Chapter 1

Introduction

Optical communication is becoming more and more important in the processing and exchange of information. The increasing popularity of broad-band subscriber services such as asymmetric digital subscriber line (ADSL), fiber to the home (FTTH), voice over Internet protocol (VoIP) services and cable television (CATV) has greatly increased the internet traffic in metropolitan areas. As a consequence, future mobile communication systems will have to become more heterogeneous in nature, providing an integrated network environment that comprises various wireless technologies and access systems in a complementary manner [1]. Transparency requires not only the compatibility between data transfer and control layers in 4G technologies, but also the seamless integration of services and applications [2]. All of these applications will require the transfer of an increasing amount of data that can only be achieved by optical transmission techniques [3]. In order to achieve this, higher capacity backbone wavelength division multiplexing (WDM) transmission systems have been introduced into trunk networks to increase the transmission capacity of optical fiber [4]. If WDM technology are to be used in metropolitan areas, multiplexed optical signals must be processed and routed rapidly. However, it is clear that the conventional systems, where optical signals are converted to electrical signals and processed electronically, will reach capacity because of processing delays or limited processing ability. Wavelength routing is a key technology bringing solution by directly routing optical signals without converting them to electrical signals. [5]–[7].

Wavelength multiplexers and demultiplexers, capable of adding and dropping different spectral channels, are the key components of WDM network. There are a variety of demultiplexer and multiplexer technologies like thin film filters, fiber gratings with optical circulators, free space grating devices and integrated planar arrayed waveguide gratings (AWG) [8]. State-of-the-art silicon-on-insulator (SOI) AWG will be downsized for devices with higher channel counts and narrower channel spacing (CS) [9].The integration of different functions on a single chip will not be feasible for practical systems unless the size of the individual functional elements is significantly reduced.

Optical Fiber System Laboratory had already created a 64 × 64 AWG device based on SOI substrate with 50GHz channel spacing center at wavelength 1550nm [10] in 2005. We have found a trade-off value of waveguide separation (dPA = 7.3μm) at junction between arrayed waveguide and free propagation region. With this searched parameter, we can get a better uniformity for 64×64 AWG channel output spectrum transmittance with investigation of compromising value for insertion loss and crosstalk. Then, we apply tapered waveguide structure at the junction between input/output waveguide and the FPR. This successfully improved the transmittance spectrum and crosstalk reduction from 5dB and –21dB to 3.4dB and –31dB, respectively, for a 64×64 AWG based on SOI substrate with 50GHz channel spacing centered at wavelength 1550nm. An experiment was used to measure the surface structure profile and the depth of the phase array waveguide for a 64×64 AWG on these devices and the mode pattern and transmittance of output port for 64-output channels on these devices.

In the advance research, we expect to find the 64×64 WDM MUX AWG that can be applied in a DWDM high capacity metropolitan area optical communication networks. For this reason, we analyzed all possible that could cause propagation loss. From the top view of the waveguide optical microscope photograph, we found irregular sidewall roughness. Chapter 2 will report on propagation loss calculations taking into account the propagation loss coming from sidewall roughness as well as from leakage toward the substrate for various wavelengths. These simulations have been done on square strip waveguides. The relative importance of the different contributions mentioned above in the propagation loss evolution is discussed in relation with the waveguide defects.

In Chapter 3 and Chapter 4, we will present a novel technology of waveguide fabrication using laser to fabricate waveguides. The laser technique was originally demonstrated in the 1980’s [11-13]. Laser-fabricated waveguide has recently become a promising fabrication route for optical waveguides materials allowing reliable, cost-effective and without resorting to the complexity of conventional fabrication techniques. Lasers can also work on most materials and are environmentally friendly. Laser-fabrication had been used in various laser sources, materials and waveguide structures listed in Table I. In Chapter 3 and Chapter 4, we conducted an experiment using two kinds of material with two writing technologies to fabricate our waveguide. In Chapter 3, laser writing in fused quartz glass will be fabricated and discussed. In Chapter 4, we will study laser writing waveguide based on SOI wafer by using both Nd:YAG laser and Nd:YVO_4 laser.

Finally, in Chapter 5, we will compare the waveguide devices we designed with various laser sources and materials. According to the analysis result of optical waveguide fabricated by laser direct-writing, we have compared sidewall roughness caused from different power, speeds and writing times. These results will be very useful for the experimental works in the future.

Table I. Summary of laser direct-writing optical waveguide

Ref	Year	Laser Source	Wavelength (nm)	Substrate Material	channel size	Note
14	1996	ARGON ION	315-363	POLYMER LAYER	2μm	rib/ ridge
15	2002	UV	244	Chalcogenide (Ga:La:S) Glass	6 μm	buried channel
16	2003	Ti:sapphire	775	fused silica	10μm	buried channel
17	2004	ArF excimer laser	193	Polymer	5–7 μm	rib/ ridge
18	2004	Nd:YAG	355	GaAs	50*50 m	rib/ ridge
19	2005	Ti:sapphire	815	chalcogenide Ga-Ge-S, As_2S_3 and Ga-Ge-S	2 μm	buried channel
20	2005	He-Cd	325	liquid photo-polymer	30μm	rib/ ridge
21	2005	Ti:sapphire	796	$LiNbO_3$	7μm	buried channel
22	2005	Ti:sapphire	800	SiON	10μm	buried channel
23	2005	excimer laser	248	ZPO:MAPTMS sol-gel glass	6μm	rib/ ridge
24	2006	proton beams	3.5-MeV	poly-methylmethacrylate (PMMA)	NA	buried channel
25	2006	Ti:sapphire	775	β-BaB_2O_4 (BBO)	10μm	rib/ ridge
26	2006	cavity-dumped femtosecond Yb:glass laser	1040	erbium-ytterbium co-doped phosphate glass	9μm	buried channel