Aim of the thesis is to design PQF to handle high energy pulse stretching, amplification and compression. As an introduction to the thesis, we reviewed the linear and nonlinear properties of microstructure fiber. Then we discussed the design procedure for solid and hollow core PQF. Next we dealt with the various numerical methods employed in this thesis. In order to analyze the characteristics of the PQF, we used the finite element method. The properties such as effective mode area, dispersion, bending loss, overlap factor and nonlinear coefficient were studied using FEM. The bandgap determination for hollow core PQF has also been done using FEM. The pulse stretching as well as compression was simulated using SSFM. Finally, we used RK method for simulating the performance of large pitch PQF fiber amplifier.

The work in this thesis has been divided into three parts. The first part deals with a large mode area PQF with high normal dispersion. The novelty in this work is that the large mode area of the fiber is maintained along with the high normal dispersion. This property is highly useful in high energy pulse stretching in fiber based CPA. We report a GVD of 1000 ps²/km at 1.06 µm and an inner core effective mode area of 35 µm². This resulted in high stretching ratio (>10⁵) as well as less nonlinearity and hence, paved the way for distortionless fiber stretching.

The second part of the work is the designing of large mode area PQF with high amplification factor. Here, we optimized the doping diameter of fiber and efficiency of the amplification. The large pitch fiber design has been chosen for the proposed PQF. This has resulted in very large mode area (4660 µm²), less attenuation (0.42 dB/km), high overlapping factor (0.55 for the fundamental mode) and low bending loss. These properties helped amplify the high average power ultrashort pulses with less distortion and high efficiency.

The third part of the work deals with pulse compression of high energy pulse. We designed a hollow core PQF with high second order dispersion (-3000 ps²/km), low \(\frac{\beta_2}{\beta_3}\) ratio (0.5 fs) and moderate effective area (68 µm²) at 1.06 µm. These properties have been exploited for compressing high energy short pulses with negligible distortion. Thus
the stretching, amplification and compression of the high energy ultrashort pulses have been enhanced using various PQFs.

6.1 OUTLOOK

In this thesis, we dealt only with chirped pulse amplification system. But an ultrafast fiber laser system essentially includes a laser oscillator and CPA amplifier. We have enhanced the CPA system performance by using the proposed fibers with high energy ultrashort pulse. Similarly, laser oscillator performance also can be improved by using PQF. The PQF can be used as a passive fiber, an active fiber and even as a hollow fiber in laser oscillator. This work may be extended as a future work and by which it could be possible to realize all-PQF ultrafast fiber laser system. In addition, the PQF hollow core fiber characteristics can further be explored to get higher compression ratio with low higher order linear and non-linear effects.