Plasma density limits of laser hole boring and superthermal electron generation by relativistic picosecond lasers

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Intense lasers can penetrate into overdense plasmas by the laser hole boring (HB) where giga-bar-level radiation pressure pushes the critical plasma surface forward. The HB proceeds with making a sharp laser-plasma interface which plays an important role in energy transfer from laser to electrons. Hence, the HB is a fundamental concern in applications such as ion acceleration and fast ignition-based laser fusion. Conventionally, the HB had been considered to proceed as long as the laser pulse continues [1]. However, recent studies have found that during over-picosecond (ps) laser irradiation, surface plasma starts to expand towards the laser resulting the superthermal electron production [2].

In this study, we find that under the continuous laser heating in ps time scale, the pressure balance between plasma and laser light is established being assisted by the sheath electric field, which acts as the surface tension, and the HB stops consequently. Based on the pressure balance equation, we theoretically derive the limit density for the HB, i.e., the maximum density laser light can reach, as $8a_0^2 n_c$ where a_0 is the normalized laser amplitude and n_c is the critical density [3]. The time scale for the laser front to reach the limit density is found to be in the ps regime. After the laser front reaches the limit density, the hot plasma starts to blowout back towards the laser. In the blowout plasma, electrons interact with the intense laser multiple times and stochastic electron heating can be enhanced. This results in generating copious superthermal electrons and affects the subsequent phenomena in the laser-plasma interaction, such as ion acceleration [4].

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