Quantum physics in waveguide arrays

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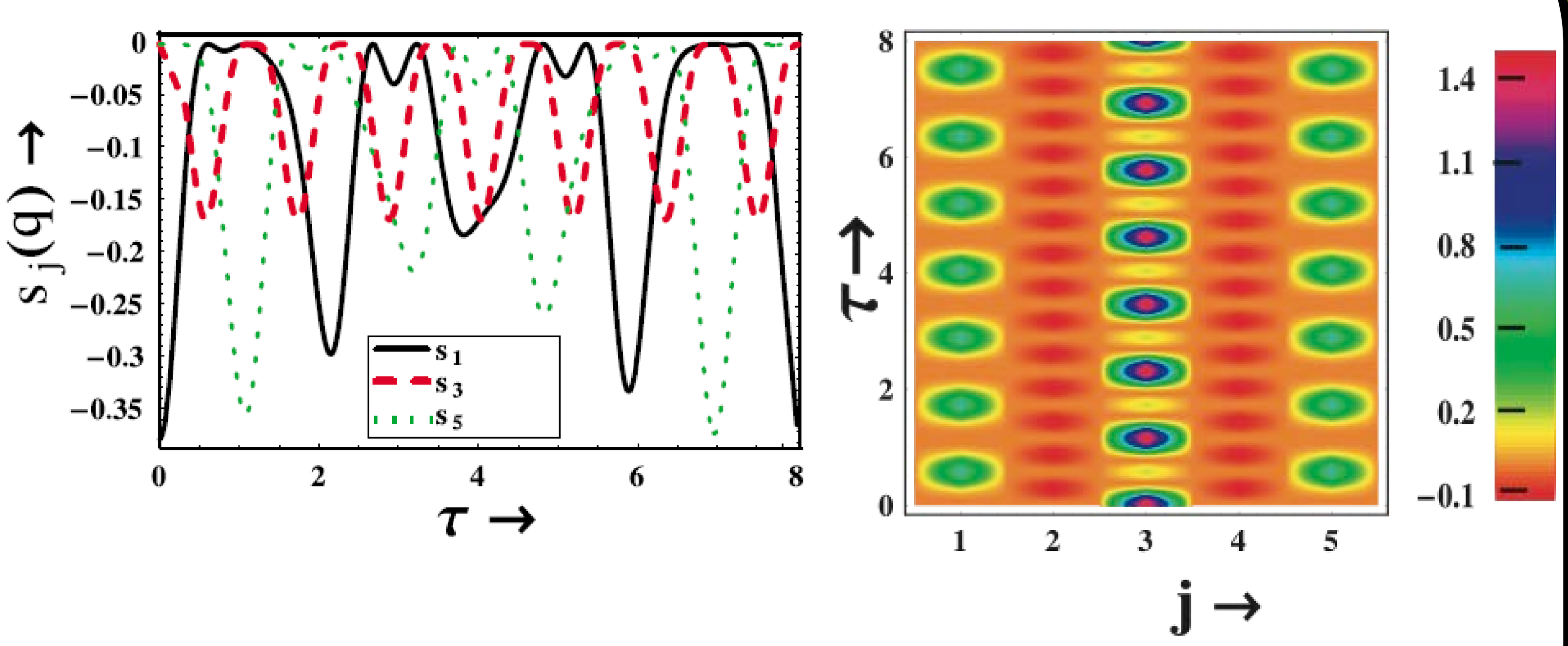
Introduction

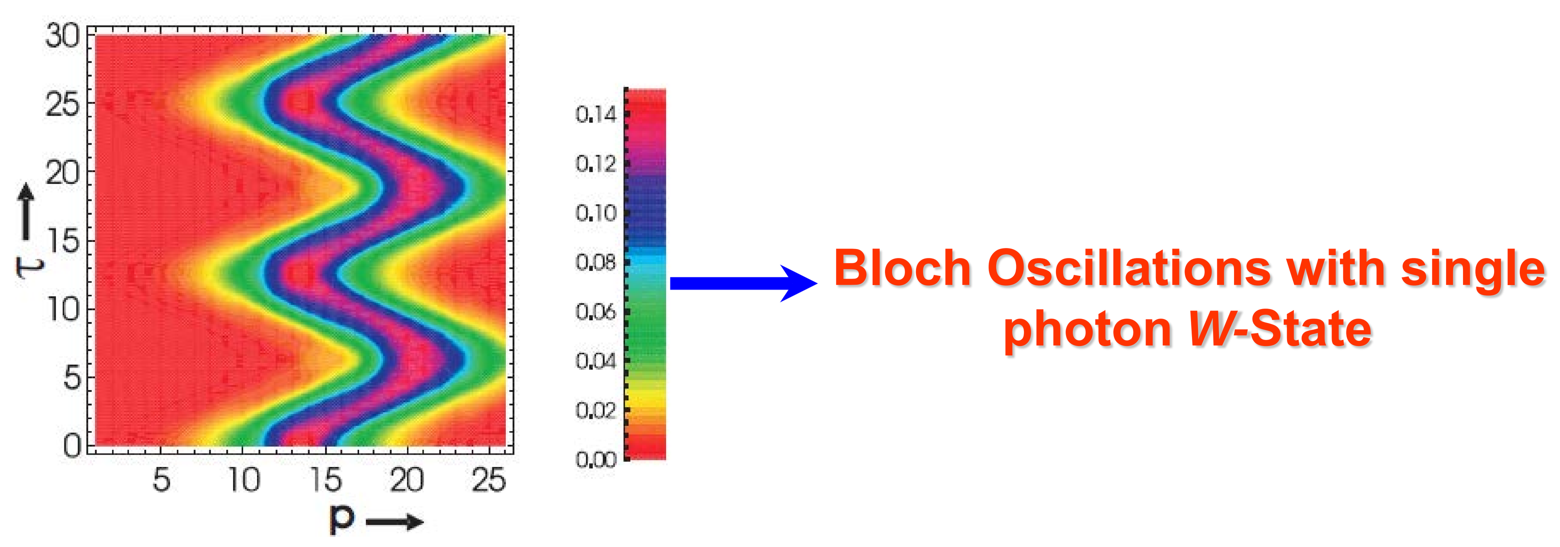
- We present a summary on some of our studies on optical waveguide arrays.
- We note that the propagation of light in a coupled system of waveguides has been studied extensively and the applications of such systems in the field of integrated optics are well known.
- Moreover, it is also recognized that array of classical waveguides are suitable structures for realizing a number of quantum effects [1].
- For example, Bloch oscillations have been investigated in coupled waveguides using coherent beam of light.

Transport of Nonclassical Light in Waveguides



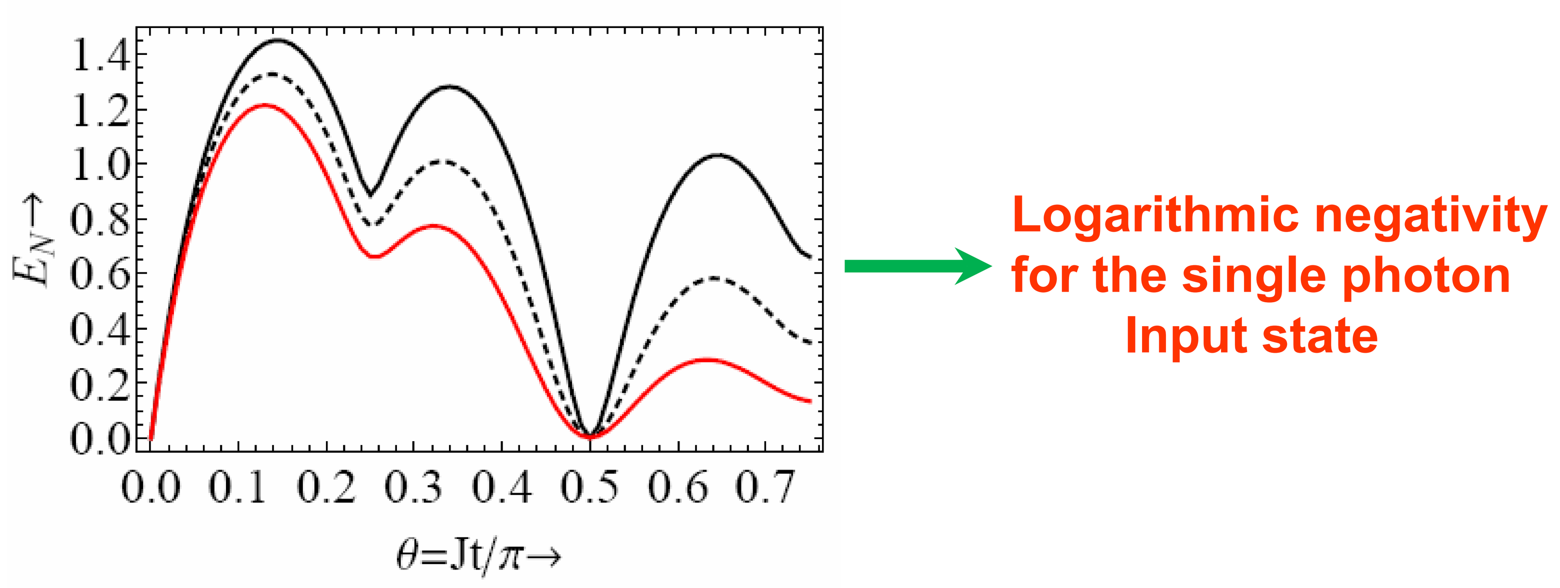
- We investigated the propagation of non-classical light in the form of single photons and squeezed light.
- Using the single photon input we studied an analog of the Hong-Ou-Mandel interference effect in waveguides.
- We further showed how non-classical light at one input port could entangle different waveguides.

Bloch oscillations with single photons



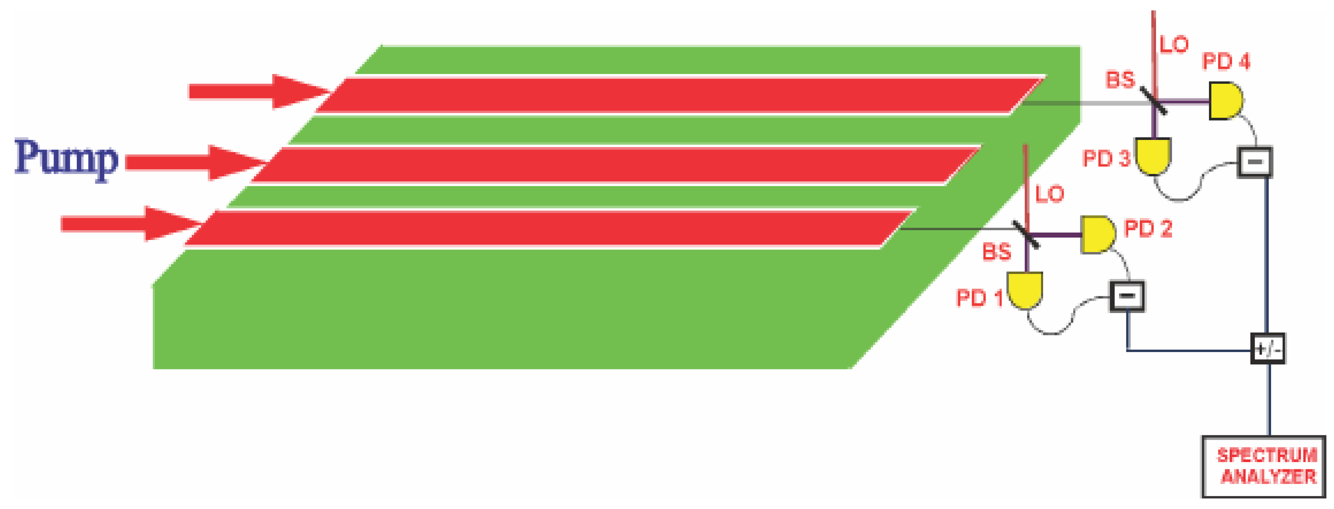
- We wanted to inquire whether Bloch oscillations are possible with single photons.
- We found that Bloch oscillations are indeed possible with single photons provided we prepare single photons in a *W-state.*
- We showed that the *W*-state input produced using a multi-port arrangement can lead to the observation of Bloch oscillations with single photons thus providing strict analog of Bloch oscillation of electrons.
- The *W*-state has strong quantum correlations even though it has no coherent component for the field amplitudes. The quantum correlations in the *W*-state are responsible for restoring the coherent effects [2].

Quantum entanglement in coupled lossy waveguides



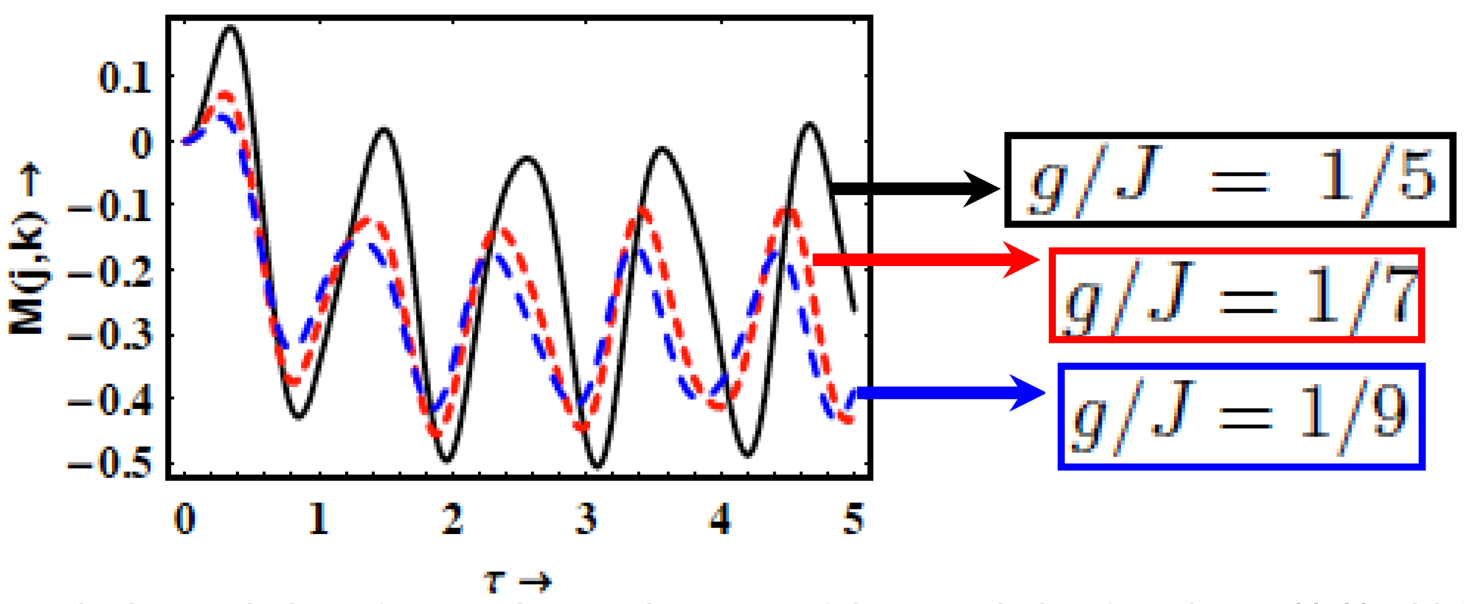
- We consider a simple system of two single mode waveguides which are coupled through the overlap of evanescent fields.
- We quantify the evolution of entanglement in terms of the logarithmic negativity.
- For the Single photon input state, we studied the behavior of logarithmic negativity for realistic values of losses.
- We found that the decrease in entanglement is not substantial even for the higher decay.

Generation of non-classical light in waveguide arrays



- We study a class of waveguide arrays where the waveguides contain second order nonlinearity and are coupled through the evanescent overlap of the guided modes.
- We assume that the pump field is in a strong coherent classical field, which is strong enough to remain undepleted of photons over the entire length of the waveguide.
- We ignore the evanescent coupling between the pump beams because the coupling coefficient for the pump beam would generally be much smaller compared to the signal ones, due to the weaker overlap between the waveguide modes at higher frequencies.
- The entanglement generated between the waveguide modes can be experimentally measured by using the homodyne detectors scanning across the waveguide array output.

Results: Entanglement between Spatially Separated Modes

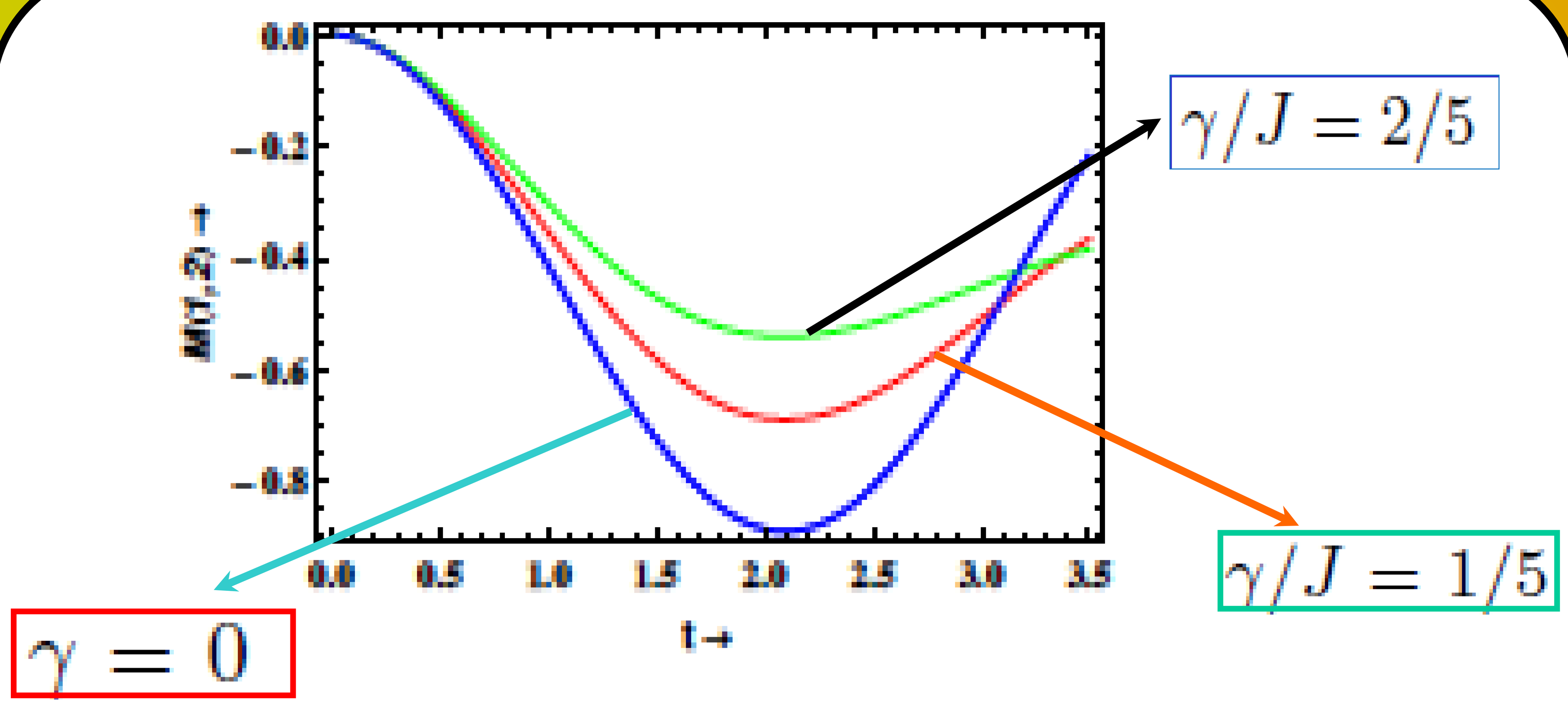


- We study the evolution of entanglement in terms of the correlation function *M(j, k)* which is defined as :

$$M(j,k) = \langle a_j^\dagger a_j \rangle + \langle a_k^\dagger a_k \rangle + e^{-2i\phi} \langle a_j a_k \rangle + e^{2i\phi} \langle a_j^\dagger a_k^\dagger \rangle$$

- We study the correlation function *M(j, k)* for the case of five waveguides.
- The correlation function M(j, k), can be probed by using homodyne detectors scanning across the waveguide array output.
- The negative values of M(j, k) clearly shows the entanglement between the waveguide modes.

Effect of Leakage on Entanglement Dynamics



- The range of values studied here are similar to the numerical values used in the recent experiments.
- The decrease in entanglement is not substantial even for the higher decay.

Conclusion

- We considered the waveguide arrays with second order nonlinearity and studied the generation and manipulation of non-classical light in such a system.
- We propose an integrated approach towards continuous variable entanglement based on integrated waveguide quantum circuits which are compact and relatively more stable [3].
- The possibility to generate broadband entanglement from waveguides could also help to avoid the use of optical cavities from many key experiments in the area of broadband continuous variable quantum information processing [4].

References

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3. S. L. Braunstein and Peter van Loock, Reviews of Modern Physics 77, 513 (2005).
4. Amit Rai and Dimitris G. Angelakis, Phys. Rev. A 85, 052330 (2012).