CHAPTER-10

SUMMARY AND CONCLUSION

The self-focusing of laser beam in plasma is considered to be an important and captivating process that occurs during laser-plasma interaction as it is caused by the change in refractive index which arises due to relativistic mass effect, ponderomotive force, induced plasma diffusion and non-uniform ohmic heating. The up-to-date advances in such laser technology have made the experimentalists to use the pulses focused to extremely high intensities of the order of ($I \geq 10^{20} W/cm^2$). This makes it possible to explore the parameters both in atomic and plasma physics. With the advent of maser, laser and other radiation sources, coherent electromagnetic waves having well defined frequency and phase, have been shown to have wide ranging applications and their interaction with the plasma has been a captivating field of research in recent years. Because of intense electromagnetic radiations, the electron velocity in the plasma becomes quite large as compared to the velocity of light. Therefore, one must take in to account the relativistic mass variation. It therefore leads to self-focusing as the dielectric constant of plasma is an increasing function of the intensity. It is the ponderomotive force of the focused laser which then urges the electrons to move away out of the region having high intensity, reducing the local electron density, and consequently increasing the plasma dielectric function which leads to sooner and even stronger self-focusing. Further, the studies of laser beams with plasmas have attracted the researchers as the waist size is connected to beam width parameter. Therefore, studies of beam width parameters variation becomes an important subject of high power laser beams. Furthermore, a laser beam exhibits oscillatory behavior while propagating in plasma. In order to improve the self-focusing effect, the plasma density transition is introduced.

In the present thesis, we considered the density transition type based self-focusing of a short pulse laser in plasma for HchG, ChG, HcosG, simple Gaussian and chirped Gaussian beams. Due to density transition the spot size of the beam decreases up to a Rayleigh length and does not increase much. By choosing optimized parameters, the combined effect of density ramp, decentered parameter which is a characteristic of cosh-Gaussian beams and linear absorption on the beam width parameter behavior shows that self-focusing occurs sooner, becomes enhanced with shorter propagation distance and then its defocusing takes place. The absorption weakens the self-focusing effect and density transition sets an earlier and stronger focusing. Therefore, the study of such beams can be analyzed in plasma, but the essential thing is that the plasma density ramp, decentered parameter and absorption coefficient act in such a way that they change the self-focusing or defocusing nature of the beam in a significant manner. Further, due to dominance of self-focusing term over the diffraction term, the self-focusing of HcosG beams occurs in an enhanced manner. However, in uniaxial crystals the HcosG beam spreads in the $x-y$ plane with increasing propagation distance, and its beam profile remains unchanged for a short propagation distance. But, as the decentered parameter is increased, the laser spot size of HcosG beam gets reduced during propagation in plasma under density transition and the beam then converges rapidly and focuses to a smaller spot size. Further, since the laser beam used is highly powerful, the relativistic nonlinear effect emerges from the relativistic mass correction and depends on intensity factor αE_0^2 and relative plasma density ω_{p0}/ω. The nonlinear term is responsible for self-focusing and the divergence of the beam is due to the diffraction term. Further, when the plasma density is increased at relativistic intensities, most of the electrons of the beam having relativistic nature travel with the laser pulse. With the result, a higher current and consequently a higher magnetic field get generated, which further leads to enhancement of self-focusing.

Now, as the initial electron density depends on the distance of propagation. Therefore, as soon as the laser beam passes deeper in to the plasma, the dielectric constant of plasma decreases rapidly. The laser beam then shows an oscillatory behavior and the frequency of oscillation increases, which in turn decreases the amplitude gradually close to the axis of propagation. Therefore, by considering the density transition (ramped density profile) and taking in to account the effect of relative density, the self-focusing process of laser occurs earlier and becomes stronger. Again, with increase in ramp slope of plasma density curve along the propagation axis, the process occurs sooner and hence laser beam is more focused. Further, by increasing the intensity, the diffraction of the propagating beam in a nonlinear medium starts earlier. Thus, one can say that it is the intensity of the beam that controls the behavior of beam width parameter. Again, due to increase in the value of intensity, highly energetic electrons will continue to move forward without loss of energy. Furthermore, the beam width parameter is a function of laser spot size and depends on the intensity of beam. Therefore, the intensity rise results in the reduction of spot size very close to the axis of propagation and the density transition leads the beam width parameter to decrease with a higher rate. Consequently, the self-focusing of laser beam is enhanced to a greater extent by exploiting the density transition in plasma. Thus the density transition has a crucial role in laser-plasma interaction.

The chirp parameter increases the electron energy and hence momentum so that the electron escapes from the laser beam. The value of chirp parameter decreases with laser intensity and initial electron energy. Although, without chirp, the laser beam shows self-focusing up to a certain critical value but, as the propagation distance increases, it starts to experience defocusing. The chirp parameter minimizes the defocusing and increases the ability of process of self-focusing of laser in plasma. Further, the amplitude of oscillations decreases with the distance of propagation so that sooner, earlier and stronger self-focusing effect is achieved. Also, on increasing the values of negative chirp, the self-focusing at first is strengthened and after attaining a critical value the laser beam defocuses. This is because the frequency of a linear and negative chirped laser beam changes during the propagation in the plasma. The spot size of laser beam depends on ξ and at extended propagation distances the temporal shape of the chirped laser beam will be changed. Therefore, the defocusing of laser beam is weakened and there by the self-focusing effect is strengthened by using chirp. Hence, the chirp parameter plays a significant role in minimizing the defocusing and increasing the ability of process of self-focusing in collisional plasma. Now, for the case of rippled density magnetoplasma, it is the magnetic field that has a serious influence on the beam width parameter variation. As the magnetic field is increased, the nonlinear term begins to control over the diffractional divergence term and the propagation characteristics of the medium are changed. Due, to strong interaction between the magnetic and laser fields, the laser beam is more focused. Thus, one can say that the magnetic field has a significant role in enhancing the self-focusing effect in rippled density plasma. Further, due to large ripple wave number, the wavefront curvature continues to focus the laser beam inside the magnetoplasma. Thus, one can say that the self-focusing strength of laser beam increases in rippled density magnetoplasma.

The present work has direct applications to accelerators based on plasma including laser-driven fusion, inertial confinement fusion, x-ray lasers etc. In such applications, it is important for a highly powerful laser beam to propagate over extended distances without loss of energy so that an efficient interaction with the plasma is preserved. But during such laser-plasma interactions, the resultant intensity of the laser beam is being affected by instabilities such as scattering processes like stimulated Brillion scattering and stimulated Raman scattering. These processes can greatly affect the absorption of light in laser produced plasmas because they can prevent light from reaching the critical density region. The laser pulses are very useful in studying the mechanism of powerful terahertz radiation generation from gas targets. The quasi-static transverse currents created by laser field ionization in plasmas are responsible for the THz emission. The chirped laser pulses are used to generate strong THz pulses with amplitudes scaling linearly with the laser amplitude. Thus, density transition is considered to be important in laser plasma interactions, particularly for the self-focusing of short pulse laser in an under dense plasma. Increase in initial density and ramp slope decreases the minimum spot size of the laser beam. The laser and plasma parameters are crucial for self-focusing process in plasmas as it is enhanced with such optimized laser and plasma parameters.