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In-Situ Ion Heating with Pulsed CO_2 Laser

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Laser energy is preferentially absorbed by the lighter electron species of the plasmas as they respond at the fast laser frequency. The energetic electrons thus generated are then often employed to heat ions in applications such as fast ignition etc., for creating hot spot in the plasma for ignition [1,2]. This is a secondary process to heat ions and consequently somewhat inefficient. The propagation of energetic electrons is marred by several instabilities which lead to their divergence and loss. Moreover, the Rutherford electron – ion collisional cross section to enable the transfer of energy reduces with increasing electron energy. It is thus desirable to have laser energy directly coupled to the heavier ion species. In addition there are also many other applications where ion acceleration/heating is of importance, e.g. proton radiography, biomedical applications [3].

The advantages of direct in – situ ion heating/acceleration are many. For instance, there would be (1) Efficient coupling directly to fusion species, viz. background DT species ; (2) Ions being non relativistic and total current being much less than Alfven critical current for ions, magnetic fluctuations are expected to play negligible role in beam transport and beam stopping; (3) Classical collisional stopping of few MeV ions in dense core will be adequate; (4) Return currents, if any, will excite electrostatic ion acoustic modes leading to anomalous heating of the background plasma. Therefore, there is need to look for the possibility of new absorption mechanisms through which laser energy can directly be transferred to heavier species of plasma for efficient ion acceleration. This is the prime focus of our study here.

It is shown that the use of a several Kilo Tesla of external magnetic field transverse to an inhomogeneous plasma would bind the electrons preventing their motion along the density gradient. The long wavelength CO2 laser is then shown to get coupled to a lower hybrid ion plasma resonance [4].

This method can thus accelerate ions efficiently (~ 1 MeV). This has been confirmed by carrying out numerical experiment through Particle-in-Cell (PIC) simulation using OSIRIS code.

The technological requirements for such experiment also seem within reach. The CO_2 lasers are today well known as efficient industrial laser available in the market for long pulse and continuous wave applications. However, the short pulse CO2 lasers are also now available and hence short pulse applications such as the one discussed here can now be easily explored. Furthermore, 10 kilo Tesla magnetic fields have already been prepared in laboratory [5]. It is merely a matter of time now when several Kilo Tesla of magnetic fields can be generated, thereby paving the way for conducting experiments for direct in-situ ion heating proposed in this work.

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