# Abstract

The mesoscopic behaviour of light can be examined very efficiently in the photonic realm as we have various ways of tuning the mean free path of photon by intelligently designing the medium. One of the many ways to tune the mean free path is by applying deliberate disorder to an otherwise periodic photonic structure forming a coupled wave-guide lattice. By appropriately optimising the disordered structures, various exotic phenomena can be observed. Owing to the development of state-of-the-art technologies to fabricate photonic microstructures, coupled waveguide lattice has emerged as a versatile platform for the study of light-matter interaction.

The work carried out in this thesis investigates the propagation dynamics of light through disordered photonic media in presence of complex coupling such that mesoscopic behavior can be studied. It is demonstrated that the photons undergo Lévy walk when the appropriate disorder is introduced to a coupled waveguide lattice in presence of optimum gain. Earlier reports have claimed that to observe Lévy flight of light we need specially structured glass known as Lévy glass where the distribution of scattering particles follow Lévy statistics. Another exotic phenomenon known as branched flow of light wave is observed for the very first time in disordered photonic lattice under appropriate circumstances. Branched flow is a universal geophysical phenomenon being observed in different length scales ranging from microscopic systems to interstellar activities. It is established that due to the filament-like and non-diffractive propagation of light under the regime of branched flow, a new class of nanolaser can be designed targeting the area of precision surgery as well as various other specialty applications. Furthermore, being a versatile test-bed for the investigation of various mesoscopic phenomena of light, the onset of the topological phenomenon in coupled waveguide lattices to host loss-less topological interface state and its robust propagation is also investigated in this thesis. Study of topology unleashes new design mechanism being adapted in photonics where the unique geometrical modifications lead to robust propagation of light despite dislocations. It is observed that by appropriately tuning the thickness of the high-index layer of a topologically trivial optical lattice, it can be transformed into a topologically non-trivial lattice, and a specialty topological lattice is proposed by joining the trivial and the non-trivial lattice of optimized dimension. The study of light dynamics through this specialty lattice reveals that an interface topological state exists at the intersection of the trivial and non-trivial lattices that are robust despite presence of lateral dislocation, a common issue encountered during the splicing of two optical wave-guides in the industry. Additionally, this loss-less robust edge-state can be amplified by introducing an optimum gain. Further, the effect of deliberate disorder on the trivial as well as the non-trivial lattice is also investigated. Contrary to the expectation, transverse Anderson localization ($TAL$) is not observed in non-trivial lattices, indicating that non-trivial lattices are more resistant to disorder than trivial lattices. Exploiting this fact, a novel light guidance scheme is proposed where coexistence of $TAL$ state and topological interface state is demonstrated by the interplay of deliberate disorder and band-topology.

The unconventional range of photonic lattice prototypes and the intriguing features of

the exotic light dynamics studied in this thesis are extremely important for the advancement of future all photonic devices and circuits. Furthermore, from the standpoint of fundamental studies, these investigations would establish a new paradigm to mimic and gather insights into diverse wave-based phenomena.