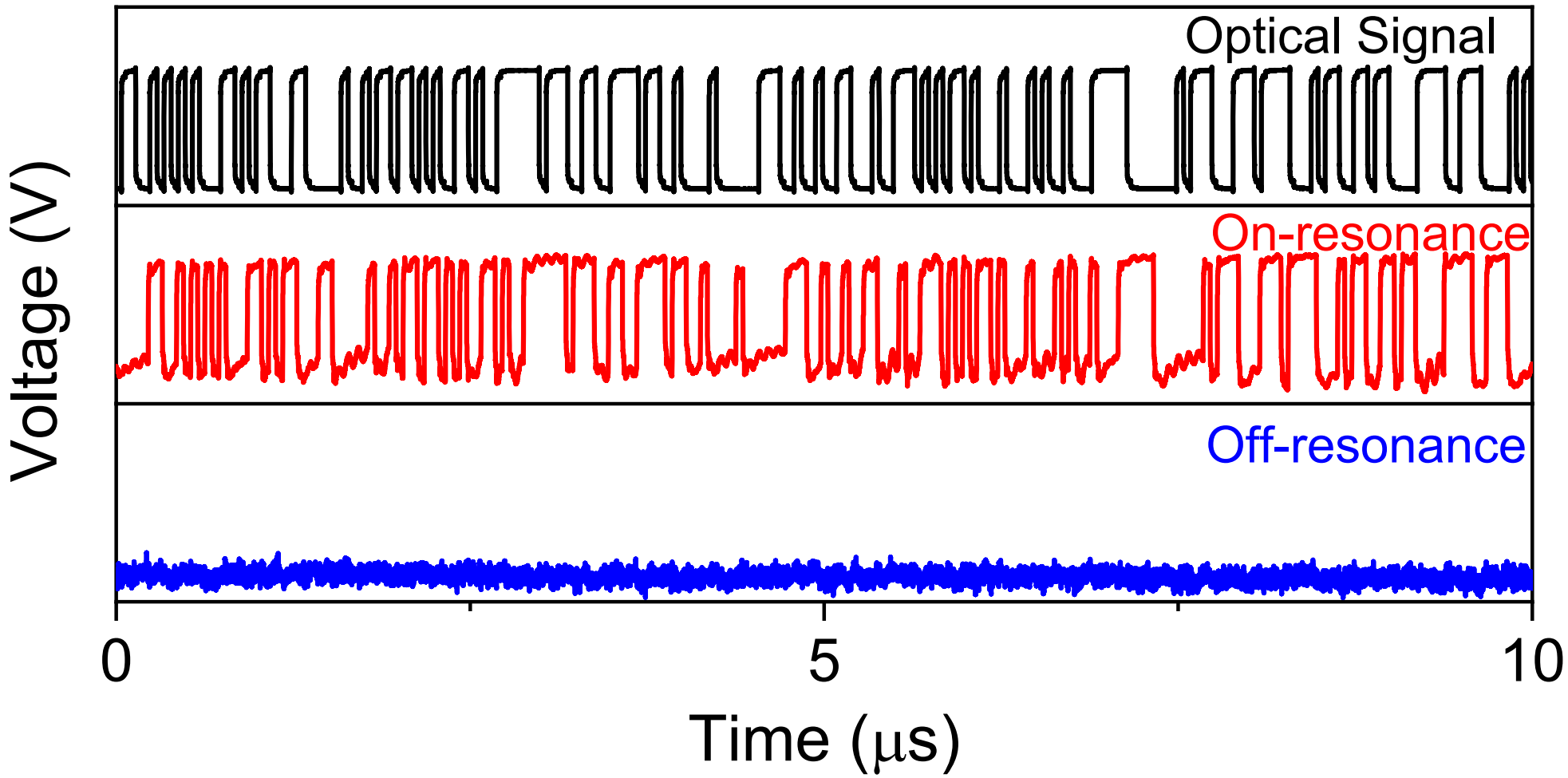
Time-domain measurement



-3 dB cut-off frequency shows at 0.15 GHz

0.1 Gb/s photoreceiver demonstration

Pseudo random bit sequence pulse



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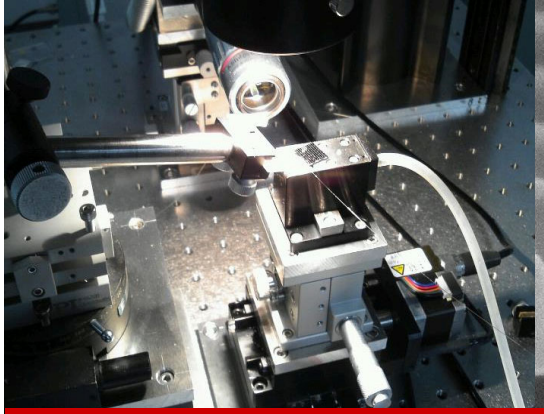
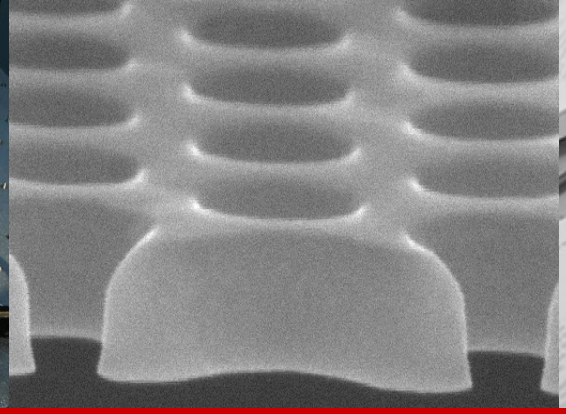
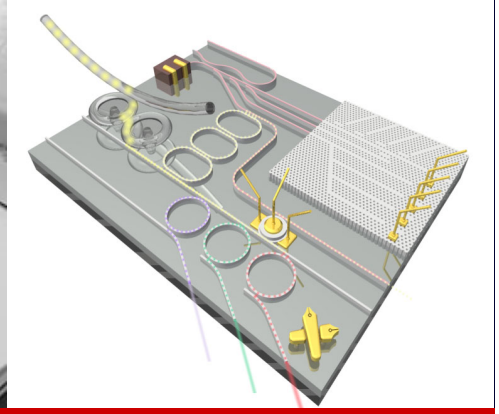
Achievements of current work

	Quant. eff.	Dark current	Min. detectable in. light power	Device length	Operation voltage	Speed	Coupling w/ fiber	Referen
Si PhC (SiO_2 clad)	0.89%	37.6 pA	~100 nW	8.4 μm	-3V	0.1 GHz	-1.6 dB	This wo (2018
Si PhC (AB)	9.7%	15 pA	0.9 nW	8.4 μm	-3 V	0.1 GHz	-12 dB	APL **96** 10110 (2010)
Ge on Si	71%	169 nA	~190 nW	50 μm	-2 V	31 GHz	NA	OE **15** 13965 (2007)
Si^+ mplanted Si	~16%	0.5 nA	~2.5 nW	3~4 mm	-5 V	0.2 GHz	NA	IEEE-P **18,** 188 (2006



Thank you

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