Abstract

The present thesis is an attempt mainly to understand the application of laser plasma interaction during photodisruption of crystalline lens (human eye lens) in order to cure presbyopia. This thesis also include the application of laser plasma interaction in compression of high power short laser pulse and study of turbulence in mega gauss magnetic field produced during high power ultrashort pulsed laser plasma interaction. The objectives of the present thesis have been achieved by solving the model equation through numerical simulations as well as by semi analytical technique under the paraxial ray approximation.

Presbyopia is the functional loss of the accommodative property of eye. It arises due to hardening of crystalline lens with aging. Selective photodisruption of crystalline lens increases the elasticity of lens. Photodisruption is process of minimal invasive surgery, through plasma generation via laser induced optical breakdown of medium utilizing femtosecond laser pulses, used in ophthalmology.

Focusing of laser pulse at the preferred position in a small area is the most important part during photodisruption of crystalline lens. The laser pulse dynamics decide location of focusing point and spot size of laser pulse inside the crystalline lens. Crystalline lens has parabolic graded refractive index (GRIN) structure. Along with dispersive and diffractive property of crystalline lens GRIN structure of crystalline lens also play role in determination of laser pulse dynamics during photodisruption of crystalline lens. During photodisruption dielectric constant of medium changes appreciably due to formation of electron plasma via laser induced breakdown (LIB) and an intensity dependent part of dielectric constant also arises due to high intensity of laser pulse. This intensity dependent part of dielectric constant makes the laser pulse dynamics nonlinear.
The second chapter of this thesis deals with the effect of collisional nonlinearity on the laser pulse evolution inside crystalline lens. The density gradient arises due to the nonuniform heating of plasma generated by the same laser pulse of the order of nanosecond duration or more. In chapter three, femtosecond laser pulse has been considered for the photodisruption in the crystalline lens, which has intensity high enough to generate plasma through LIB by multiphoton absorption. Generation of plasma by multiphoton absorption is a nonlinear phenomenon which changes the laser pulse dynamics. Chapter four of present thesis deals with spatiotemporal evolution of the femtosecond laser pulse during propagation of laser pulse in crystalline lens in presence of Kerr self focusing. This spatiotemporal dynamics is much more informative than only spatial dynamics because it gives the more exact estimate of the peak intensity available for plasma generation. Energy absorption from laser pulse via multiphoton absorption and plasma absorption processes play important role in spatiotemporal dynamics of the laser pulse during photodisruption of crystalline lens. Hence, a comprehensive model has been discussed in the chapter five for a focused laser pulse inside crystalline lens. This model contain the effect of transverse beam diffraction, group velocity dispersion, Kerr self-focusing, laser induced breakdown in which an electron plasma is generated, plasma absorption and multiphoton absorption.

These studies (from chapter two to five) show that self focusing of longer laser pulse happens due to collisional nonlinearity but plasma generation by the femtosecond laser pulse causes defocusing of pulse. Kerr nonlinearity of medium causes self focusing of laser pulses. This self focusing (which arises due to spatial response of nonlinearity) is not only decides the spot size at focusing point of laser pulse and location of focusing point but also plays crucial role in the breakdown of medium which is main part of the photodisruption technique. These
results also show that evolution of pulse duration (which governed by the temporal response of nonlinearity) decides the available intensity of laser pulse for photodisruption. Spatiotemporal evolution of pulse shape inside crystalline lens decides the nature of pulse beyond the focusing point. These studies also points out the relevance of the present investigations to cavitation bubble formation for restoring the elasticity of the crystalline lens. This study presents a rough estimate of plasma temperature at the focusing point during cavitation bubble generation. This type of work along with experimental predictions is very useful in understanding the process of elasticity enhancement of eye lens.

In the sixth chapter of this thesis, possibility of compression and intensity enhancement of a high power short laser pulse, utilizing relativistic nonlinearity induced by same pulse in plasma, has been discussed. It is found that pulse compression is highly sensitive to plasma frequency and initial value of electric field of pulse. Seventh chapter of this thesis deals with the turbulence in giant magnetic field reported in laboratory experiments. This study has been done by considering the relativistic nonlinearity induced during laser plasma interaction at high power. It is found that chaos in magnetic field the laser pulse play an important role in the magnetic field turbulence during the laser plasma interaction.