LOGICAL VIBRATIONAL RESONANCE in a VCSEL

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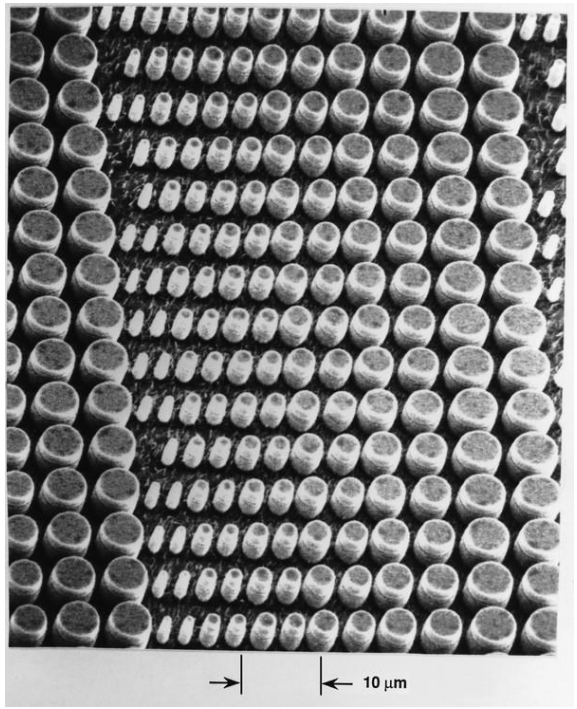
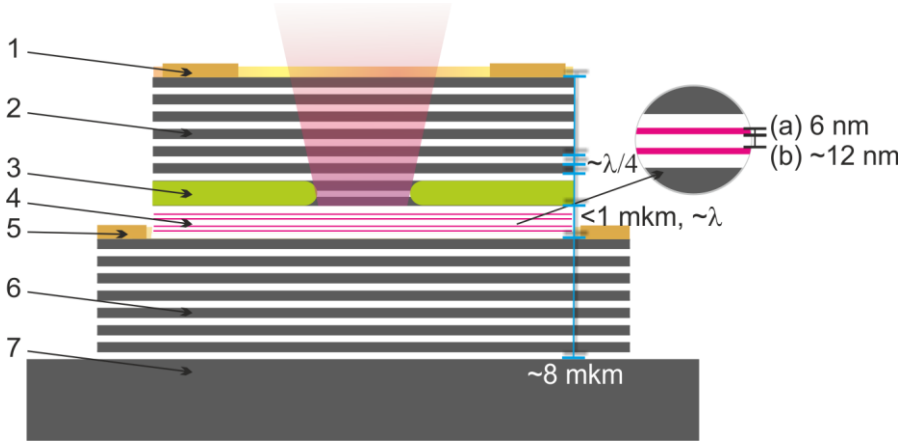
THE CENTRE OF QUANTUM OPTICS AND QUANTUM INFORMATION

VCSEL (vertical-cavity surface-emitting laser)



SEM image of a 6x8mm chip with over 1 million VCSELs.
Photo by Axel Scherer, 1989

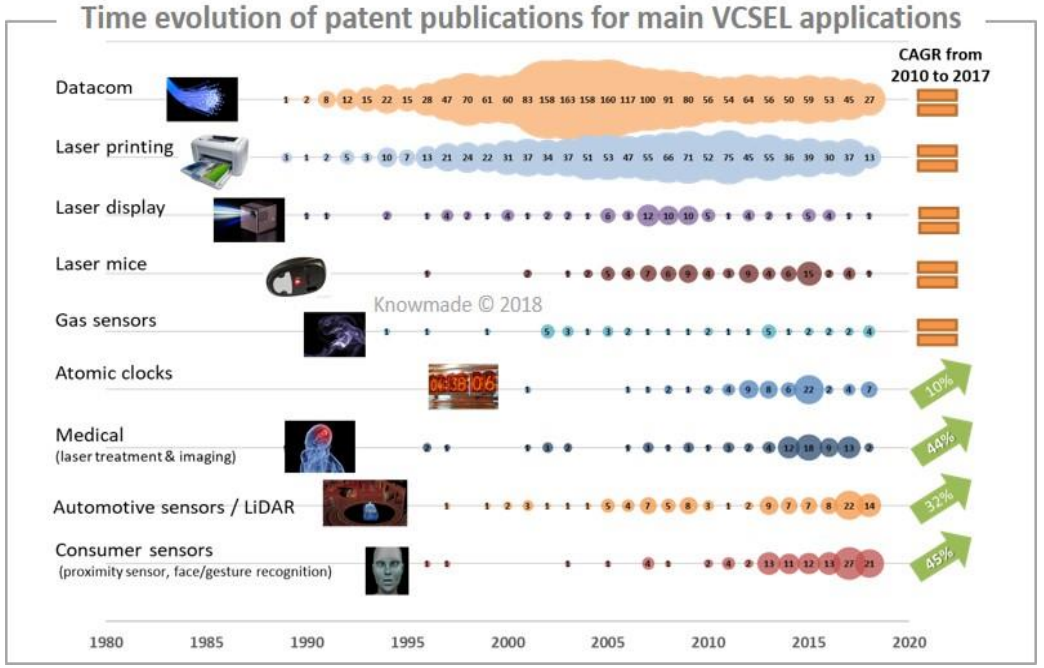


1-p-electrode,
2-upper (output) distributed Bragg diffraction grating of the resonator,
3- aperture,
4 - active region,
5 - n-electrode,
6 - lower distributed Bragg diffraction grating of the resonator,
7 - substrate

Advantages:

- Low-power (small threshold current, typical values ~2 mA)
- Hight-quality beam parameters
- Silicon-based production technology -> easy to scale to array

VCSEL application area



https://www.knowmade.com/downloads/vcsel-patent-landscape/

Practical

LIDARs and other distance sensors
3D vision systems
Solid state lasers pumping
Vibration sensors
Fiberoptic networks

Fundamental

Building fundamental models
Model systems for systems with complex sample preparation (biology, chemistry, ecology, etc.)

Outlook for LVR investigation

Experiment with electrical circuits

Enhanced logical vibrational resonance in a two-well potential system

Chaos, Solitons & Fractals
Volume 138, September 2020, 109952
Rong Guia Yue Wanga Yuangen Yaoa Guanghui Chengb
https://doi.org/10.1016/j.chaos.2020.109952

Set–reset latch logic operation in a bistable system under suprathreshold and subthreshold signals

Cite as: Chaos **30**, 023119 (**2020**); https://doi.org/10.1063/1.5134888
Submitted: 04 November 2019 . Accepted: 20 January 2020 . Published Online: 06 February 2020

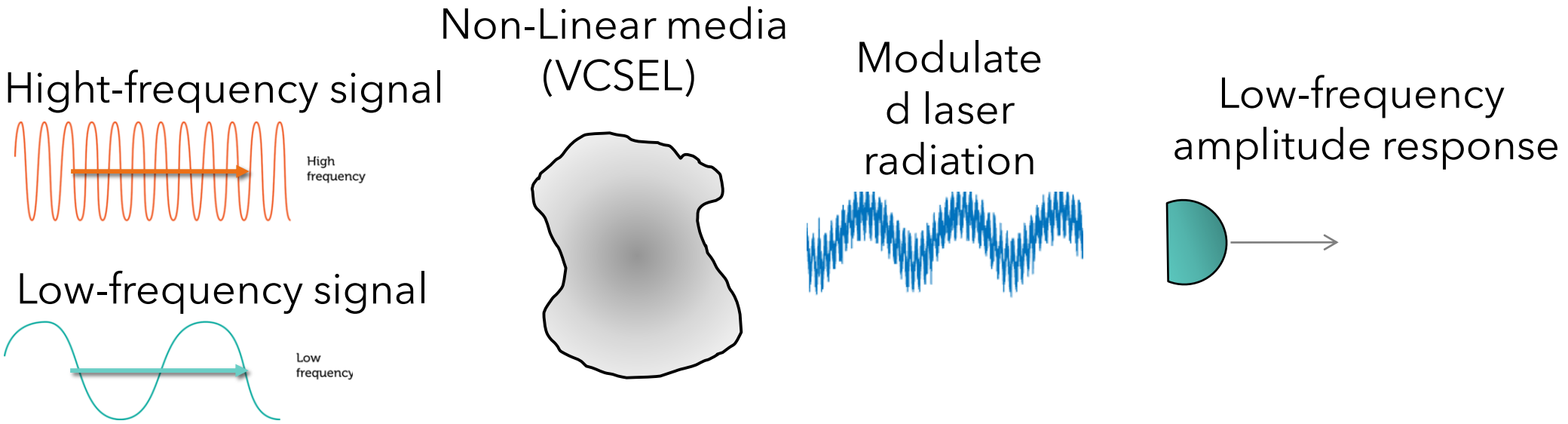
Analytical analysis and numerical experiment

Vibrational resonance and implementation of dynamic logic gate in a piecewise-linear Murali–Lakshmanan–Chua circuit

Communications in Nonlinear Science and Numerical Simulation
Volume 39, October 2016, Pages 271-282
P.R.Venkatesh, A.Venkatesan
https://doi.org/10.1016/j.cnsns.2016.03.009

and many other..

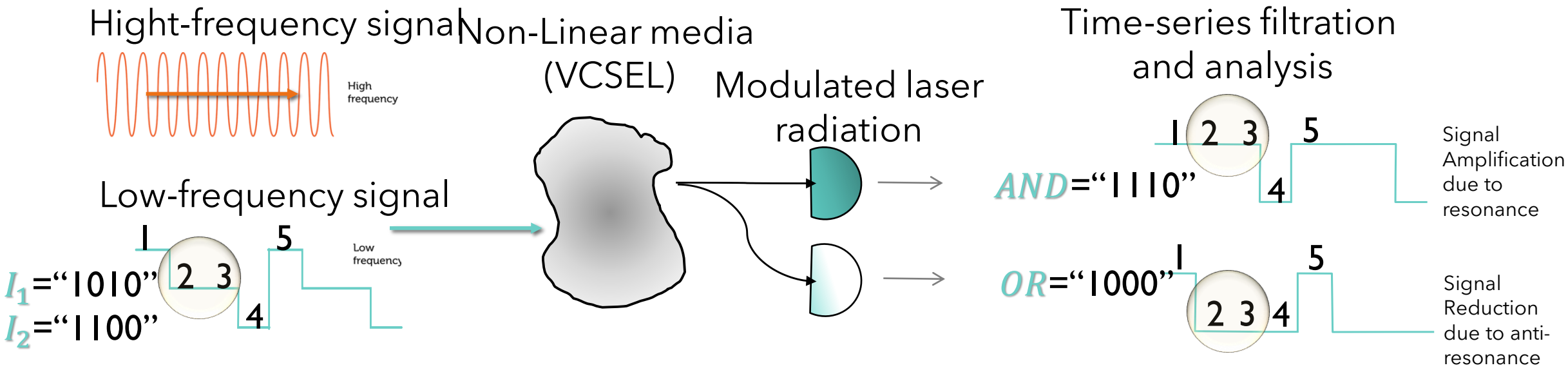
The IDEA of VR (vibrational resonance)



Classical bistable oscillator model + LF + HF modulations

$$\dot{x} - x + x^3 = \mathrm{A}\cos\omega_{HF}t + B\cos\omega_{LF}t$$

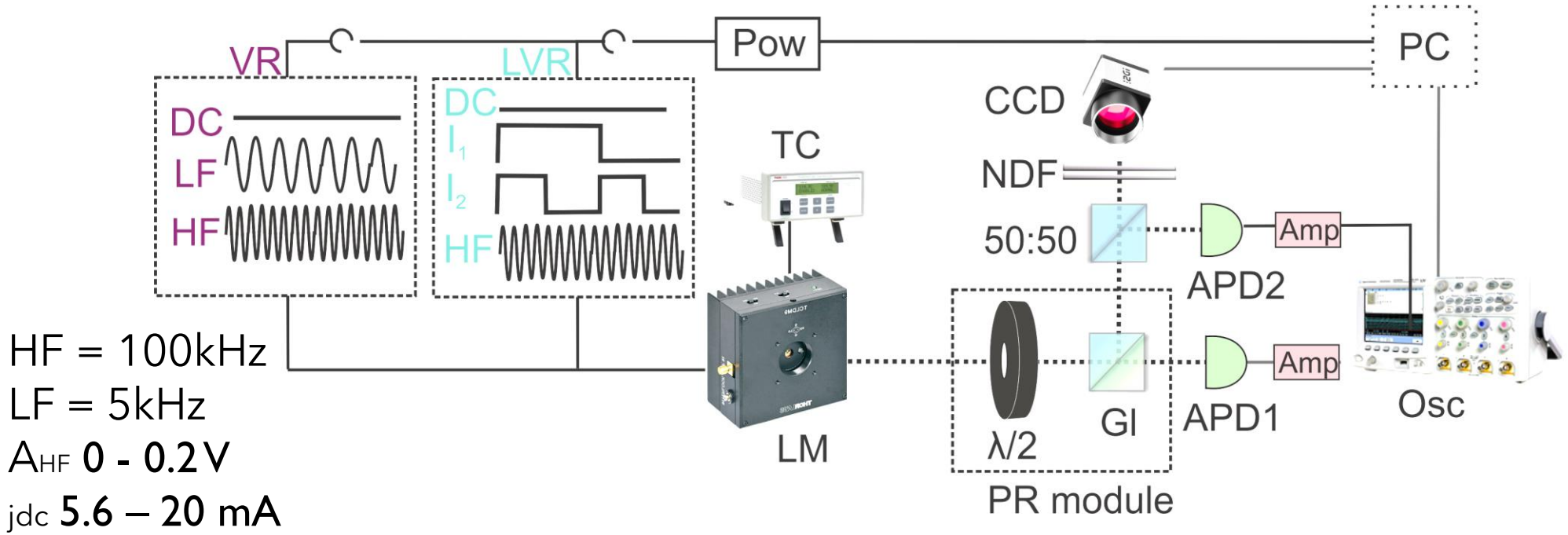
The IDEA of LVR (logical vibrational resonance)



Classical bistable oscillator model + HF modulation + LF logical signals

$$\dot{x} - x + x^3 = \mathrm{A}\cos\omega_{HF}t + I_1(\omega_{LF}) + I_2(\omega_{LF})$$

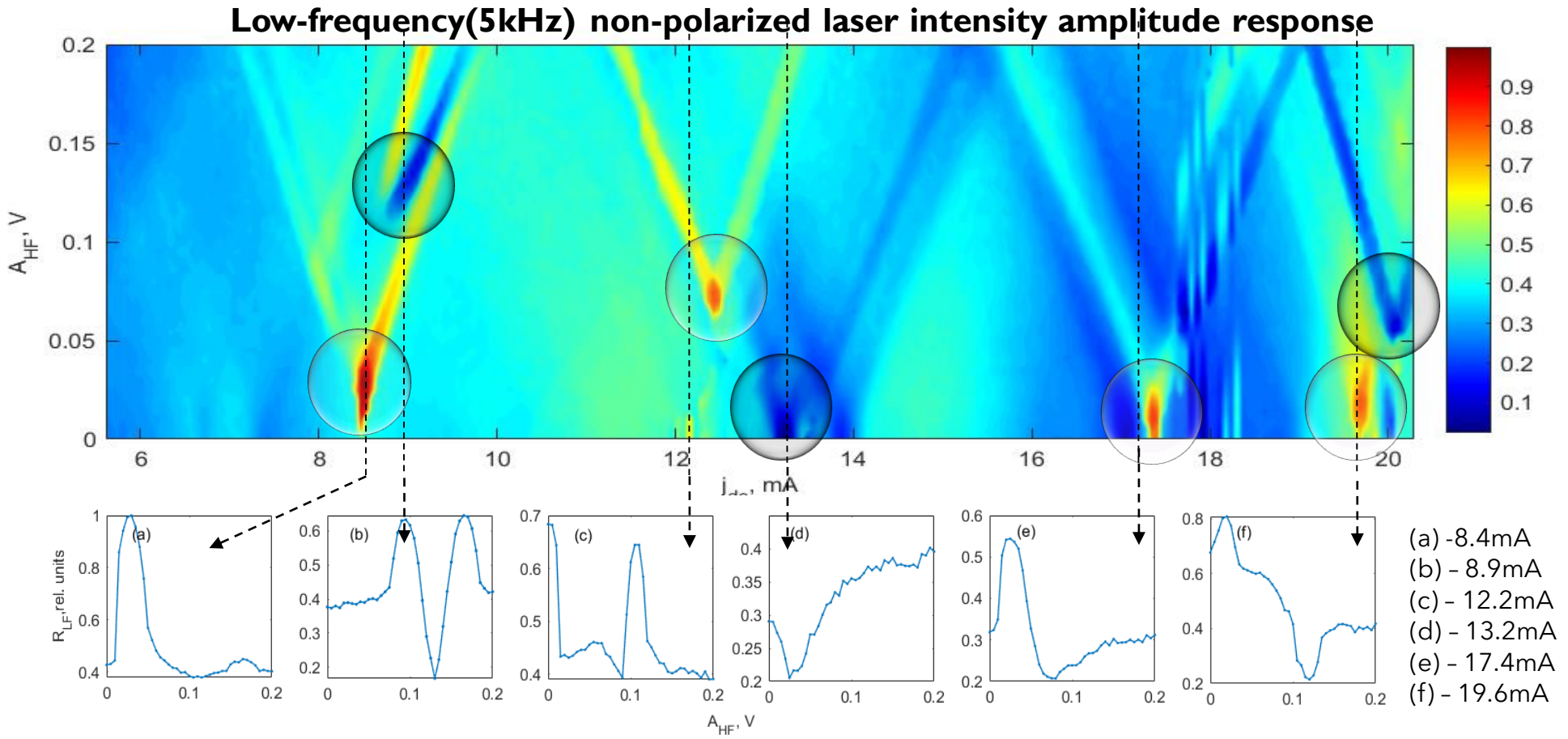
Experimental setup



HF = 100kHz
LF = 5kHz
A_{HF} 0 - 0.2V
jdc 5.6 – 20 mA

Experimental setup: **LM** – laser module (the 850nm-VCSEL HFE4084-322 installed), **PR module** – optics for polarisation resolving (**λ/2** – half-wave plate, **Gl** – Glan prism), **APD1,2** – avalanche photodiodes, **CCD** – camera (u-eye 3240NIR), **PC** – computer, **Osc** – oscilloscope (Agilent DSO5034), **Pow** –signal generator, **TC** – temperature controller (Thorlabs TC200C, 25±0.01°C), **50:50** – non-polarizing beam splitter, **NDF** – neutral density filters, **Amp** – signal amplifiers.

VR experiment – the VCSEL characterization



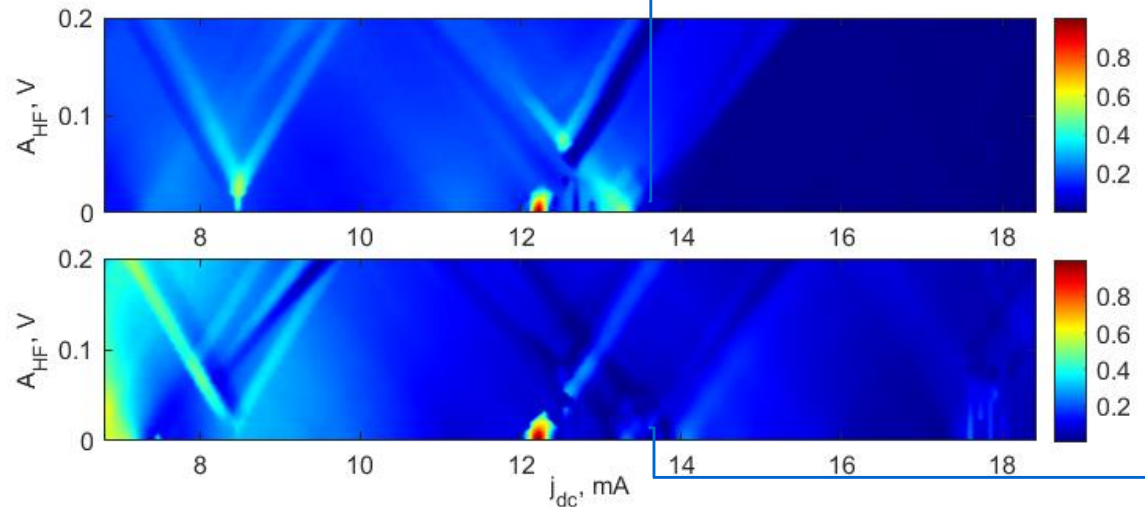
Polarization resolved VR

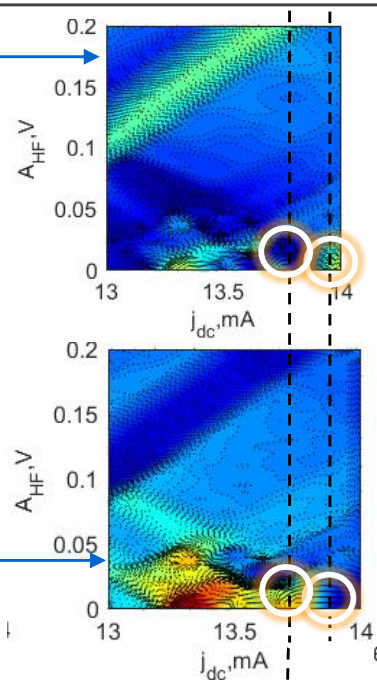
Determined parameters
j_{dc}=13,65 mA
A_{LF}=15mV (5kHz)
A_{HF}= 15mV (100kHz)

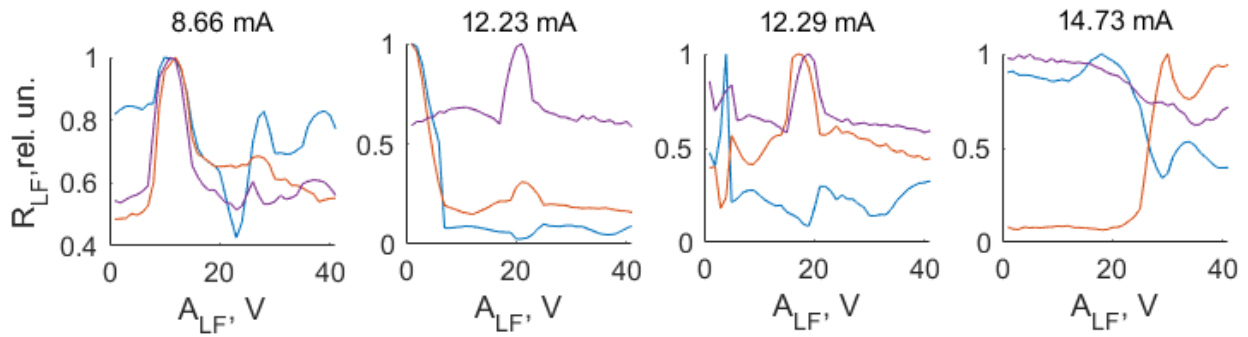
Determined parameters
j_{dc}=13,85 mA
A_{LF}=15mV (5kHz)
A_{HF}= 3mV (100kHz)

APD1
– X pol. component

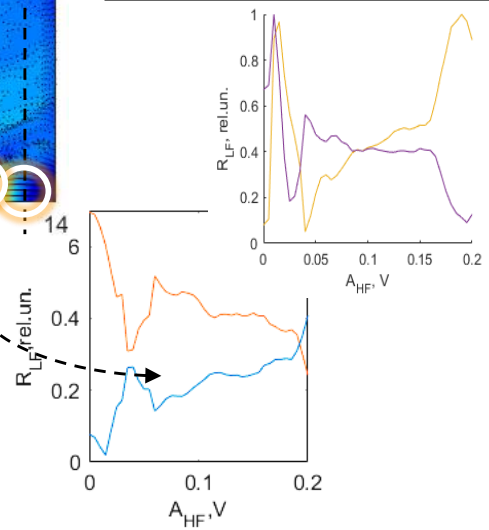
APD2
– Y pol. component



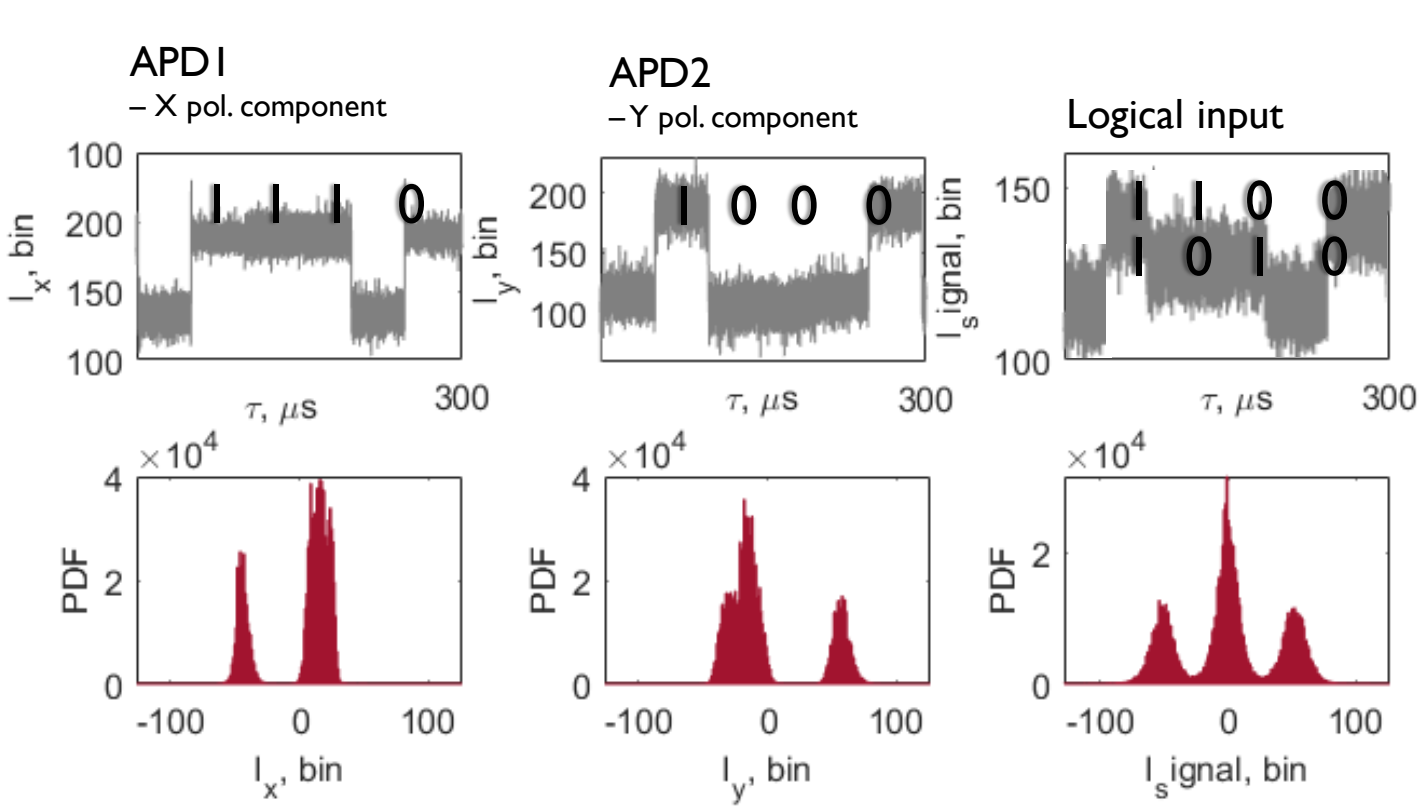


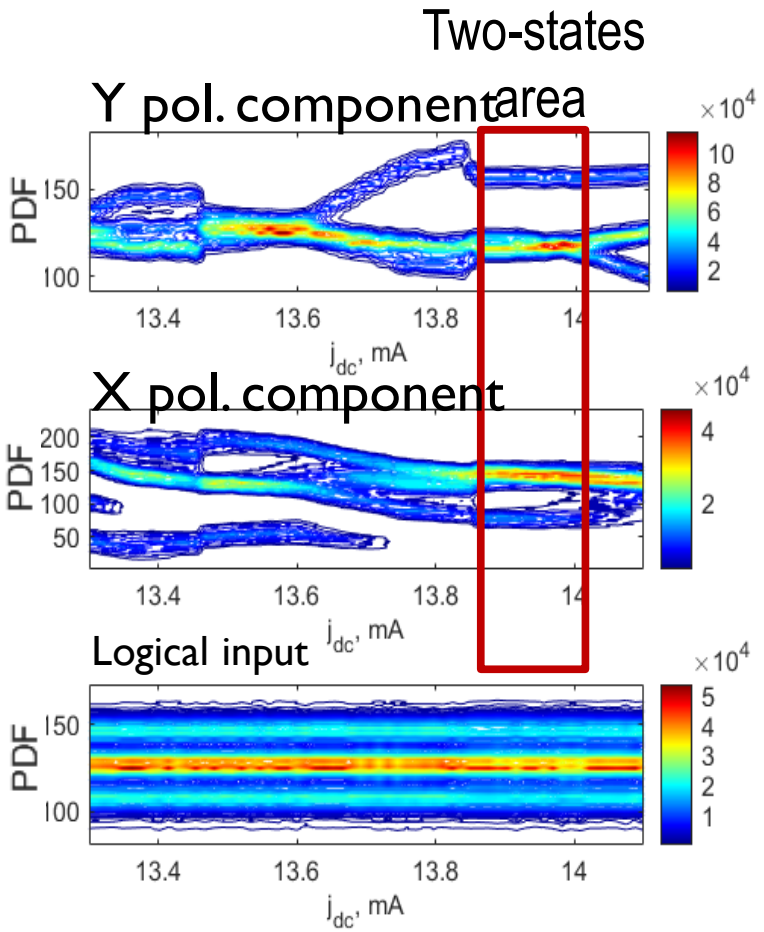


R_{LF-X}
R_{LF-Y}
$R_{LF-Integra}$



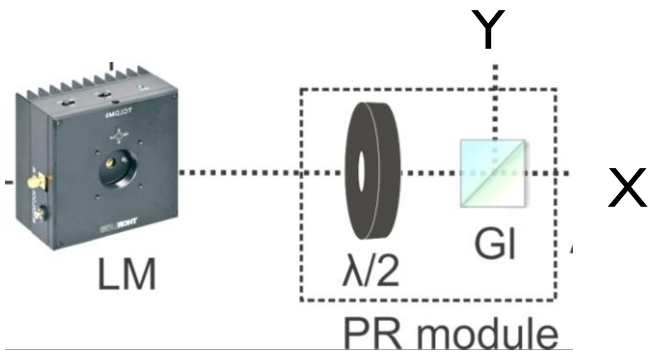
VCSEL output with logical input





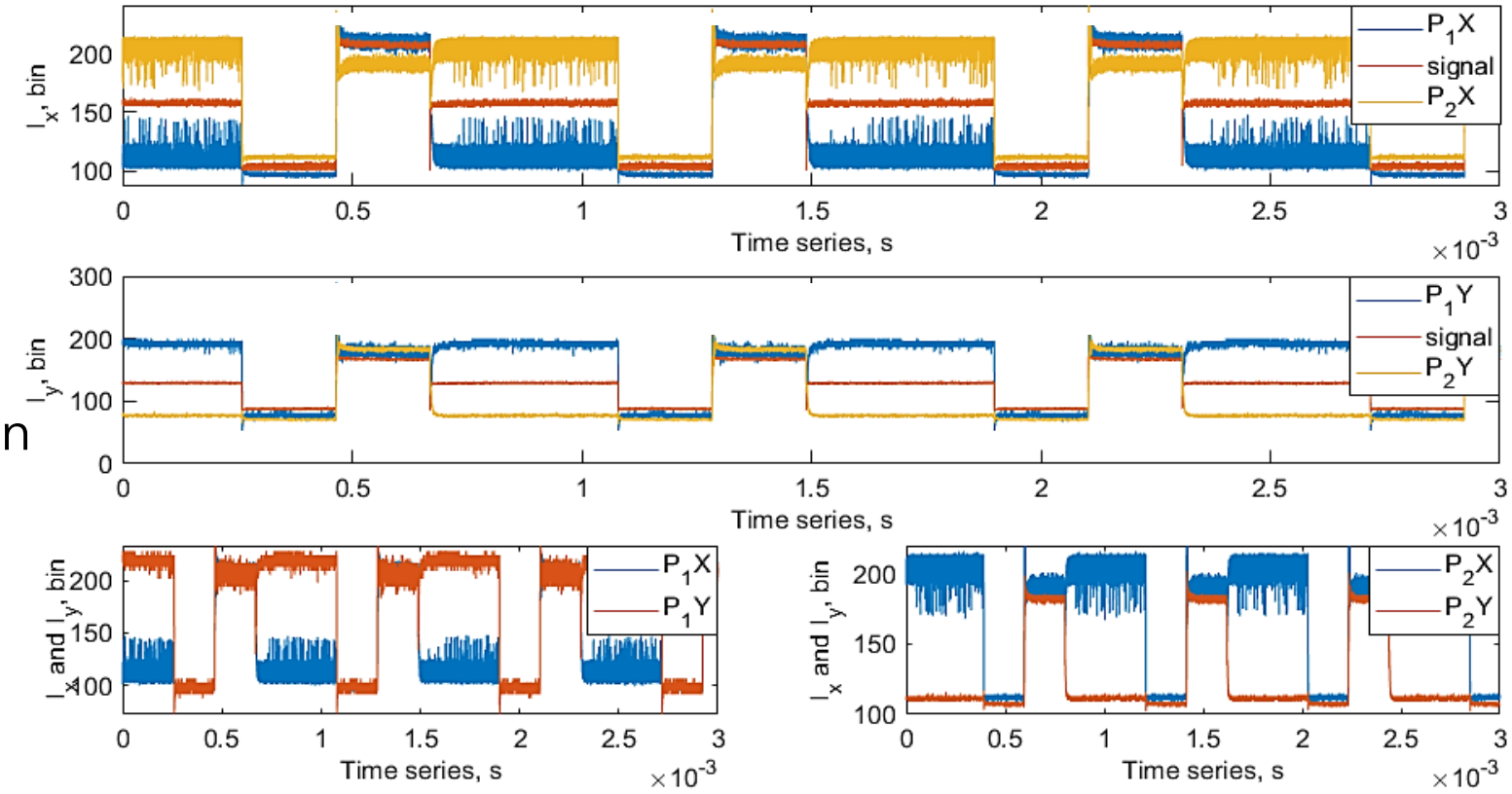
j_{dc}=13,65 mA, A_{LF}=15mV (5kHz), A_{HF}= 15mV (100kHz)

AND/OR operations based on LVR in VCSEL laser intensity on orthogonal polarizations



P_1, P_2 – orthogonal orientation of the half-wave plate

j_{dc}=13,85mA, A_{LF}=15mV (5kHz), A_{HF}= 3mV (100kHz)

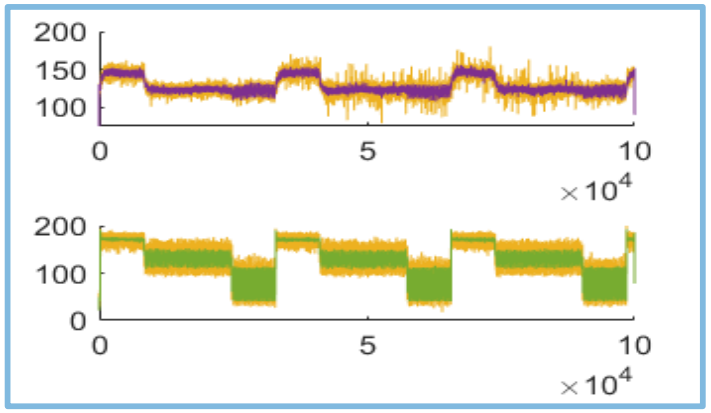


VCSEL output not at the resonance conditions

APD1 (Resonance)
– X pol. component

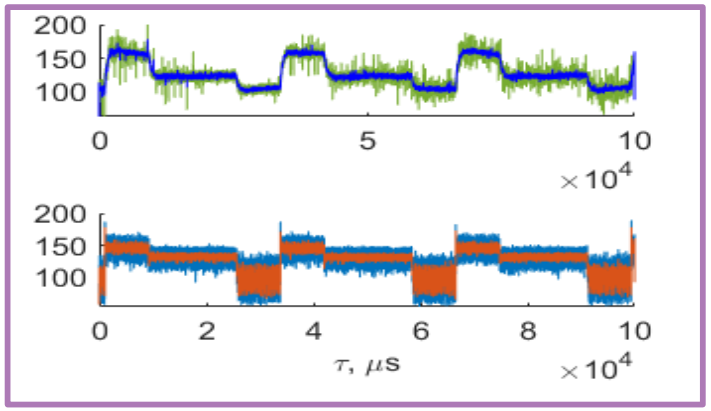
But

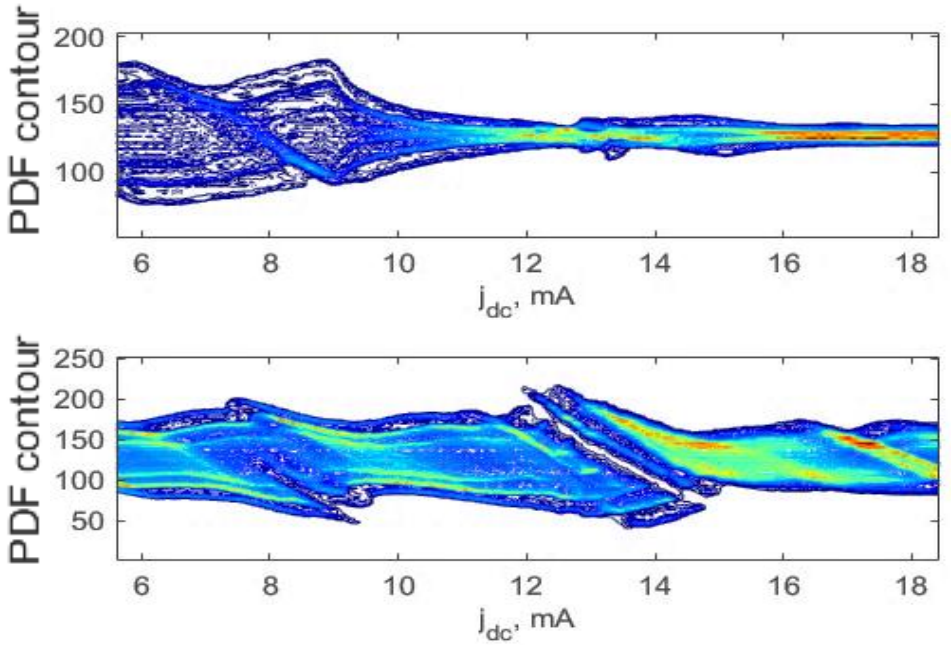
APD2 (not in resonance)
– Y pol. component



APD1 (not resonance)
– X pol. component

APD2 (weak resonance)
– Y pol. component





To much HF amplitude

Conclusions

1. Experimental evidence of the vibrational resonances, antiresonances and logical vibrational resonance in VCSEL (HFE4084-322, 850 nm, T = 25°C) with and without polarization selection are presented.
2. Implementation of the logical operations with digital signals AND and OR on the orthogonal polarizations was shown. Also the ability of selection the type of operation by half-wave plate rotation was presented.
3. The logical operations are performed based on the same principle as it was performed in Murali–Lakshmanan–Chua circuits

Thank you for your attention!

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