Preface

Laser physics and nonlinear optics are two integrally involved subjects and existence of one is at stake without the other. The high spectral intensity available from a laser was responsible for observing nonlinear optical effects of different orders and on the other hand nonlinear optical phenomena are indispensable for generation of tunable coherent radiation starting form deep ultraviolet to far-infrared region. Most importantly, nonlinear optical processes are widely used in different passive mode-locking techniques for generation of ultrashort optical pulse train, which is a tool for studying higher order nonlinear optics and ultrafast nonlinear optical processes. Out of different passive mode-locking techniques, nonlinear mirror mode-locking, which relies on nonlinear optical frequency conversion processes, is the simplest for picosecond pulse generation. The merit of a mode-locked laser depends on the self-starting and stability of mode-locking. Self-starting of mode-locking is obvious in nonlinear mirror technique owing to strong nonlinear loss modulation. However, like other passive mode-locking techniques, the stability of mode-locked pulse train remained an issue in nonlinear mirror as well. The aim of this thesis is to explore nonlinear mirror mode-locking in a laser diode array pumped Nd:YVO_4 laser and study the stability of mode-locked pulse train to establish it as a simple, efficient and stable source for picosecond pulse generation. Nonlinear mirror realized in this thesis exhibited two interesting observations for extensive study: (1) the dependence of mode-locked pulse evolution on the phase-matching of intracavity frequency conversion, (2) the passive Q-switching instability in cw mode-locking which forces the laser to run in simultaneous Q-switched and mode-locked regime. The response of a nonlinear mirror is like a fast saturable absorber for it's fast response due to electronic nonlinearity. The derived equivalent fast saturable absorber parameters of a nonlinear mirror show the critical dependence of the saturation power on the phase matching and determine the domain of phase mismatch up to which it can behave as fast saturable absorber. The parameter ranges are also identified corresponding to the single pulse mode-locking. The issue of passive Q-switching instability is, however, addressed in two ways in this thesis. The minimum intracavity pulse energy required for pure continuous wave mode-locking is found to be too high to realize in moderate power nonlinear mirror mode-locked laser, and as a consequence, it is difficult to avoid passive Q-switching instability in nonlinear mirror mode-locking. Simultaneous Q-switched and mode-locked operation can generate very high peak power, but of limited use because of rapid fluctuations in amplitude and repetition rate of the pulse train. The technique of actively Q-switched and nonlinear mirror mode-locking, presented in this thesis can stabilize the Q-switched envelope and helps achieving a peak power which is orders of magnitude higher than that can be achieved in cw mode-locking. However, in some cases, where mode-locked pulses of equal amplitude are necessary, passive Q-switching instability is to be suppressed. Inverse saturable nonlinear mirror is realized by intracavity third harmonic generation, where the laser loss first decreases with intensity like a fast saturable absorber and beyond certain intensity it starts to increase. The inverse saturable nonlinear mirror reduces critical energy for continuous wave mode-locking by orders of magnitude and helps achieving pure continuous wave mode-locking without being affected from passive Q-switching instability.