Prologue

“This doctoral work addresses research issues concerning to the structure, design and analysis of all optical coupling devices such as couplers, splitters etc. and their compatibility with recent communication technologies to achieve high bit rate and negligible losses. It includes the basic principle and performance enhancement of single coupling elements, when incorporated in high dimension coupler architecture. Our work has been motivated by these fundamentals and to fulfill need of fast and efficient communication systems. The research includes the following sub-domains:

1. Evaluation of basic all optical coupling phenomena
   - Directional waveguides based optical coupler.
   - Multi Mode Interference (MMI) coupler.
   - Photonic crystal fiber based optical couplers

2. Analysis and design of optical coupling and optical power splitting architectures.
   - Evaluation of basic architectures.
   - Modifications to minimize constraints regarding irregular and variable path delay, crosstalk (CT), blocking/non blocking characteristics and on-chip compatibility.
   - Evaluation of architectural limitation when roused to very high dimensions.
   - Enhancement in switch design and their practical implications”.

The doctoral work has been towards replacement of generic on-chip electronic components by the all optical sub-components for performance enhancement. It has also aimed at detailed study and investigation of the single elementary all optical couplers and splitters and with their ability to work with requisite switching networks. Over the past few years, design and fabrication of all optical devices such as couplers, splitters and switches possessing short response time, wide
wavelength spectrum, low losses and CT levels with, polarization independence, high extinction ratio and stability has become an urgent and necessary issue. Driven by these requirements, exclusive progress has been done towards both the structure and the materials useful for realization of optical devices such as couplers, switches, modulators etc. Therefore selection of reasonable optical material is one of the effective ways to improve the performance of such devices. “All structures considered in this thesis are designed and simulated using Optiwave design and simulator tool (ver. 6.0), using its various modules. The coupling behavior and optical field propagation characteristics have been performed using Beam Propagation Method (BPM), a popular technique to analyze optical devices with structural and design variations. It is a highly computation-intensive program and easily applicable to channel waveguides, though it requires huge computer run-time and memory”.

In the initial part of the thesis, the design and analysis of a 2×2 optical coupler has been described using conventional multi-mode interference waveguiding structures supporting the self-imaging principle. “High-quality channel waveguides that constitute the MMI structure have been assumed with various material compositions such as Lithium Niobate with use of Ti-indiffusion, instead of other conventional techniques (high-energy ion implantation or Proton Exchange). The refractive index profile of such waveguides can be modified as a function of the optical needs through the choice of the Ti-strip thickness before indiffusion process, with very low degradation of basic properties of LN”.

The optical coupling in the designed coupler layouts has been facilitated by appropriate selection of coupling region, input and output waveguides, etc. Optical power imbalance in such
waveguiding structures is another source of generated crosstalk among the output ports, which is caused by waveguide irregularities. “Considering these facts, repetitive iterations have been performed to define the most suitable thickness of titanium strip for indiffusion process to take care the possible imbalance in the structure. The work is dedicated to modify basic coupling architecture, which is a reconfigurable optical coupler. To meet out the tremendous growth of traffic demands, wavelength division multiplexers purely based in all optical domains are becoming the natural choice as future backbones for communication systems”. This is also predicted that all optical multicast systems are beneficial for such applications. To generate multicasting optical systems, optical splitters may be placed at various switching nodes along the network. It has also been demonstrated that the optical multicasts can be made practical for both 1:2 optical power splitters and 1: N optical power splitters through the proper selection of light guidance phenomena in conventional optical coupling structures.

The thesis also addresses the physical designer perspective for multicast feasibility from an architectural standpoint. Simulation of designed optical splitters have been done with use of an all optical CAD simulation tool from Optiwave inc. taking into account relevant operating principles and performance issues.