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Physical Mechanism of the Intrinsic Transverse Instability In laser Radiation Pressure Ion Acceleration

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With the invention of ultra-intense lasers, nanometer scale foils can be readily driven to relativistic speed in femtoseconds time scale, arousing strong interests on "light sail" and "flying mirror" driven by laser pressure, which may also lead to useful applications such as ion acceleration and coherent light sources. However, many simulations indicated that such "light sail/flying mirrors" may suffer instabilities that can break up their surfaces. With intense research for more than a decade, the physical mechanism behind these instabilities has not been clarified. In this work, a theoretical model and supporting two-dimensional particle-in-cell (PIC) simulations are presented to decipher this mystery. It turns out that the ripples on the foil surface are mainly induced by the coupling between the transverse oscillating electrons and the quasi-static ions. The predictions of the mode structure and the growth rates from the theory agree well with the results obtained from the PIC simulations in various regimes, indicating the model contains the essence of the underlying physics of the transverse breakup of the foil.