Principles and applications of high-intensity lasers

Jyhpyng Wang
Institute of Atomic and Molecular Sciences, Academia Sinica
National Central University

Since the invention of laser 50 years ago, there are many great leaps in laser technology. An important line of development is the generation and amplification of ultrashort laser pulses. Immediately following the realization of the ruby laser, the Q-switch technique was demonstrated, which already shortened the pulse duration to ~10 ns and brought the peak power to the 100-MW level. However, the most impressive development occurred between 1980-1990, when the invention of passive mode-locking shortened the pulse duration to less than 100 fs and the invention of chirped-pulse-amplification enabled amplification of femtosecond laser pulses to the terawatt level. Now it is possible to construct a 100-TW laser that can be focused to 10^{20} W/cm^2 in a university laboratory. The intensity is 10^{21} times of sunlight on the earth surface, and the corresponding optical pressure is as large as 10^{10} atm. Such strong optical pulses have pushed the frontier of experimental physics. For instance, the laser wakefield in plasma can accelerate electrons to the GeV level in the centimeter length scale. The accelerated electron bunch has the duration of a few femtoseconds, which can be utilized to generate femtosecond hard x-ray by synchrotron radiation or femtosecond gamma-ray by inverse Compton scattering. The laser can also generate large sheath field at the surface of a thin film to accelerate protons and ions, or produce high-temperature plasma to serve as the gain medium for soft x-ray lasers. With the highly relativistic interaction between such a strong radiation field and plasma, it may be possible to simulate astrophysical processes in laboratory. Such experiments require precision control of the laser waveform as well as ingenious measurement techniques to meet the challenge of exploration. With its potential impact in fundamental physics and great promises in downstream application, I think this is an exciting new field for the new generation of young physicists.