Chapter 6

Summary and future studies

6.1 Summary of the thesis

In this thesis, the propagation, dynamics and generation of ultra-short optical solitons are investigated in resonant and non-resonant optical fibers by using the coupled amplitude-phase formalism, the projection operator method and the linear stability analysis, respectively.

In the second chapter, we derived the coupled HNLS equations that governs the propagation of optical solitons in birefringent optical fibers from the Maxwell’s equations. We generated the solitary wave solutions to coupled HNLS equations for two specific cases through the coupled amplitude-phase formalism and discussed the properties of these solutions. We reported that both bright and dark solitons can exist in both anomalous and normal dispersion regimes. We also showed that the solitons can maintain their pulse shape and width during propagation in the optical fibers.

In the third chapter, we used the projection operator method to study the spatial dynamics of ultra-short pulse propagation in birefringent DM optical fibers. In particular, we applied the projection operator method to coupled HNLS equations and obtained the collective variational equations by using Gaussian pulse shapes. The results showed that the frequency shift as well as temporal shift due to the impact
of stimulated Raman scattering effect, at the input pulse width 11.8 ps. In the case of DM soliton systems, we have verified our results by solving the coupled HNLS equations using SSF method and used ordinary differential equation solvers to verify our analytical results. In both cases the numerical simulations are agreed well. The main virtue of our variational equations is that they show explicitly the mode of action of each physical effect on the pulse parameters, thus giving a deeper insight into the dynamical behaviour of the localized structure. It would have been practically impossible to obtain comparable information through a theoretical analysis that does not use a collective variable approach.

In the fourth chapter, we presented the detailed mathematical description of the NLS-MB equations which describe the nonlinear pulse propagation in the resonant optical fibers. In this chapter, we used LSA for deriving MI condition, required for the generation of high-repetition arrays of ultra-short optical pulses, for both anomalous and normal dispersion regimes. At the picosecond regime, we reported that the non-conventional MI conditions found in the normal dispersion regime. Non-conventional MI processes have a substantial advantage over the ordinary MI process, that is, is the possibility to obtain large MI frequencies. We found that the MI peak gain not only depends on the input peak power but also depends upon the sign and magnitude of GVD parameter for the resonant fibers. It was shown that both the peak gain and the optimum modulation frequency are obtained from LSA agreed well with the direct simulation. We also investigated that the distortion less SIT bright and dark solitary waves can occur in anomalous as well as normal dispersion regimes.

In the fifth chapter, we derived the model equations describing the forward and backward direction propagation of intensive electromagnetic waves in the uniformly doped FBG with two-level resonant atoms. We then examined the MI in the uniformly doped FBG with two-level resonant atoms and showed the existence of MI process for both upper and lower branches of the dispersion curve. At near the resonance case,
we found the MI conditions, which do not require any power threshold condition at lower branch. Such MI process are offering more possibilities to obtain large MI bandwidth. It was verified that the gain spectra, and especially the optimum modulation wavelength, as predicted by the LSA, agree well with their counterparts that can be extracted from direct numerical results. In addition, we also reported that both bright and dark SIT gap solitons can be realized at the PBG edges.

### 6.2 Future studies

Many challenges remain on the way towards further realization and optimization of the nonlinear optical fiber media proposed in this work. There remains a substantial uncertainty regarding which nonlinear optical fibers are the best candidates for optical switching and optical communications. Various research groups have used different approaches for generation and propagation of optical solitons in various nonlinear optical fiber media. The future directions for the continuation of this work as follow:

- In the chapter four, the studies of the physical system of equations have been restricted only to the ideal system. For the real world system, extend the physical model to account for inhomogeneous spectral broadening, absorption and saturation of the Kerr nonlinearity in the resonant fiber.

- The physical model equations derived in chapter five can be used for studying the optical switching and pulse compression in the uniformly doped FBG with two-level resonant atoms. It will be of great interest to study the optical switching in uniformly doped nonlinear periodic structure. The nonlinear periodic structure is complementary to the bistable optical switching devices. The uniformly doped nonlinear periodic structure can be theoretically predicted to have the capability of achieving multiple optical signal processing functions including limiting, reshaping, logic operations and pulse compression.