Low perturbative observation of moderately coupled plasma using a probe laser induced fluorescence

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A radio frequency (RF) trap is a device which confines charged particles using oscillating quadrupole electric field. By applying the laser cooling method to the trapped ions, gas, liquid, and solid phase one-component plasmas are able to be generated under well controlled condition. We are studying the effect of inter-particle correlation on the screening mechanism of Coulomb potential. Debye screening is commonly accepted as a screening mechanism valid in weakly coupled plasma (WCP), on the other side, the ion sphere model is adopted in strongly coupled plasma (SCP). Since the screening mechanism affects many processes in plasma, it is interesting to clarify how these screening mechanisms change mutually at the intermediate region between SCP and WCP. Since the laser-cooled plasma is very fragile, we developed a low perturbative laser induced fluorescence (LIF) system using a weak probe laser for the detailed study of spectrum shape. The ion temperature and ion-ion collision frequency are derived from the LIF spectrum. The change of the screening mechanism in the plasma is able to be clarified from the temperature dependence of the collision frequency. In this paper, we report the spectrum measurements at the ion temperature of 0.01 K to 100 K. At the low temperature side, the collision frequency was proportional to $T^{1/2}$; the dependence implied the validity of the ion sphere model. On the other hand, at the higher temperature side (but still much lower than room temperature), the spectra were slightly deformed by the cooling and heating effect of the probe laser even though the laser power was decreased to about 5 $\mu$W. This is because the laser cooling efficiency is decreased in order to keep the ion temperature relatively high and in contrast the effect of the probe laser becomes considerable. Although the deformation is small, it affects critically the evaluation of the spectrum. We are improving the stability and tunability of the laser systems and a high frequency laser modulation system is introduced in order to minimize the probe laser power. The latest results taken by the improved system will be presented.