Can Two-Way Direct Communication Protocols Be Considered Secure?

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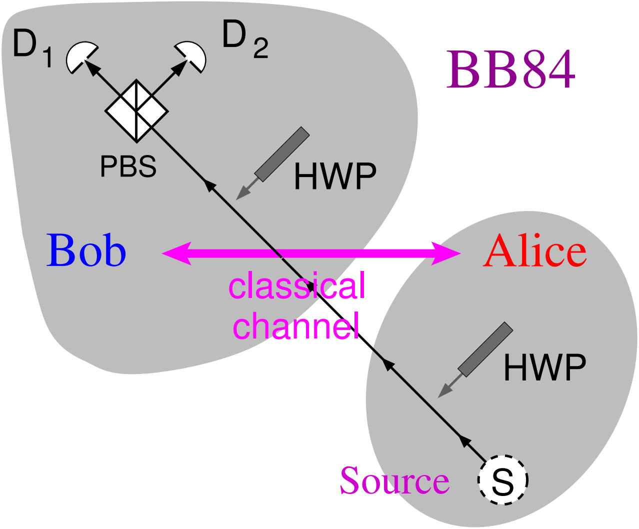
Quantum Cryptography, QKD, BB84 Protocol



Direct Two-Way Communication with Entangled Pairs of Photons in Bell States

Linear optics:

Two Bell States, $|\Psi^{\mp}\rangle = \frac{1}{\sqrt{2}}(|H\rangle_1|V\rangle_2 \mp |V\rangle_1|H\rangle_2)$, *Ping-Pong* Protocol.

Kim Boström and Timo Felbinger, Deterministic Secure Direct Communication Using Entanglement, *Phys. Rev. Lett.*, **89**, 187902 (2002).

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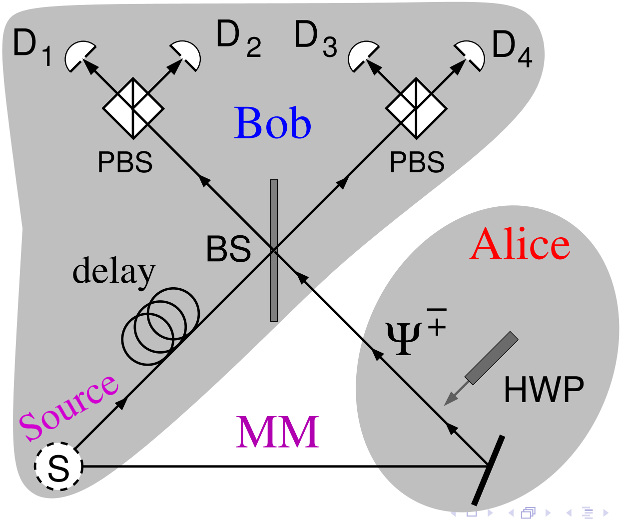
Non-linear optics:

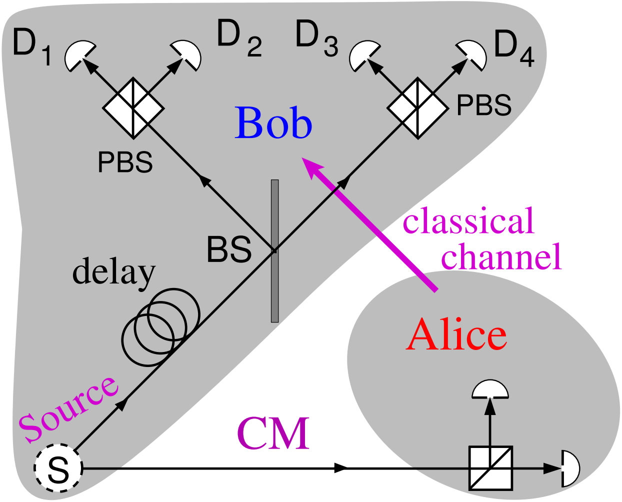
Four Bell States, $|\Psi^{\mp}\rangle$, $|\Phi^{\mp}\rangle = \frac{1}{\sqrt{2}}(|H\rangle_1|H\rangle_2 \mp |V\rangle_1|V\rangle_2)$.

Quing-yu Cai and Ban-wen Li, Improving the Capacity of the Boström-Felbinger Protocol, *Phys. Rev. A*, **69**, 054301 (2004).

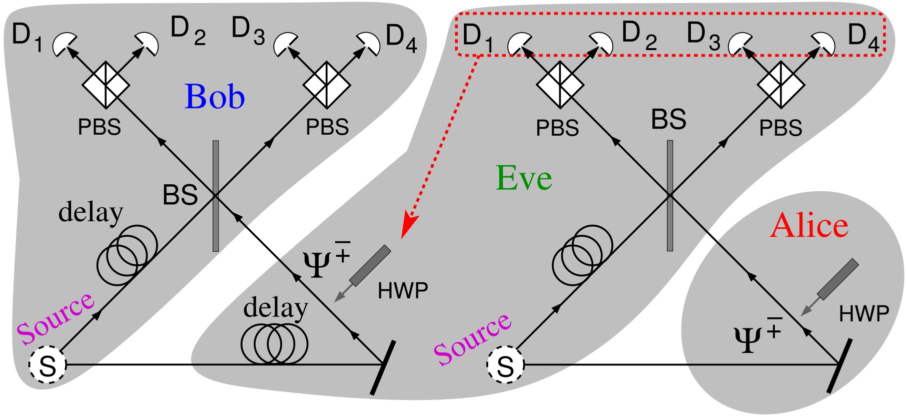
Direct Quantum Communication, QKD, Ping-Pong Protocol; Message Mode (MM)



Direct Quantum Communication, QKD, Ping-Pong Protocol; Control Mode (CM)



Nguyen's Attack on Ping-Pong Protocol, Nguyen, B.A., *Phys. Lett. A*, **328**, 6 (2004).



Undetectable Eve copies all messages in MM (msg. mode)

Direct Two-Photon Communication with Single Photons

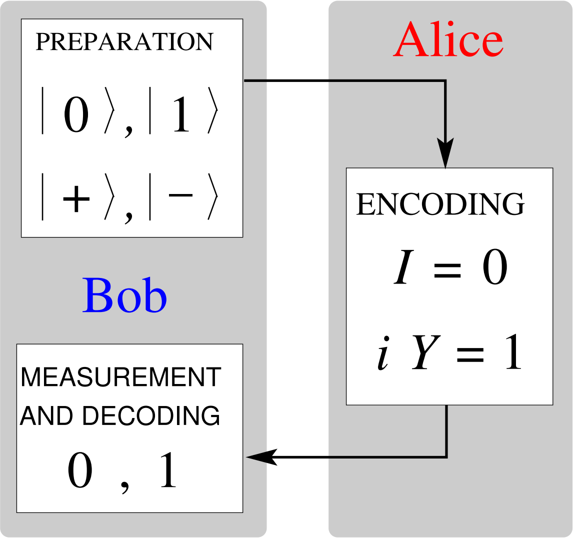
Linear optics:

Single photon states, in two bases ($\{|0\rangle, |1\rangle\}$ and $\{|+\rangle, |-\rangle\}$) as in the BB84 protocol

Marco Lucamarini,
Quantum Decoherence and Quantum Cryptography,
PhD Thesis, *University of Rome La Sapienza*, 2003,
http://sapienzadigitallibrary.uniroma1.it/identifier/RMSFI_00000130

Marco Lucamarini and Stefano Mancini,
Secure Deterministic Communication without Entanglement,
Phys. Rev. Lett., **94**, 140501 (2005)

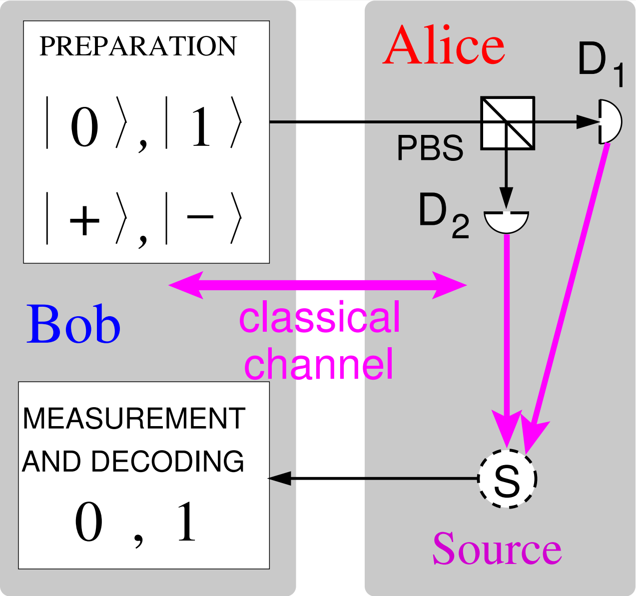
Lucamarini-Mancini Protocol—LM05—Message Mode



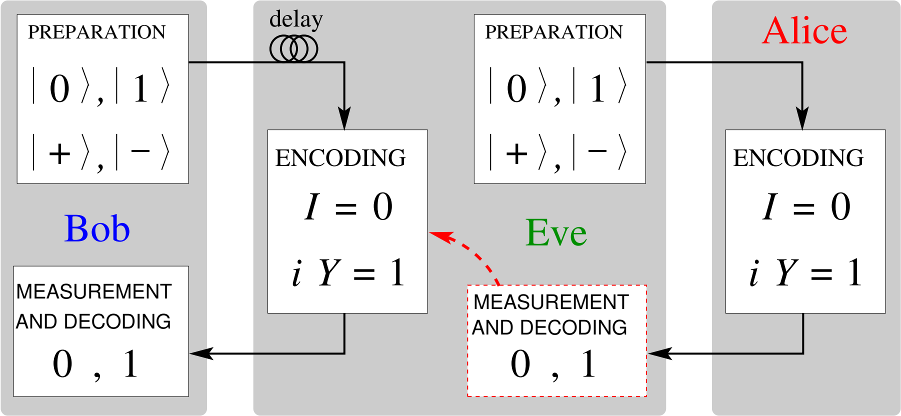
$$I|0\rangle = |0\rangle$$
$$I|1\rangle = |1\rangle$$
$$I|+\rangle = |+\rangle$$
$$I|-\rangle = |-\rangle$$

$$iY|0\rangle = -|1\rangle$$
$$iY|1\rangle = |0\rangle$$
$$iY|+\rangle = |-\rangle$$
$$iY|-\rangle = -|+\rangle$$

Lucamarini-Mancini Protocol—LM05—Control Mode



Lucamarini's Attack on LM05, Lucamarini,M., PhD Thesis, *University of Rome La Sapienza* (2003); p. 61, Fig. 5.5,



Undetectable Eve copies all messages in MM (msg. mode)

Alice-Bob and Alice-Eve Mutual Information

Security of a protocol, critical QBER via secret fraction

$r = \lim_{N\to\infty} \frac{l}{n} = I_{AB} - I_{AE}$

l = length of the final key, n = length of the raw key,
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In BB84—D = disturbance in MM:
$I_{AB} = 1 + D\log_2 D + (1-D)\log_2(1-D)$,
$I_{AE} = -D\log_2 D - (1-D)\log_2(1-D)$

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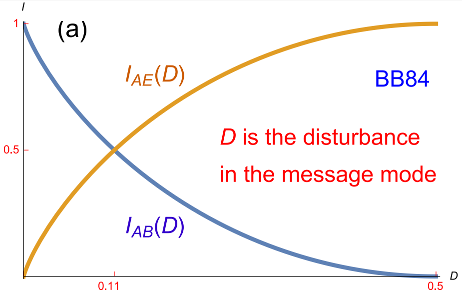
In two-way protocols—D = disturbance in CM:
$I_{AB} = 1$,
$I_{AE} = -D\log_2 D - (1-D)\log_2(1-D)$

In MM D = presence of Eve;
$D = 0$—Eve is absent; $D = 0.5$ (max disturbance)—Eve is always present.

BB84 has a critical *D*—2-way protocols do not



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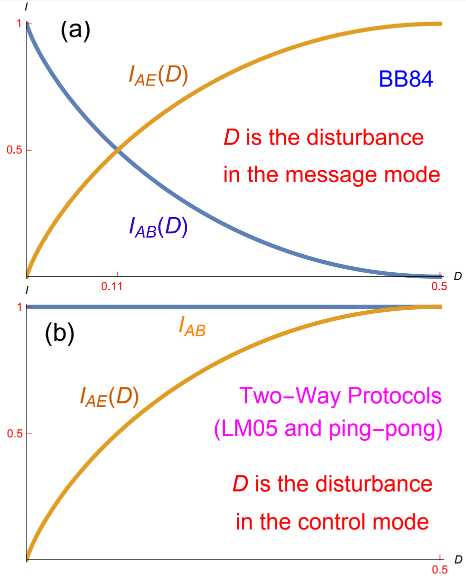

Proofs of security of two-way protocols

Han, Y.-G. et al., Security of Modified Ping-Pong Protocol in Noisy and Lossy Channel, *Sci. Rep.*, **4**, 4936 (2007).

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Both proofs are made for variable I_{AB} which depends on D and both proofs assume that Eve changes I_{AB}, while for the above attacks $I_{AB} = 1$.

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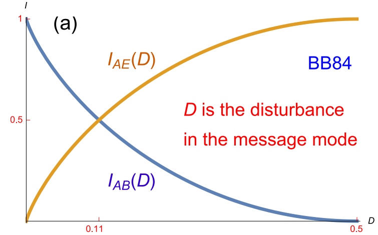
There is nothing in CM which can determine critical D for MM $\Longrightarrow$ the proof of unconditionally security of 2-way protocols cannot be valid.

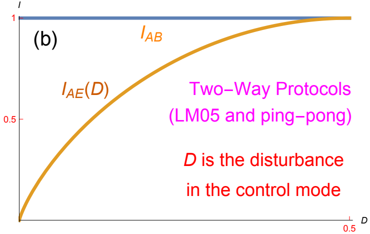
Can Two-Way Protocols Be Considered Secure?

There is no disturbance in the message mode (MM).

Disturbance D belongs to the control mode (CN)

MM and CM are completely disjoint and D from CM cannot have any influence on I_{AB} from MM—which is constant $I_{AB} = 1$.





Privacy amplification cannot work when Eve is in the line all the time.

Can one find a level of Eve's presence—determined by D from CM—for which the privacy amplification would unconditionally work?

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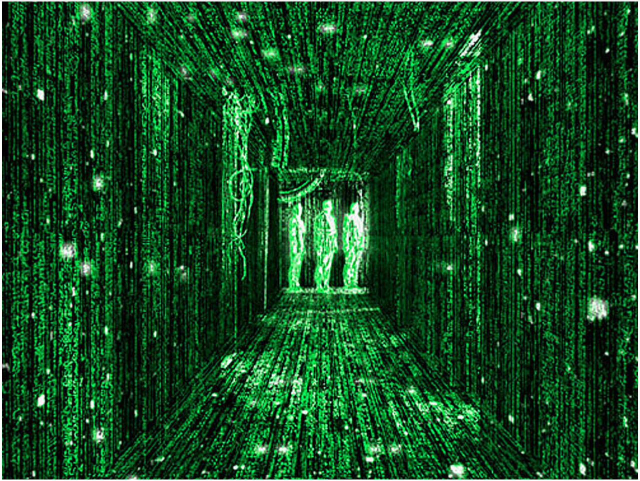
Thanks for your attention 😎



http://cems.irb.hr/en/research-units/photonics-and-quantum-optics/
http://www.irb.hr/users/mpavicic/