Mie scattering by a charged dielectric particle: proposal for a novel plasma probe

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We study the scattering of light by a negatively charged dielectric sphere. Depending on the electron affinity $\chi$ of the dielectric surplus electrons are trapped in the image states for $\chi < 0$ or the conduction band for $\chi > 0$. Their phonon-limited (surface) conductivity either modifies the boundary condition of the electromagnetic fields ($\chi < 0$) or the polarisability of the material ($\chi > 0$).

The effect of surplus electrons is most significant near an extinction resonance in the infrared which is tied to the transversal optical phonon mode of the dielectric. Surplus charges lead to a blue-shift of the resonance for micron and sub-micron-sized particles, and this effect becomes stronger the smaller the particle is (see Fig. 1).

Our results suggest to use the resonance shift as an optical measurement of the particle charge. While Mie scattering is routinely used as a particle size diagnostic, the particle charge has not yet been determined from the Mie signal. For dusty plasmas an optical measurement of it would be very attractive because established methods for measuring the particle charge require plasma parameters such as $T_e$ or $n_e$ that are not precisely known whereas Mie scattering does not. Moreover particles showing the effect could be used as minimally invasive electric probes with an optical read-out. Determining their charge from Mie scattering and the forces acting on them by conventional means would provide a way to extract plasma parameters locally.

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References