Petawatt laser physics

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This page contains a list of petawatt-level lasers in operation, under construction, or proposed. The list is compiled from existing academic reviews.[1][2]

The world"s most powerful laser systems currently provide peak powers of a petawatt (1015W = 1.000.000.000.000.000 W) or even more. Reaching these extreme powers is possible via Chirped Pulse Amplification (Nobel Prize in Physics 2018, Donna Strickland & Gerard Mourou). Here a short, low energy pulse is stretched in time and then amplified in several so-called power amplifiers.

In conclusion, intense light acts as a snowplough for electrons, pushing them out of the way, and leaving the plasma ions behind, thereby generating large, quasi-static charge-separation fields. As they are in part oriented parallel to the propagation direction, this process effectively transforms the oscillating transverse laser fields into longitudinal acceleration fields.

Recent ultra-short high-power lasers can provide ultra-high laser intensity over 1022 W/cm2. Laser fields of such extreme strengths instantaneously turn matter into plasma, which exhibits relativistic collective dynamics, thereby leading to unprecedented physical systems with potential breakthrough applications. In this article, we introduce the basic concepts and trace the progress in ultra-high intensity laser development and relativistic laser-plasma interactions, including laser-driven charged particle acceleration.

"New directions in science are launched by new tools much more often than by new concepts. The effect of a concept-driven revolution is to explain old things in new ways. The effect of a tool-driven revolution is to discover new things that have to be explained," [1] said Freeman Dyson, one of the founders of quantum electrodynamics (QED) [2]. The term "tool-driven revolution" may be just the right words to describe the progress of strong field physics wherein a quantum jump in laser intensity has always led to novel physics areas.

In this article, we present the basic concepts and recent progress in strong field physics. First, the key technologies in ultra-intense laser development are described, and the performance of the state-of-art lasers is mentioned. Relativistic laser-plasma interactions are then explained, starting from single-electron dynamics and culminating in laser-driven charged particle acceleration, which has emerged as one of the most intensively pursued topics in this field. Finally, the main conclusions are given along with a brief mention of upcoming topics.

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An ultra-high intensity laser can serve as an excellent tool to explore novel physical phenomena. Matters exposed to extremely high intensity can exhibit exotic phenomena through laser-matter interactions. Recently, laser intensities have reached 5 x 1022 W/cm2 [17], thanks to advanced laser technologies. In this section, the status of ultra-high intensity lasers and the key advanced technologies are presented.