CHAPTER 7

SUMMARY AND CONCLUSIONS

7.1 GENERAL

The objective of the present research is to study several types of photonic crystal fibers established on different geometries and materials. Various parameters of PCF have been investigated viz. effective index, chromatic dispersion, effective area and normalized frequency. In addition to, a highly sensitive bio-chemical sensor based on 2-dimensional photonic crystal structure has also been proposed in this research.

Following conclusions have been drawn based on our present study.

1. In case of a hexagonal photonic crystal fiber, for a particular value of refractive index of core (n_{core}) and other design parameters, negative dispersion increases with increase in the ratio of diameter of hole to the pitch (d/Λ) values in the same communication band. There is observed dispersion flattening at and near the prime optical communication wavelength 1.55 µm. with a quite small variation in dispersion, equal to 2.5 ps/nm-km. This type of PCF can be utilized in the applications such as dispersion compensation, dispersion flattening and band-pass or band-reject filters in optical communication networks. It can possibly be employed as a part of multimode data communication apart from only single mode, in this way making it to exchange more information at a particular time. It can likewise represent as polarization filter in optical systems by having the capacity to distinguish between scalar or polarized field one at a time.

2. A square lattice photonic crystal fiber with circular air-holes has been modelled and investigated for its applications. Metals which obey Drude-Lorentz dispersive model are

placed into the air holes of this PCF and computation of dispersion along with normalized frequency parameters has been performed in the wavelength range 0.4-1.0 µm. Dispersion flattening is observed with the case of only air in PCF holes between 0.7- 0.9 µm wavelength with a deviation of only 1.0 ps/nm-km in dispersion. The dispersion graphs of the metals applied in the PCF viz. gold, copper, aluminium and chromium show a huge amount of negative dispersion for the wavelength range taken into consideration. Silver and nickel doped PCF dispersion curves show mostly positive dispersion with only -100 ps/nm-km negative dispersion in case of nickel from wavelength 0.9 to 1.0 µm. Positive dispersion generated in a conventional optical fiber in the range of thousands of ps/nm-km could be compensated with the help of metal based PCF's. The highest negative dispersion is visible in the case of metal aluminium applied to PCF which is equal to -40000 ps/nm-km whereas the lowest negative dispersion is seen for the metal nickel applied to PCF as -100 ps/nm-km. So the metal aluminum could be the best choice to be employed into PCF for compensating large amounts of positive dispersion.

When metals are included in the PCF there are a variety of normalized frequency curves obtained. Gold, silver and copper filled PCF show an increase in the amount of V_{eff} with increase in wavelength. Aluminium embedded PCF shows nearly constant variation of V_{eff} in the wavelength ranges 0.4-0.7 µm and 0.85- 1.0 µm with only 2.5 percent divergence in V_{eff} parameter. There is almost a linearly decreasing slope of normalized frequency in case of chromium filled PCF in the wavelength range 0.4-0.8 µm and thereafter a constant value of V_{eff}, equal to 3 is maintained. The normalized frequency curve of nickel loaded PCF shows an increase in the wavelength range 0.4-0.65 µm and acquires almost a uniform state up to 1.0 µm. Thus the number of modes that can enter and travel along the length of a photonic crystal fiber for a particular wavelength range can be adjusted according to the metal chosen for filling the cladding holes of the fiber.

3. Temperature based dispersion compensation ability of a hexagonal photonic crystal fiber has been studied. InSb material has been applied into the cladding air-holes of PCF since its refractive index is a function of temperature and is responsible for a significant change in dispersion of PCF with small variation in temperature. It is seen that as the temperature is increased the value of dispersion also increases in the positive direction. The dispersion is more flattened for lower value of temperature as compared to the higher one. An average of 2 ps/nm-km climb in dispersion per degree Kelvin rise in temperature is observed for PCF with $d/\Lambda=0.4$ at communication wavelength 1.55 μm. A PCF whose dispersion can be shifted with the effect of temperature is proposed for the first time in our work. Places where temperature is not constant and keeps varying, this type of PCF can be installed for multiple optical channel dispersion compensating applications. Also in harsh environments where temperature increases or decreases substantially this PCF can show flattened dispersion at a particular temperature without the help of any special equipment.

Effect of temperature is also observed on the normalized frequency characteristics of the PCF. It is seen that, with the change in temperature there is no shift in the values of V_{eff}. Thus we can say that the mode carrying capacity of the PCF remains the same irrespective of the surrounding temperature. This application is particularly useful when the number of modes or quantity of information needs to be preserved but dispersion of the PCF is to be varied with temperature.

4. A novel structure of PCF based on square holes in a square lattice cladding with a solid circular core has been proposed. Negative dispersion has been achieved for wavelengths in the range of 1.3 to 1.8 μm and beyond for this structure. A flattened dispersion with maximum variation of 5 ps/nm-km is obtained for C and L band combined together i.e. from 1530-1610 nm for d/Λ ratio=0.47. The distinctively significant feature of this structure is it's high dispersion tolerance capability at the communication wavelength of 1.55 μm. There is only 2.4 ps/nm-km change in dispersion observed by variation in distance between first ring and core from -5 to +5%.

5. Two types of photonic crystal ring resonators have been proposed for bio-chemical sensing based on square shape and circular shape of inner rings. The major difference between the output resonant peaks of square ring and circular ring structure is, the first peak of the circular ring structure is shifted in the right direction on the wavelength scale as compared to that of square ring structure. The output resonant peaks extracted by varying the refractive index of inner ring rods only show a high sensitivity as compared to the peaks obtained by varying the refractive index of coupling rods or combination of coupling and inner ring rods. The average shift in the output resonant peaks for the square ring structure and circular ring structure comes out to be 2.75 nm and 3.5 nm respectively, on the wavelength scale for each 0.02 change in refractive index considered of inner ring rods alone. It is deduced that both the square and circular ring photonic crystal resonators can act as real time bio-chemical sensors when the sample to be sensed are applied only on the inner ring for achieving high sensitivity. Nano photonic device based on our ring resonator structure can act as a potential candidate to serve in industrial or research sector which are working in the field of medicines, food testing, defence etc.

7.2 FUTURE SCOPE OF STUDY

In the present study design and analysis of photonic crystal fiber for dispersion compensation in optical communication channel is presented. A bio-chemical sensor based on photonic crystal ring resonator is also proposed. Looking at the present study, following areas of research can be explored.

1. Shapes of air holes as well as ring structures in the cladding of PCF can be modified in future to generate unique dispersion characteristics.
2. Along with the structural geometry, different materials could be applied to the background and / or air holes of the PCF.
3. Confinement loss, effective area and birefringence properties of PCF can also be evaluated along with the dispersion parameters.
4. Different Ring resonator structures based on photonic crystals can be studied in future for a wide range of applications such as optical sensors, optical filters, optical multiplexers and de-multiplexers.