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Perfect state transfer between qubits by dispersion engineering in waveguide QED

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A propagating photon emitted by a qubit via spontaneous decay has an exponential spatial profile that is not time-reversal invariant [1,2]. As a consequence, if such photon propagates in a medium with linear dispersion relation, it cannot be perfectly absorbed by a second qubit. Even in the ideal case of a lossless, perfectly chiral 1D waveguide the maximum achievable occupation of the second qubit is limited to 4/e^2 » 0.54 [3]. This poses a serious fundamental limitation to quantum state transfer between nodes in waveguide QED. Current proposed solutions are active, i.e., they rely on active time-dependent control of system parameters [4-5].
In my talk I will present an alternative approach to perfect transfer, namely to passively tailor the dispersion relation of the waveguide. I will show that, for two qubits separated by a large fixed distance d, the optimal dispersion relation can be analytically derived using Wigner- Weisskopf theory. This dispersion optimally time-reverses the single-photon pulse emitted by one qubit, thus achieving perfect absorption by the second qubit. In the limit of short d, an alternative dispersion relation can be derived using resolvent methods, that also achieves perfect absorption. I will also discuss how numerical optimization allows to obtain, for every fixed distance d, the optimal dispersion relation to achieve near-perfect absorption. Finally, I will show how to engineer a waveguide able to achieve perfect transfer for arbitrary distances between qubits, by tailoring the dispersion relation only of a section of the waveguide between them. Our work paves the way toward harnessing dispersion engineering for waveguide QED.

References

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