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SINGLE PHOTON QUANTUM KEY DISTRIBUTION USING NV CENTERS IN DIAMOND

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QKD with Attenuated Light Sources

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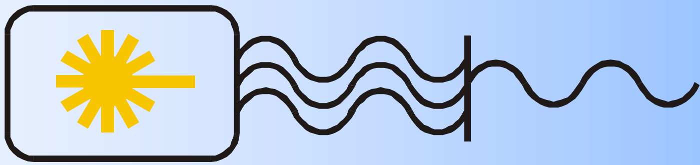
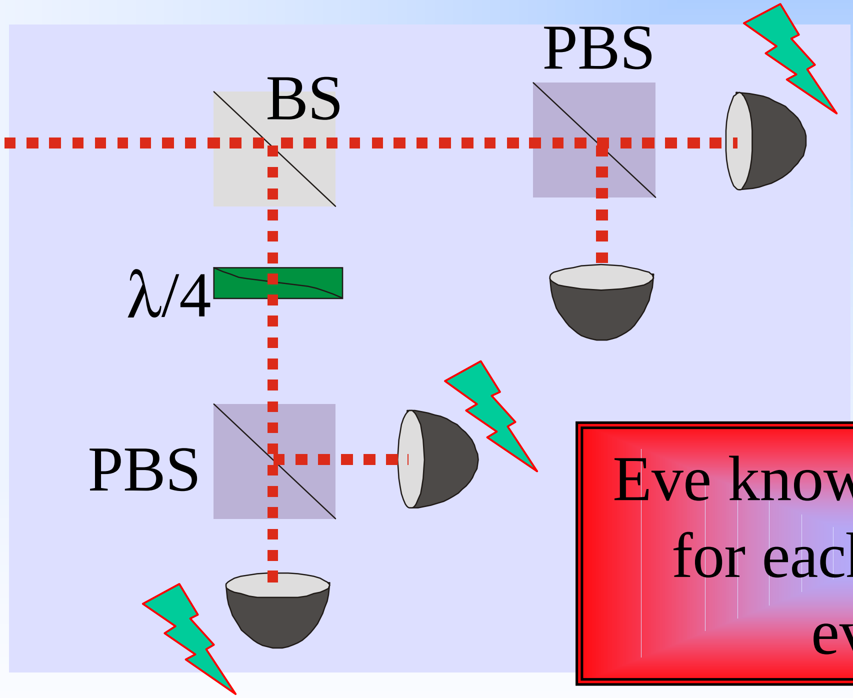
sual QKD : Pulsed
Attenuated Laser



L Poissonian Statistics with $p(1) << 1$:

$p(2) = p(1)^2 / 2$
$p(3) = p(1)^3 / 6$

Alice
4-states
BB 84
polarization
encoding)



L The line is totally unsecure unless one has $p(1)^2/16 < h$!

20 dB loss : $p(1) < 0.4$
30 dB loss : $p(1) < 0.13$

Eve knows everything for each 3-photon event !

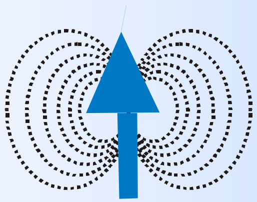
Bob
is easily
cheated

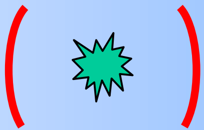
L pccc = $p(1)^3/16 = \eta\, p(1)$

Single Photon Sources

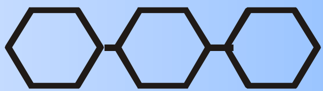
Elimination of multiple photon events : Single photon source

Pulsed Single Emitter



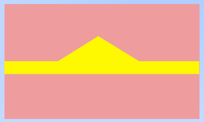


Single atom or ion in a cavity



Molecule, nanocrystallites

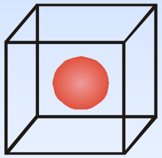
L Photobleaching, blinkin



Quantum Dot

J Narrow Spectrum

L T = 4K



Color Centers

J Stable at Room Temperature

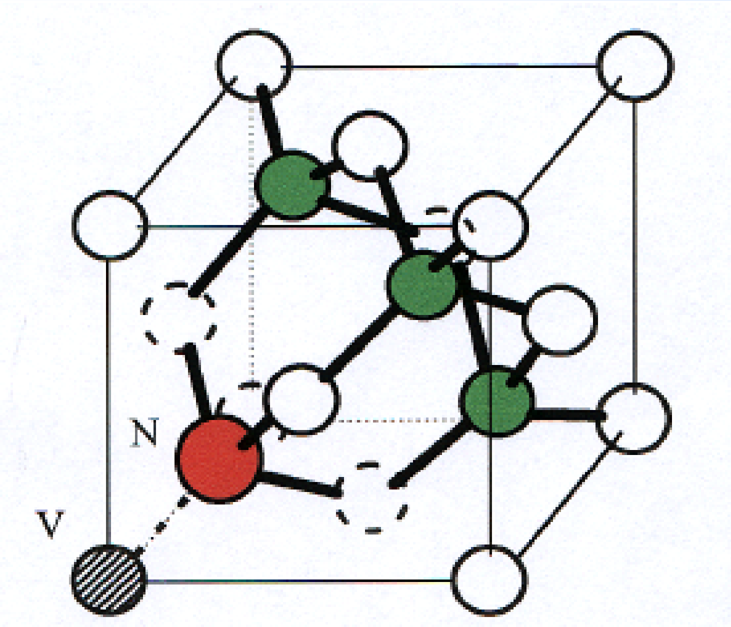
J Easy to Produce

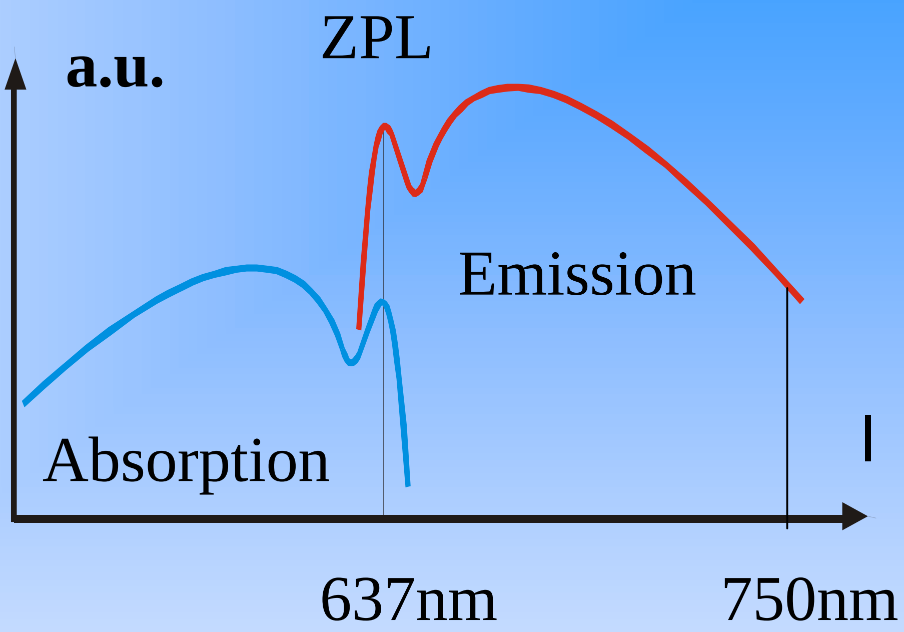
J Subpoissonian Statistics:

$$p(2) = c_N(0)\frac{p(1)^2}{2}$$

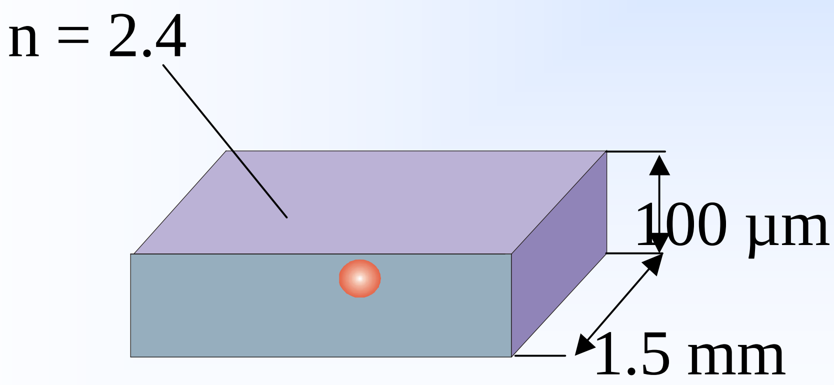
J $c_N(0) << 1$

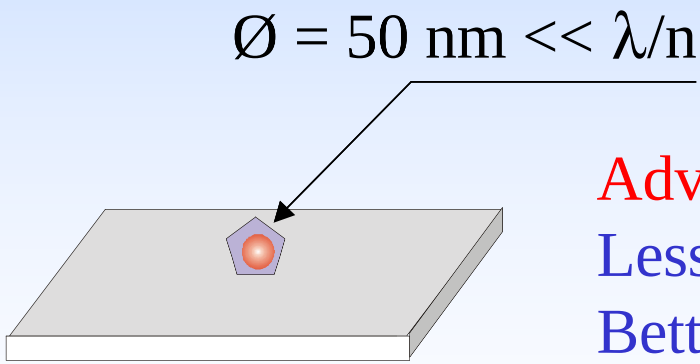
NV-Centers in diamond





Bulk or Nanocrystals





Advantages :
Less background
Better collection
Easier to handle

τ_b=11.6 ns

τ_n=25 ns

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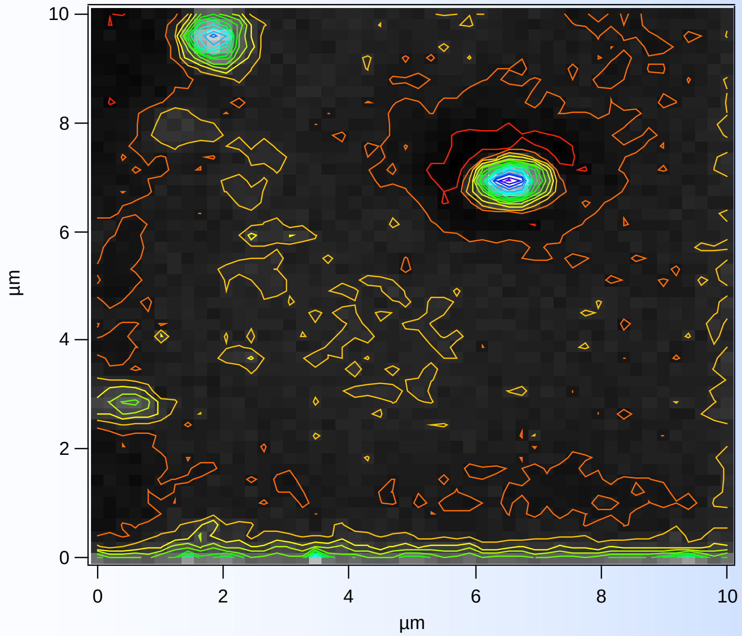
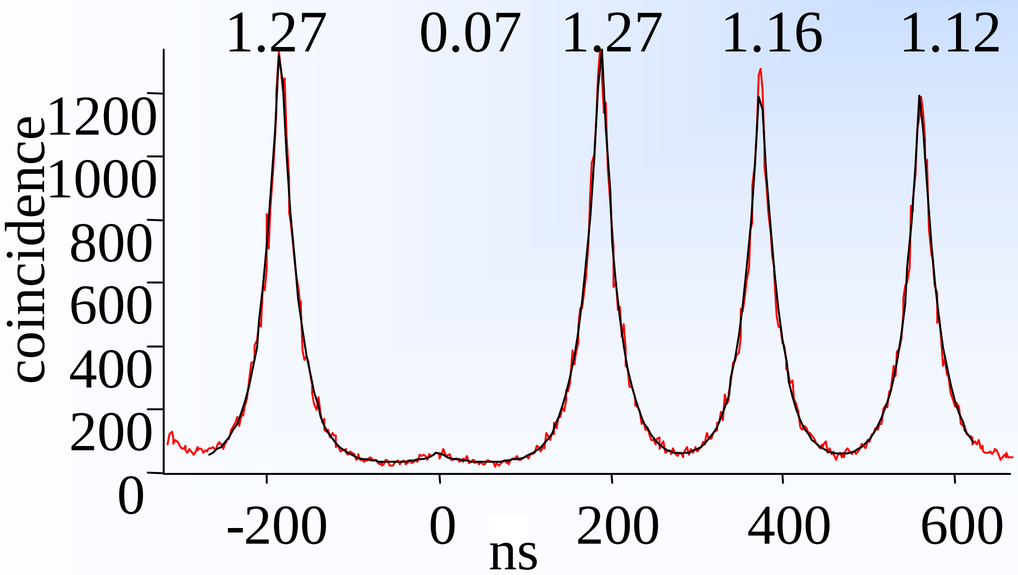
Pulsed excitation of the NV center



Scan of the sample

The background light is reduced by photobleaching of the dielectric mirror (only the NV center survives !)



Excitation rate 5.3 Mhz

Useful single photon emission rate : 116 kcps

Global emission efficiency : 2.2 %

$g^{(2)}(0) = 0.07 = 1/14.2$

Quantum cryptography demonstrator

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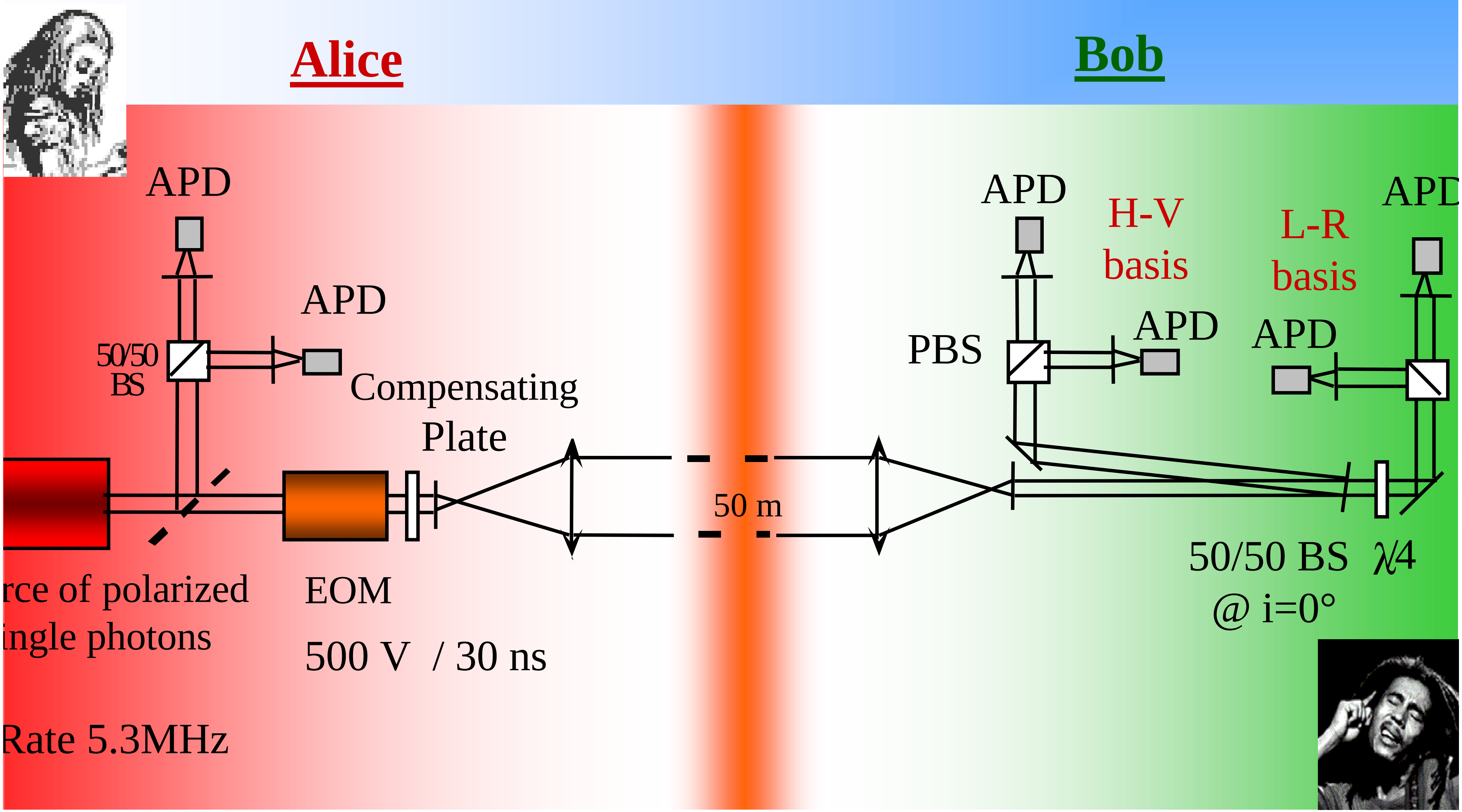

Quantum Key Distribution : Results

Alice :

- Pulse repetition rate : 5.3 MHz
- Polarized single photon rate : 116 000 s^{-1} (eff. 2.2 %)
- Very low two-photon rate : $g^{(2)}(0) = 0.07$

- 2 random numbers generators (basis, bit)
- White-light EOM with transmission = 0.65, fast HV switch

- Number of encoded single photons sent to Bob : 75 000 s^{-1}

→ **μ = 0.014**

Quantum Key Distribution : Results

Bob :

- Propagation over 50 m with 2 cm beam diameter
- Number of detected photons : 39 000 s^{-1}
- Dark counts : 150, 180, 380, 160 s^{-1} for the 4 APDs
- Time gate 50 ns => 90% of single photons, 27% of backgnd
- Data transmitted in 10 ms bursts

Static polarization error rate, HV Basis : 1.2%
Static polarization error rate, RL Basis : 3.2%
Errors attributed to HV switching : 2%
Errors due to dark count : 0.7%

Measured QBER 4.6 %

Rate of secure bits : 7.7 kbits/s

Single photon vs Weak pulses QKD

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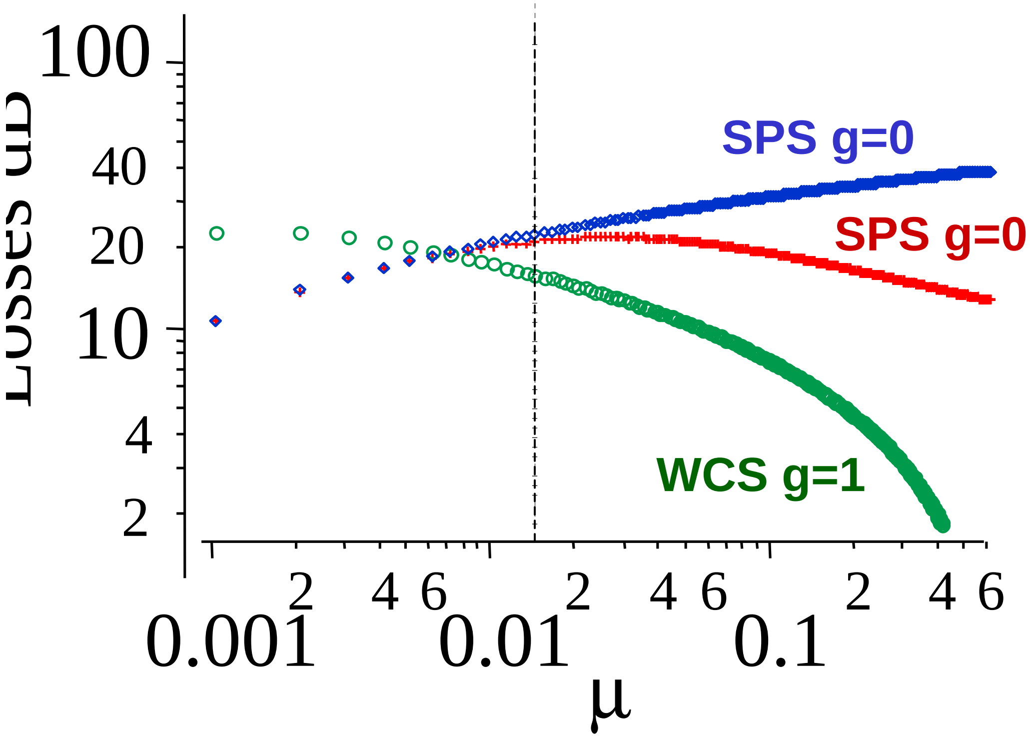
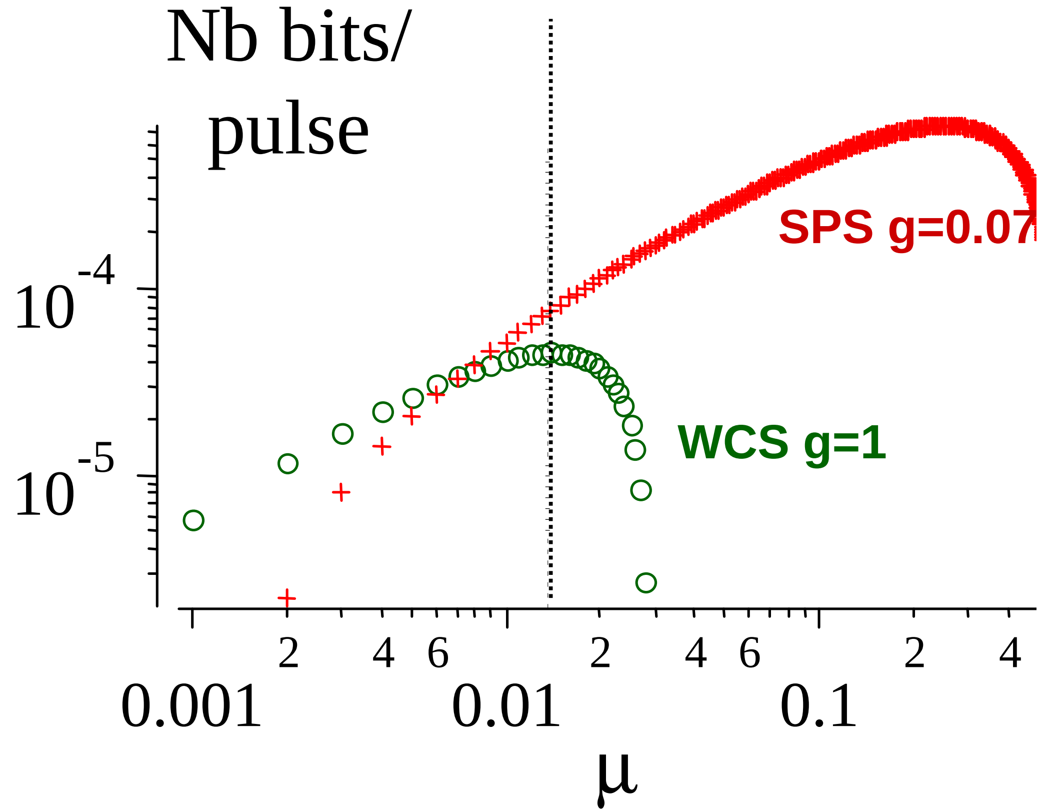
Evaluations based on N. Lütkenhaus, PRA 61, 052304 (2000)



Maximum tolerable losses vs nb photons/pulse



Secret bit rate/pulse for 12.5 dB losses

Significant advantage for a single photon source

Conclusion

Pulsed source of single photons on demand :

* Photostable at room temperature
* Very small two-photon rate : $g^{(2)}(0) = 0.07$
* Collection efficiency 2.2% (may be improved …)

Quantum cryptography :

* Distance 50m with an error rate 4.6%
* Secure bit transmission rate : 8 kbit/sec
* Quantitative advantage with respect to weak pulses

A. Beveratos et al, PRL **89** 187901(2002)