List of Figures

1.1 Peak power versus average power of various laser oscillators, Sibbett et al. (2012) ................................................................. 3
1.2 Fiber laser oscillator with graphene as saturable absorber from Bonacorso et al. (2010) ............................................................. 4
1.3 Schematic of various stages in Chirped pulse amplification from Jovanovic (2010) ................................................................. 6
1.4 Stretcher and compressor using bulk gratings from Lai et al. (1994) ... 8
1.5 Fiber based CPA system from Eidam et al. (2010) .......................... 9
1.6 SEM images of a) Standard fiber b) 85 µm core rod type PCF c) 108 µm core LPF, Eidam, T. et al. (2011b) ................................. 10

2.1 Cross sectional SEM image of a solid core single mode photonic crystal fiber (manufactured by Crystal Fiber A/S) ......................... 15
2.2 Cross sectional SEM image of a hollow core photonic crystal fiber (manufactured by Blazephotonics Ltd.) ................................. 17
2.3 (a) Schematic of basic quasi-crystal elementary unit b) SEM image of a 12-fold symmetry photonic quasi-crystal from Zoorob et al. (2000) ... 18
2.4 Schematic of 6 fold symmetry photonic quasi-crystal fiber from Kim, S. et al. (2007) ................................................................. 19
2.5 Schematic of 6 fold symmetry hollow core photonic quasi-crystal fiber from Sun, X. and Hu, D.J.J. (2010) ................................. 20
2.6 V parameter for six fold symmetric PQF for various $\frac{d}{\Lambda}$, Kim, S. et al. (2007) ................................................................. 25
2.7 PCF is divided into substructure using triangular elements (meshing) 29
2.8 Quarter of the PCF meshed with triangular elements .................... 31
2.9 Schematic diagram of PCF with PML boundary ............................. 31
2.10 Bandgap diagram for a 2D photonic crystal ............................... 35
2.11 Schematic illustration of the symmetrized SSFM used for numerical simulations. Fiber length is divided into a large number of segments of width h. Within a segment, the effect of nonlinearity is included at the midplane shown by a dashed line. ................................. 37
3.1 Schematic cross section of PQF. White circles denotes air holes. \( \Lambda \) is the distance between the adjacent air holes, \( d_1 \) is the diameter of inner cladding air holes, \( d_2 \) is diameter of outer cladding air holes, \( d \) is the diameter of germanium doped inner core.

3.2 Effective index of the fundamental modes in inner core (solid line) and outer core (dashed line).

3.3 Electric Field distribution in inner core and outer core at 1.06\( \mu \)m.

3.4 Electric Field distribution in outer core above 1.06\( \mu \)m.

3.5 Second order (solid curve) and third order (dashed curve) dispersion of the proposed PQF.

3.6 Effective Mode area (inclusive of inner and outer core) versus wavelength.

3.7 Field distribution in the crosssection due to the bending of the fiber for the bending radius of 10 cm.

3.8 Spliceloss between dual core PQF and SMF as a function of offset value \( \delta \) for the wavelength of 1.06\( \mu \)m.

3.9 (a) Gaussian pulse of 0.1 ps to the stretcher input (b) Stretched output pulse of 1 ns.

4.1 Schematic cross section of PQF. White circles denote the air holes. \( \Lambda \) is the distance between the adjacent air holes, \( d \) is the diameter of the air holes and core is index depressed (grey).

4.2 (a) Field distribution of LP\(_{01}\) mode and (b) First order field distribution with index depression of \( 4 \times 10^{-5} \).

4.3 (a) FM loss for different values of \( d/\Lambda \) (b) FM loss for PQF and PCF for \( d/\Lambda = 0.3 \).

4.4 Bending loss of the fundamental mode of PQF as a function of bending radius.

4.5 Electric field intensity distribution of PCF and PQF for the bending radius of 50 cm.

4.6 Index depression vs effective area and overlap factor for the doping diameter of 50 \( \mu \)m.
4.7 Doping diameter vs effective area and overlap factor for the index depression of $10^{-5}$.......................... 57
4.8 Average signal output power of the amplifier vs pump power .......... 60

5.1 Schematic cross section of 12 fold hollow core PQF. White circles denote the air holes. $\Lambda$ is the distance between the adjacent air holes, $d$ is the diameter of the air holes. .................................................. 63
5.2 Electric Field distribution at 1.06$\mu$m. ........................................ 64
5.3 Fundamental modal index versus wavelengths of interest ................. 66
5.4 Effective index versus normalized wavelength .............................. 66
5.5 Variation of bandwidth of operation for various values of 'D' ............ 67
5.6 Second order dispersion of the hollow core PQF. ......................... 68
5.7 Third order dispersion of the hollow core PQF. ........................... 69
5.8 Dispersion slope of the hollow core PQF. ................................... 69
5.9 Input pulse and compressed output of the hollow core PQF. ............ 70

6.1 Energy level of Yb$^{3+}$ ions ................................................. 81
6.2 Absorption and emission cross section of Ytterbium doped in a silica material ......................................................... 81