Propagation of single and multi-photon states in integrated laser-written waveguide networks

D. Guzman-Silva[1,2]
[1]*Departamento de Física and Millenium Institute for Research in Optics (MIRO), Facultad de Ciencias Físicas y Matemáticas, Universidad de Chile, Santiago, Chile*
[2]*Institut für Physik, Universität Rostock, Rostock, Germany*
e-mail:dguzmansilva@ing.uchile.cl

Understanding how light propagates in a guided structure, such as an optical waveguide, and how its properties can be manipulated is crucial for development of new light-based technologies, both in the classical and quantum regime. In last decades, areas like quantum information [1] and quantum simulation [2] have had a great impact due to development of quantum sources, integrated circuits and detections systems, making these areas more realistic from an experimental point of view. Ultimately, all these advances in quantum technologies could be determinant in the fabrication of a possible quantum computer, which promises to outperform a classical computer in several tasks like, for example, searching database [1]. To this date, however, none of the available quantum technologies have proven to be a complete and purely quantum platform, as they execute small and simple tasks which can be performed by a classical computer in a more efficient way. Nevertheless, such technologies could be the building blocks of a future genuine quantum platform. To this end we can find different technologies such as ultracold atoms [3], trapped ions [4] and photons [5]. Photons offer significant advantages such as low decoherence, high speed transmission and the possibility to encode information in several degrees of freedom, such as polarization, path or time.

One way to control and manipulate photons is by using integrated photonic waveguides [5], which provides high stability, low noise and small size, making the integrated photonic waveguides a very controllable platform, allowing to study not only the dynamics of photons but it opens also the possibility to study other quantum systems as well through quantum simulations. In order to fabricate this integrated structure with waveguides inside, one possibility is using the femtosecond laser writing technique [6, 7]. This technique has the advantage of creating 3D structures where the waveguides are not forced to stay in the same plane. Using this technique we studied and simulated the dynamics of a quantum system coupled to a fluctuating environment. Under some assumptions the system can be understood as a reduced open quantum system with the presence of decoherence, which can be investigated using photons propagating in waveguide arrays, where the propagation constant is changing along the propagation distance. Experiments using single and multi-photon states were performed and results how the indistinguishability of photons affect the quantum coherence are presented [8].

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