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Molecular dynamics simulation of interaction between energetic electron beam with charged dust particles in a 2D dusty plasma

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Laser, electron and ion beams have been shown promising in science and technology. For example, laser beam is used to modify the electrical properties of outermost layer (or layers) of materials; ion implantation technique based on the ion beam is used to improve the corrosion resistance of metals; pulsed electron beam is used to anneal damage in ion implanted semiconductors; and so on.

Dusty plasma, composed of charged dust particles, neutral gas, and background plasma, serves as a model system to study structures, dynamics, phase transitions of soft condensed matters. Over the past almost 30 years, the laser beam had been widely used to manipulate the charged dust particles without disturbing the background plasma,[1,2] and interesting problems including transverse waves, solitary waves, shocks, heat transport, and shear viscosity were studied.

By contrast, the electron beam or the ion beam is seldom used to manipulate the charged dust particles, partially due to the following reasons: (1) instabilities may occur, in particular for the charged dust particles, during the travelling of energetic electrons or ions in the dusty plasma, (2) the charged dust particles tend to lose mass (through vaporization) when an energetic electron or ion beam bombards the charged dust particles, (3) the energetic electron or ion beam interacts not only with the charged dust particles, but also with the neutral gas and background plasma, thus involuntarily deemphasizing the manipulation of charged dust particles.

However, the recent laboratory experiments[3,4] have shown that charged dust particles irradiated by an electron beam with energy 10-14 keV behave like that of laser-driven dusty plasma (Figure 1 shows the laminar flows of charged dust particles driven by laser beam and electron beam respectively). This provides a good chance to study the interaction of energetic electrons with strongly coupled system. To well understand the laboratory experiments,[3,4] we conduct a molecular dynamics simulation with the following concerns: (1) whether the well-known Yukawa potential is still applicable to the interaction of charged dust particles during the electron beam process, particularly near the electron beam, where the background plasma is perturbed, (2) Does the electron drag force dominate in driving the flow of charged dust particles? The simulation results are compared with existing dusty plasma laboratory experiments where the electron beam is present.

References
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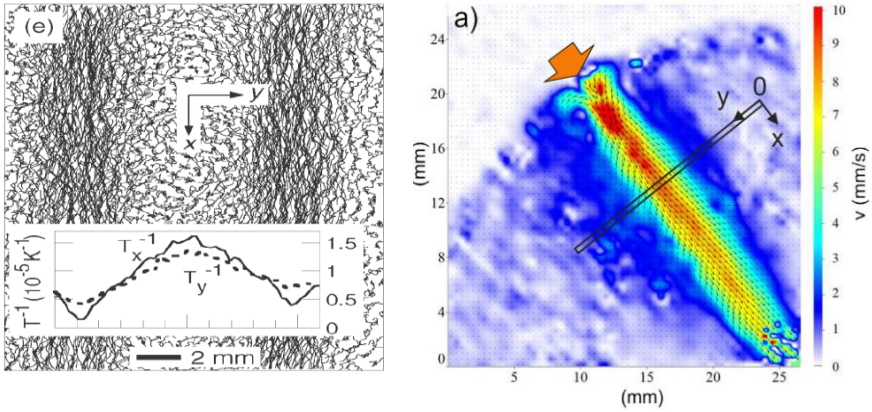

Figure 1. Left panel: the experiment conducted by V. Nosenko and J. Goree, [2] where the laminar flows are produced by using two counterpropagating laser beams. Right panel: the experiment conducted by C. M. Ticos, D. Ticos and J. D. Williams, [3] where the laminar flow is produced by using an electron beam.