Quantum walk of light in optical waveguides

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Photonic waveguides have emerged as an ideal system for the study of quantum optical effects. In addition, they find interesting applications in quantum information science. I will describe my work on the transport and quantum walk of light in optical waveguides.

Introduction

- 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.
- We are interested in studying the behaviour of single photon and squeezed state of light.
- Important for the practical implementation of quantum walk, condensed matter-like effects and quantum optical analogues.
- Coupled waveguides are also finding interesting application in the emerging filed of quantum information processing.
- Decoherence effects in these systems are relatively smaller even when we consider a long propagation distance.

Input light

We may write

$$a = (X_1 + iX_2)/\sqrt{2}$$

X_1 and X_2 → Hermitian operators

Uncertainty relation → $(\Delta X_1^2)(\Delta X_2^2) \geq 1/4$

Coherent state → $(\Delta X_1^2) = (\Delta X_2^2) = 1/2$

Squeezed state → $(\Delta X_i^2) < 1/2$

Input light

- The input light to the coupled waveguide system is usually produced by a parametric down conversion process at high and low gain which produces important non-classical states of light like the squeezed and the single photon states respectively.

- It is thus possible to study the behavior of photon numbers state and squeezed state of light in the waveguide arrays.

- Such studies are important for applications in quantum information sciences. Also employed for studying analogue of the quantum optical effects.

Model for the coupled waveguide system

$$H_{eff} = \hbar\, g \sum a_p^\dagger a_p + \hbar \sum J(a_p^\dagger a_{p+1} + a_{p+1}^\dagger a_p)$$

- g is the refractive index term for each waveguide

- *J* represents the rate at which the photons are transferred to the neighbouring waveguides.

Model for the coupled waveguide system

- The mode for the field in the *pth* waveguide is described by the annihilation (creation) operator $a_p (a_p^\dagger)$.

- The operators $a_p(t)$ *and* $a_p^\dagger$ *for the coupled waveguide system obey the boson* commutation relation:

$$[a_p, a_p^\dagger] = 1$$

- Using the Heisenberg equations of motion we get:

$$\dot{a}_p = i[H_{eff}, a_p]$$

$$\dot{a}_p = -i g a_p - iJ(a_{p+1} + a_{p-1})$$

Photon-Photon Correlations in Waveguides

- Demonstrated quantum walks of two identical photons in an array of 21 continuously evanescently coupled waveguides.

- Generate single photons using the parametric down conversion process which is non-linear process.

- Couple these photons into the waveguides using a fibre and look at the correlations at the output end of the waveguide.

- The low-decoherence property of the waveguide system preserves the non-classical features of single photons.

MODEL FOR THE WAVEGUIDE SYSTEM

- We therefore investigate next the squeezing aspect of the field in different waveguides.

- We introduce the quadrature operators for the *j th waveguide given by*

$$q_j \equiv (a_j + a_j^\dagger)/\sqrt{2}$$

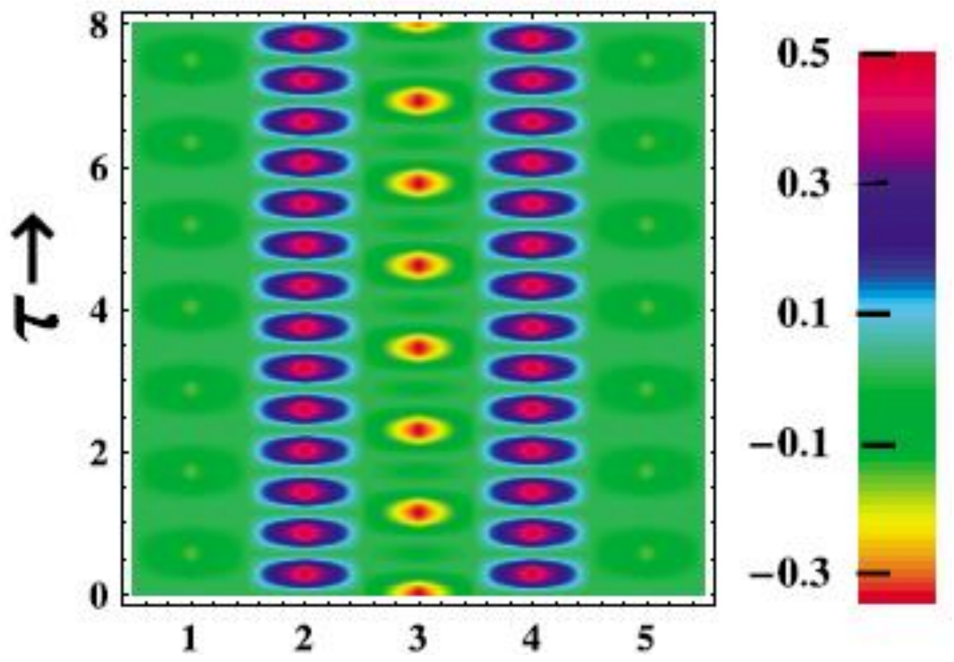
$$p_j \equiv (a_j - a_j^\dagger)/\sqrt{2}\,i$$

- We also define the squeezing factors given by:

$$s_j(q) \equiv (\Delta q_j)^2 - 1/2$$

$$s_j(p) \equiv (\Delta p_j)^2 - 1/2$$

Transport of squeezed state of light



- We study the evolution of squeezing in terms of the squeezing function $s_j(q)$.

•The negative values of $s_j(q)$ shows the squeezing.

•The correlation function $s_j(q)$ *can be measured by the homodyne detection method*.