Generation of proton beams from a hydrocarbon target irradiated by an ultra-intense femtosecond laser pulse

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Extreme Light Infrastructure (ELI) is a currently implemented large-scale European project that uses cutting-edge laser technologies to build multi-PW lasers generating femtosecond pulses of ultra-relativistic intensities $\sim 10^{22} - 10^{23}$ W/cm$^2$. The ELI lasers will have a potential to produce intense ion beams of sub-GeV and GeV ion energies demanded for research in various branches of science and technology as well as for medical applications such as the hadron cancer therapy.

This contribution presents results of two-dimensional particle-in-cell simulations of ion beam acceleration at the interactions of a 130-fs laser pulse of intensity from the range $10^{21} - 10^{23}$ W/cm$^2$, predicted for the ELI lasers, with a thin hydrocarbon (CH) target. A special attention is paid to the effect of the laser pulse intensity and polarization (linear - LP, circular - CP) as well as the target thickness on the proton energy spectrum, the proton beam spatial distribution and the proton pulse shape and intensity. It is shown that for the highest, ultra-relativistic intensities ($\sim 10^{23}$ W/cm$^2$) the effect of laser polarization on the proton beam parameters is relatively weak and for both polarizations quasi-monoenergetic proton beams of the mean proton energy $\sim 2$ GeV and $\delta E/E \approx 0.3$ for LP and $\delta E/E \approx 0.2$ for CP are generated from the 0.1-μm CH target. At short distances from the irradiated target (< 50 um), the proton pulse is very short (< 20 fs), and the proton beam intensities and the proton current densities reach extremely high values, $> 10^{21}$ W/cm$^2$ and $> 10^{12}$ A/cm$^2$, respectively, which are much higher than those attainable in conventional accelerators. Such proton beams can open the door for new areas of research in high energy-density physics and nuclear physics as well as can also prove useful for applications in materials research e.g. as a tool for high-resolution proton radiography.