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Experimental observation of cylindrical dust acoustic soliton in a strongly coupled dusty plasma

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A low frequency analog of ion-acoustic wave present in a dusty plasma is the dust acoustic wave which involves the dynamics of highly charged (~ 10^3 - 10^4 electronic charge) and massive (~ 10^{12} -10^{14} proton mass) dust grains (submicron to micron diameter). The existence of such low frequency mode in a dusty plasma was predicted by Rao *et. al* [1]and experimentally confirmed by Barkan *et al.* [2]. In the nonlinear regime, localized structure of dust acoustic perturbations similar to the case of ion acoustic solitons arises due to delicate balance between nonlinearity dispersion and described by the well-known Korteweg de Vries (KdV) equation [3-5]. In recent years the topic has been actively investigated considering the effects of dust charge fluctuation, strong coupling, size distribution etc. In laboratory, dust acoustic solitons are observed in few dusty plasma experiments [6-9]. Sharma *et al* have observed the head on collision between two dust acoustic solitons in a strongly coupled dusty plasma [10]. In two dimensional propagation, resonance interaction between two obliquely propagating planer dust acoustic solitons in a strongly coupled dusty plasma has also been reported [11]. Unlike head-on or overtaking collision, the oblique collision of solitons has a resonant state [12-13].

In this work, we present the observation of cylindrical dust acoustic soliton in a strongly coupled dusty plasma for the first time. The experiment is carried out in a glass cylinder and plasma is produced using RF (13.56 MHz, 10 W) discharge in argon at 0.1 -1 Pa [14]. Gold coated silica particles of 5 micron diameter are sprayed into the argon plasma using an electric buzzer. A large area (20 cm × 10 cm) uniform dusty plasma sheet with few layers levitating over (~ 1 cm above) the grounded base plate is produced. A green laser sheet (530 nm, 50 mW) is used to illuminate the dust layer for imaging. Typical values of measured dusty plasma parameters are: ion density ~ 10^8 cm^{-3}, electron temperature ~ 5-7 eV, dust density ~10^3 cm^{-3}, average dust charge ~10^4 e, screening length (ratio of inter-grain distance to Debye length) ~ 1-2 and Coulomb coupling parameter ~ 10-200. The ions and dust are considered to be at room temperature. The Coulomb coupling strength in the experimental device is easily controllable by varying the neutral pressure observing the transition from disorderly fluid at lower pressure to highly ordered crystalline state at relatively higher neutral pressure.

An ingoing dust density compression excited by a cylindrical exciter ring (6 cm in diameter) takes the form of cylindrical dust acoustic soliton which forms a sharp peak at the center and after collision emerges out as outgoing cylindrical dust acoustic soliton. A typical pixel intensity profile (which is proportional to the dust density perturbation) of the observed ingoing cylindrical dust acoustic soliton is shown in Fig. 1. In order to examine the oblique collision, two cylindrical outgoing dust acoustic solitons are excited from two smaller circular exciters (1cm in diameter). Video recordings of the dust density perturbations are converted into frames and pixel intensity profiles are obtained to calculate the wave parameters. We confirm that oblique collision of cylindrical dust acoustic soliton has a resonant state which does not occur in the case of head on or overtaking collision. Characteristics of the cylindrical dust acoustic soliton such as density perturbation, velocity and width are measured. Numerical simulation using fluid model is compared with the experimental results.

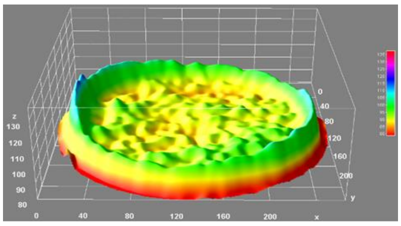

Fig. 1. A typical Pixel intensity profile of the cylindrical dust acoustic soliton emerging from the edge of 6 cm diameter cylindrical exciter.

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