Integrated Quantum Cryptography circuit on silicon (CrypSil)

Projet "EMERGENCE/PLATEFORME" 2014

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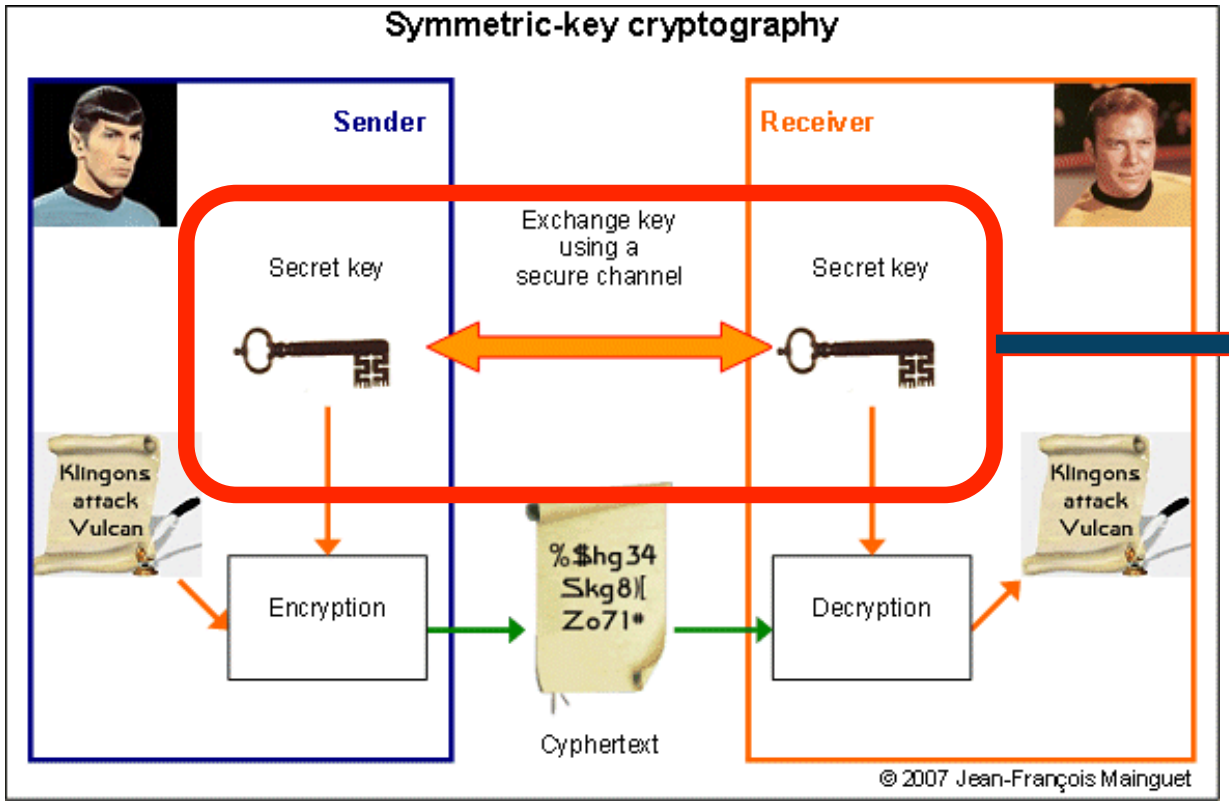
Outline

- Integration on Si-chip of a CVQKD protocol…why?
- The protocol
- Silicon Photonics and integration
- Devices chracteristics and characterisation
- Excess noise: Homodyne detection noise measurements
- Conclusions

Why Quantum Key Distribution?

Secret information → One-time pad Information theoretical security → Quantum Cryptography Security from Physics



QKD

Why Continuous Variables?

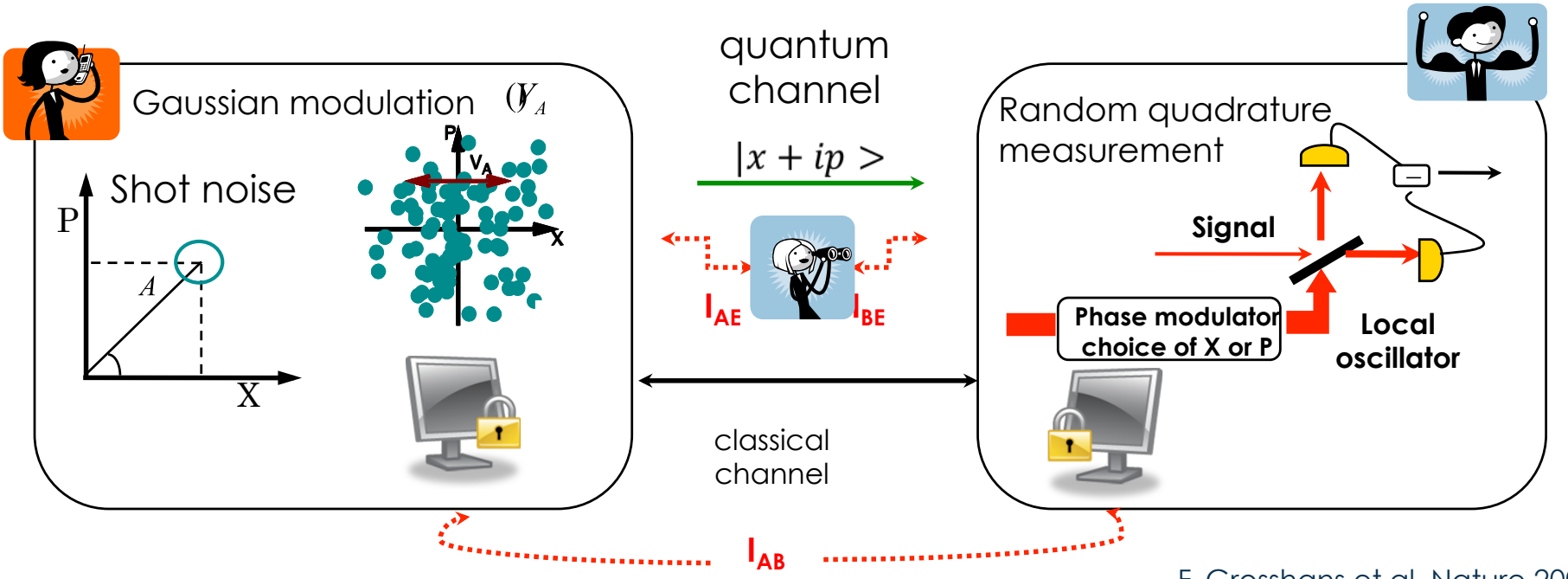
Easy implementation:
no photon counters, no cooling
coherent detection

	Discrete variables	Continuous variables
Key encoding	Photon polarization/phase	**EM field amplitude-phase**
Detection	Single-photon	**Coherent (homodyne/heterodyne)**
Performance (range, rate)	200 km, 1 Mbit/s	100 km, 100 kbit/s
Network integration	WDM	WDM
Security	General attacks, finite-size , side channels	Collective attacks, finite-size, error correction, side channels
Stability	Months	Months

V. Scarani et al, Rev. Mod. Phys. 2009
P. Jouguet et al, Nature Photon. 2013

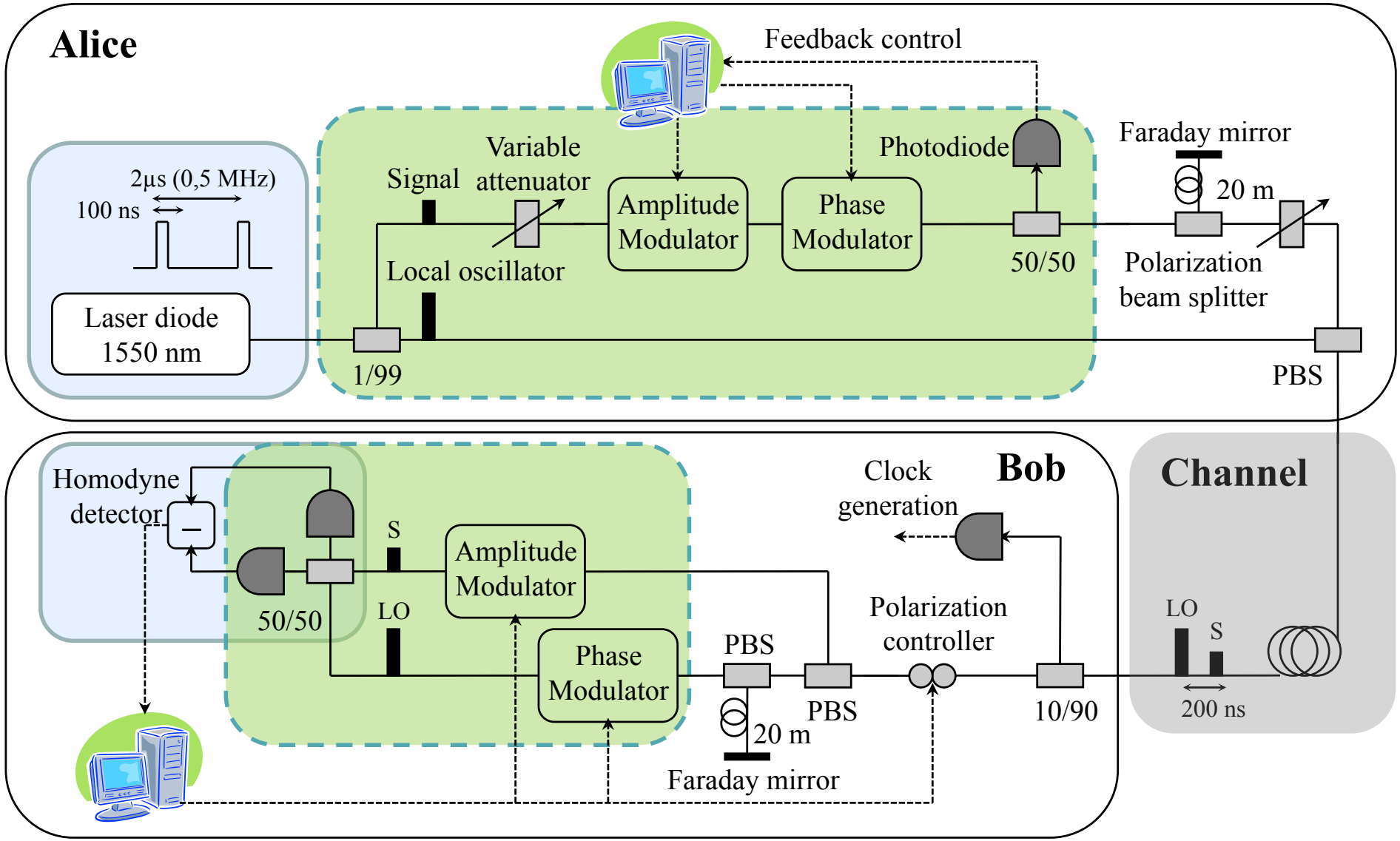
CVQKD Protocol
Grosshans & Grangier 2002 (GG02)

- Encoding: random gaussian modulation of field's quadratures
- Random choice for quadrature measurements (homodyne)
- Reverse Reconciliation
- Error correction codes
- Key extraction

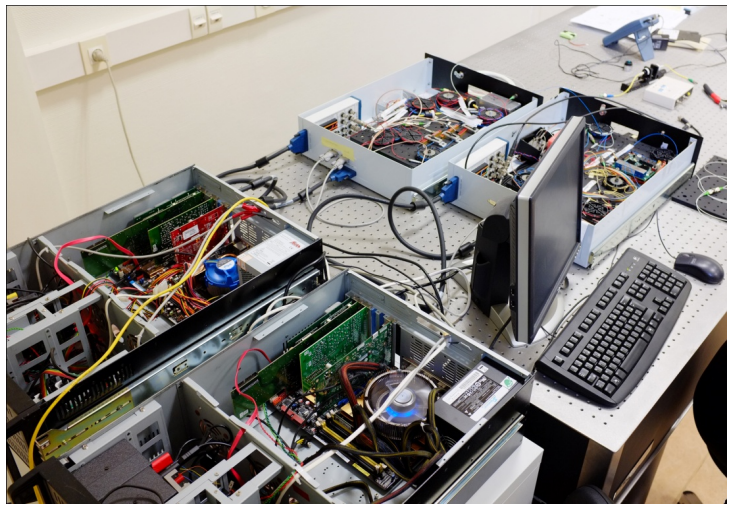


F. Grosshans et al, Nature 2003

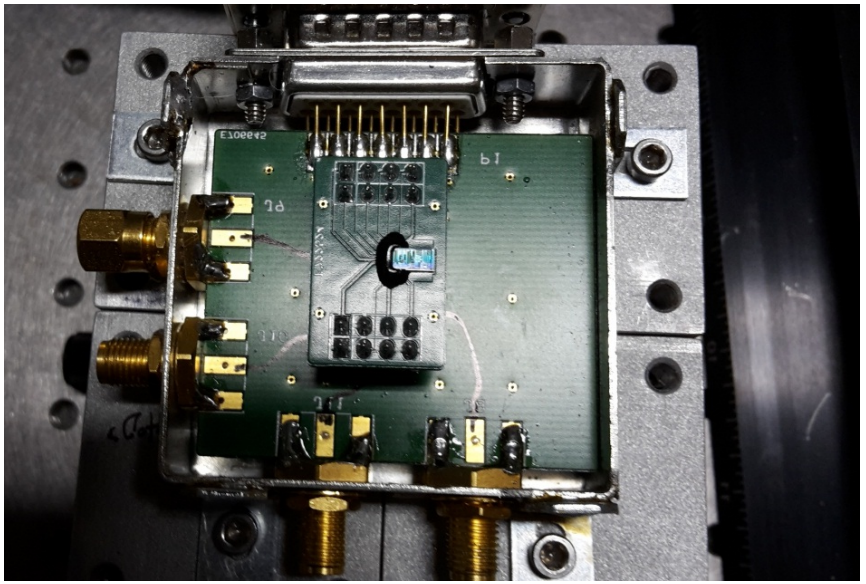
Optical Setup



Why On-Chip Integration?

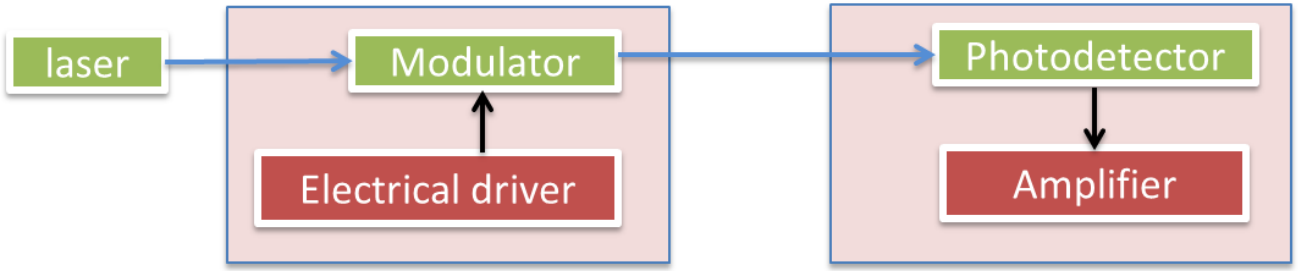


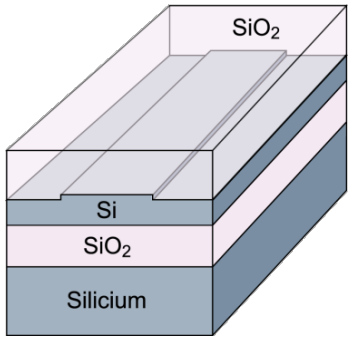
Smaller, cheaper, integration



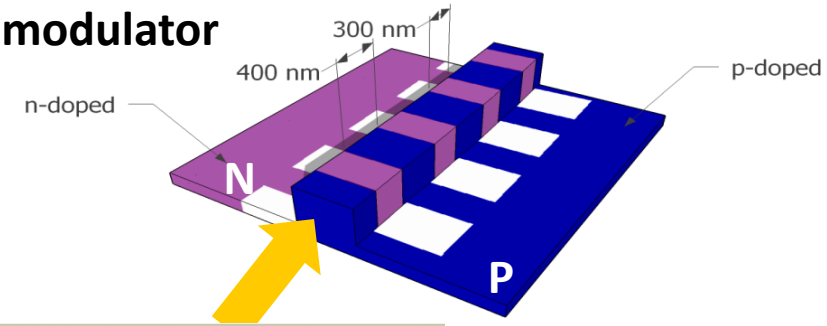
Candidate system
silicon photonics integrated continuous-variable QKD

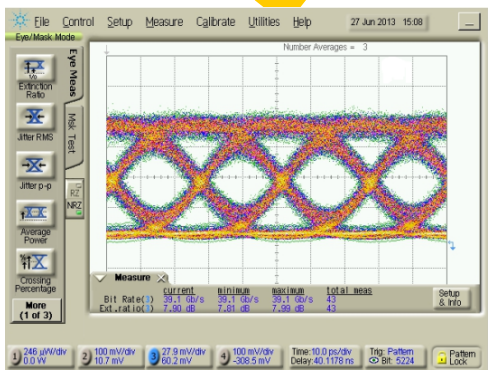
Silicon photonics





Si modulator





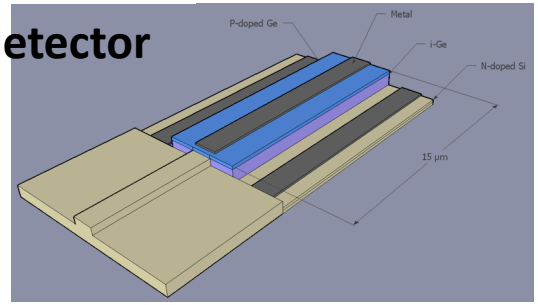
Extinction ratio = 8 dB

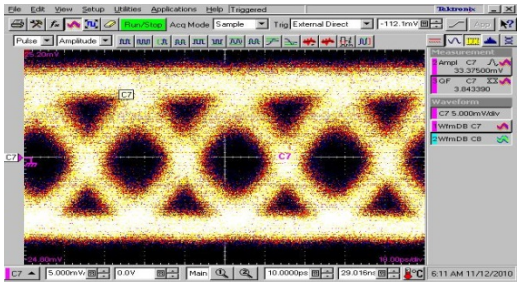
Optical loss = 4 dB

40 Gbit/s

D. Marris-Morini et al, Opt. Exp. (2013)

Ge photodetector





Responsivity = 0.5 A/W

40 Gbit/s

L. Vivien et al, Opt. Exp. (2012)

CVQKD requirements

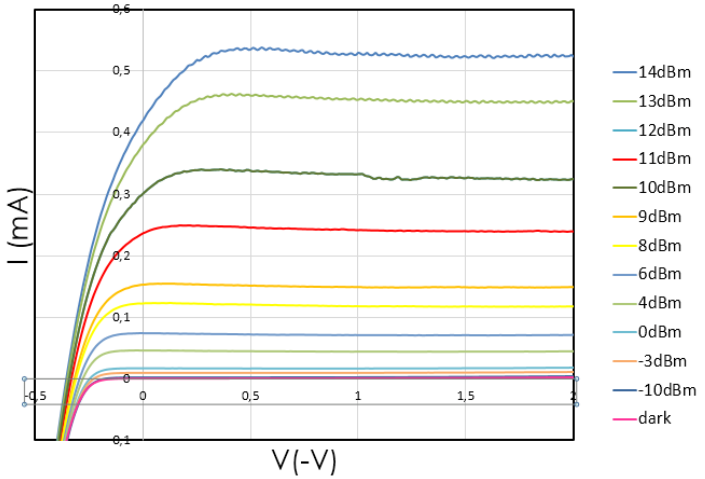
Challenge: the specifications are very different from optical telecommunications

	CVQKD requirements @ 0.1-10 MHz
Modulators	• High extintion ratio (>30dBm) • Low Loss
Photodetectors	• Linearity @ Low power • Low dark current • High Quantum Eff. • Shot noise lim. performances
Optical Attenuators	• High Optical attenuation (80dB) • No phase drift

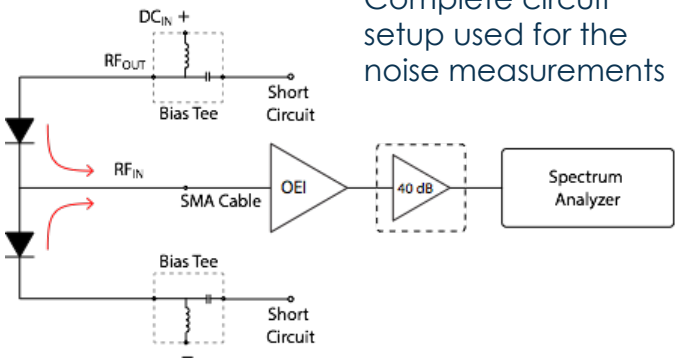
- For each building block: Design, fab, characterization
- At system level : packaging of the total circuit

Building blocks characterization

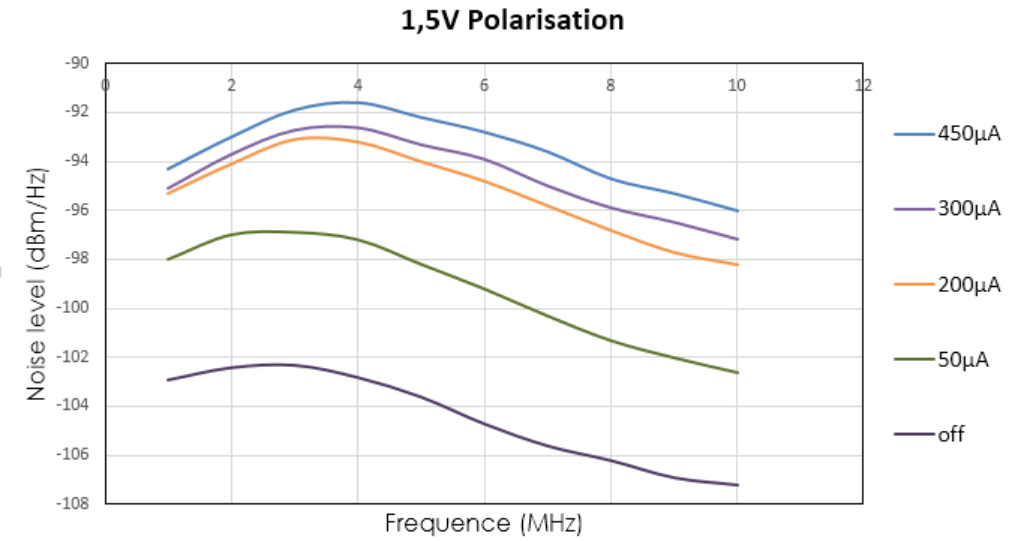
Photodiode (IV curves)



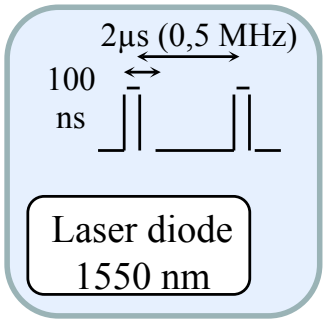
Shot-noise measurement to be to able to evaluate **excess noise** from the channel (CW optical input)



Complete circuit setup used for the noise measurements



Building blocks characterization



CW laser modulation @ pulsed laser frequency (500KHz)

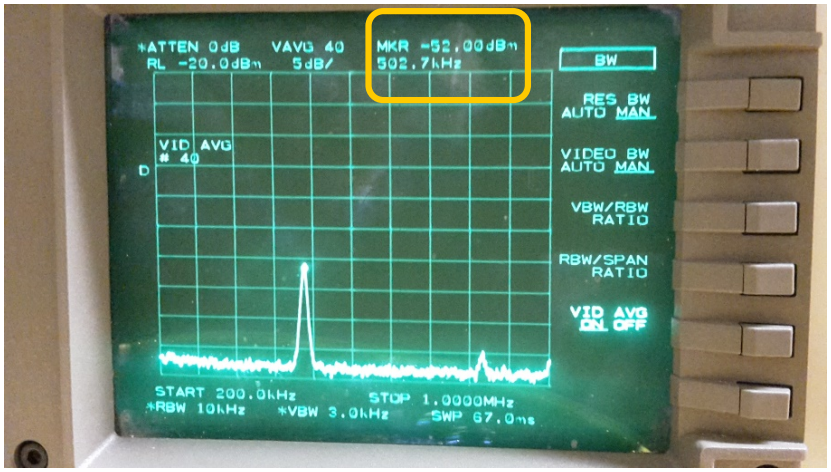
Noise peak: ≈2dBm

Homodyne detection balancing

Noise peak: ≈-52dBm

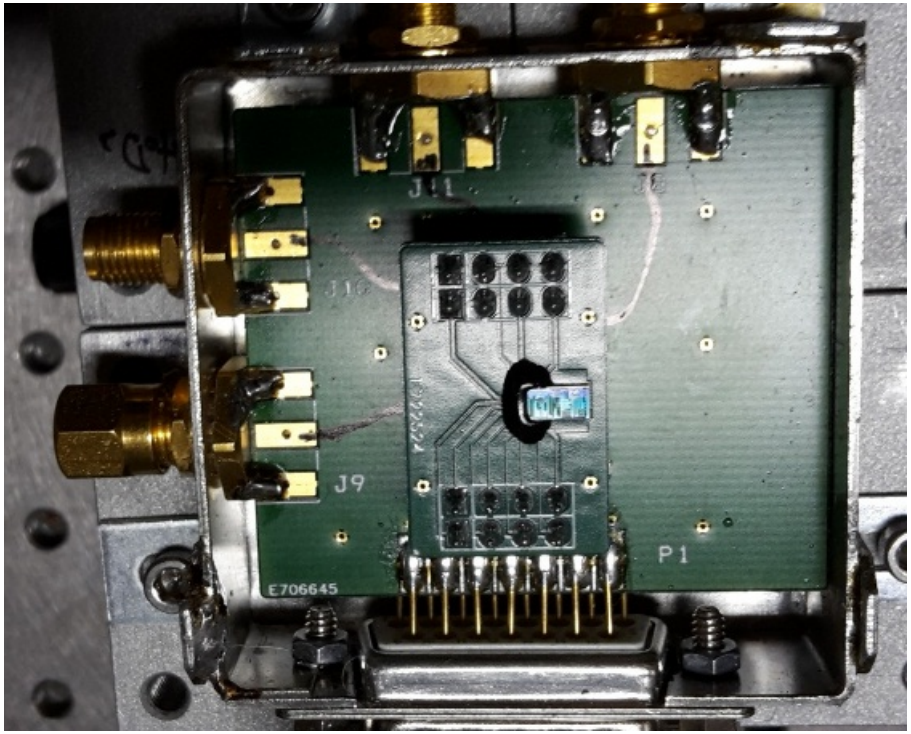
54dB common mode rejection ratio

Noise level @ 0,5 MHz , AC optical input



Next step

Packaging of the circuit (13 electrical pads + 1 optical fiber)



Under progress: Characterization of the global systems

Conclusions

- ✓ Design for a complete CVQKD system on Si chip
- ✓ All devices are ready to work
- ✓ Homodyne detection noise measurements
- ✓Next step : characterization of the global systems