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PLENARY: Development of particle-in-cell code KLAPS and its applications in laser plasma physics

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Abstract content
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In this talk, I will introduce the development of our particle-in-cell (PIC) code KLAPS[1] for laser-plasma physics studies and its applications in fast ignition for inertial confined fusion[2] and MV/cm terahertz (THz) radiation generation[3-5] etc. With the help of PIC simulation, the cooperation with experiments of femtosecond X-ray generation and complete absorption of intense laser pulses will be briefly introduced.

Fast ignition scheme was proposed in 1994 to rapidly heat a compressed fusion fuel by a short-duration (10ps=10-11s), high-power (PW=1015watt) ignition laser and then gain huge energy by nuclear fusion. It requires that fast electrons of MeV produced by the ignition laser are transported over 100mm distance to heat a high-density core region. The key is how to achieve a coupling above 10% from the laser to the core. Coupling of 20% was demonstrated experimentally in 2001 [Nature 412, 798] with a cone-inserted target. However, recent experiments reported much lower coupling of only a few percent. The very different results could be related to different preplasmas formed by the ignition laser prepulses in the cones. To clarify this point, we firstly developed an integrated PIC simulation approach [1] (named two-system PIC) to self-consistently include the whole heating physics of fast ignition. Our simulation showed that different presplasm levels caused significantly difference in the coupling. To reduce the preplasma effect, we propose a magnetically assisted (MA) fast ignition scheme [2] using a cone-free target supplemented by an external 20-megagauss magnetic field to confine the fast electron motion. Such a target also does not suffer from asymmetry in target compression, as is the case for a cone-inserted target. The MA scheme was demonstrated by our integrated PIC simulation[1]. With this PIC approach we directly obtained the laser-to-core coupling of 14%. Quantitative comparison among the MA scheme, the cone-inserted scheme, and the original scheme was performed, for the first time via integrated simulations. It is shown that the coupling can be enhanced by 7-fold with the magnetic field, which can even exceed that obtained with the cone-inserted scheme.

THz radiation sources with tunable polarization and frequencies are in high demand for diverse THz technologies such as THz spectroscopy and coherent control. Currently the widely studied two-color laser scheme can provide a powerful THz source. Such a source basically has linear polarization and a broad bandwidth[3,4]. Here, we propose an approach[5] to generate circularly polarized, narrow-band THz radiation with continuously tunable frequency. In this approach, a 100-tesla magnetic field is imposed along the propagation direction of the two-color linearly polarized laser driver. Stable magnetic fields of this order are already experimentally available. In the proposed approach, the radiation frequency is linearly proportional to the magnetic strength. The rotation direction of the new radiation can be controlled by the magnetic field sign. This radiation has a many-cycle waveform rather than the usual single-cycle waveform as in the case without the magnetic field. This approach is demonstrated by PIC simulations (with KLAPS code) and further explained by theoretic analysis.

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