# Laser based particle accelerators and its applications in various fields

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Particle accelerators play a very pivotal role in development of modern technology. It also plays an important role in understanding of basic physics of matter, its interaction and origin of universe. Higher and higher energy particle accelerators are desirable to probe the matter at extreme details which is yet known. The high energy particle acceleration accomplishes with large size accelerator structure of the order of few tens of kilometres. Thus it requires a huge installation and extremely of high cost. The size of the accelerators depends on the accelerating field gradients and energy of the particles. For RF field based accelerators it is typically < 100MV/m and therefore to achieve high energy particles viz. terra electron volt (TeV), the size becomes very large. Alternatively, very high electric field (> 100 GV/m) produced in plasmas can be used for accelerating the charge particles. Thus reducing the size of the accelerator by 1000 times.

Modern days ultrashort ultrahigh intensity Ti:sapphire lasers can produced very high intensity at the laser focus (> 1018 W/cm2). At such high intensity it can produced very high longitudinal field (> 100 GV/m) by the process of plasma oscillations known as plasma wakefield. This wakefield filed propagates behind the laser with a phase velocity close to laser group velocity (~ c). Thus the laser produced plasma wakefield provides an alternative means of the particle acceleration known as Laser Plasma Accelerator (LPA). Since the electric filed is three orders of magnitude higher than the convention RF electric field, one can achieve high energy particle over a very small size. Further, the electric field associated with high intensity laser pulses can be as high as TV/m it can accelerated the particle directly known as Direct Laser Acceleration (DLA).

Next, high intensity ultrashort laser pulses when focused on thin foil target, it generates high energy electron which can penetrate through the foil and emerges at the foil rear side generating strong electrostatic filed known as sheath filed. The amplitude of this sheath field can be TV/m at laser intensity of 1018 W/cm2. Thus this filed accelerates light ions such as proton, carbon, oxygen, nitrogen which are always present as contaminates on the foil to high energies.

At Laser Plasma Division, RRCAT studies have been performed on both electron as well ion (proton) acceleration using various Ti:sapphire laser facilities. This includes 10 TW, 50 fs and 150TW, 25 fs lasers. Recently, investigations on LPA were performed using 150 TW laser with aim to achieve tuneable electron beam energy between 100-250 MeV by controlled electron injection. Also DLA and hybrid regime of acceleration (DLA + LPA) of electrons in different gas-jet targets of He, N2, Ar and mixed gas targets of He + N2 were identified. Hybrid regime of acceleration in He has demonstrated acceleration of electrons to energy >500 MeV. Next, application of accelerated beam in electron beam radiography is explored.

Next, studies on ion acceleration using thin foil targets have been carried out. Proton energy up to 12 MeV has been demonstrated using 150 TW laser operating at relatively lower power of 90 TW. The beam has been used to successfully produced 11C PET isotope by bombarding on 11B target. Further, using deuterium ion beam higher yield of the PET isotope is achieved using 10B target. The proton beam is also used to study proton-boron fusion reaction yielding production of alpha particle. Finally, the proton beam has been used in radiography of microstructure and dense plasma. The talk will cover all broad aspects of laser accelerated particles results, our recent studies, and various applications of the accelerated beam.