

In-situ Measurements of the Temperature Gradient in Complex Plasmas

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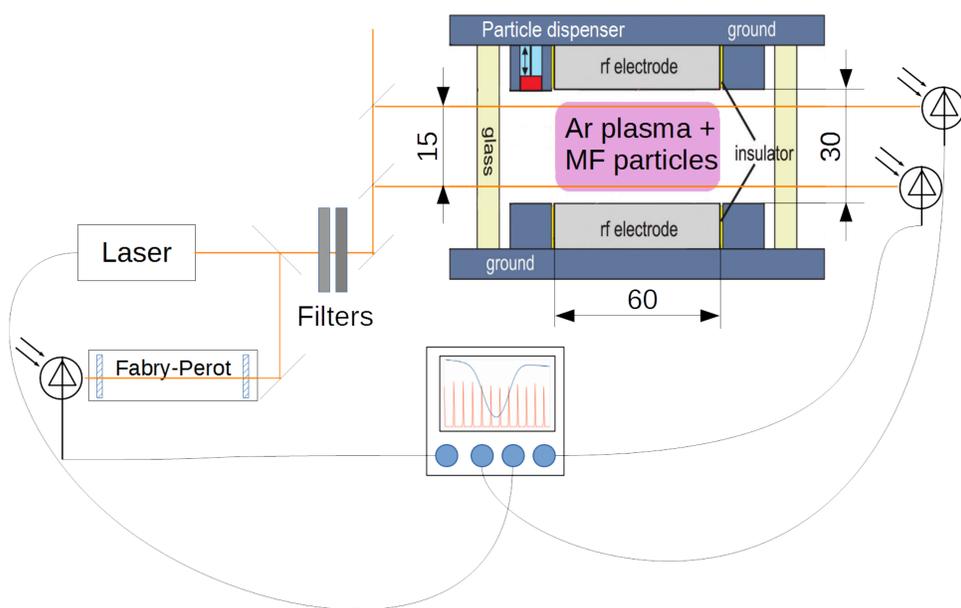
Introduction

Dusty or complex plasma contains electrons, ions, neutral gas, radiation and micrometer-sized solid particles. The particles are negatively charged up and can form strongly coupled suspensions. 3D dusty structures are disturbed by gravity in ground experiments, that's why microgravity experiments are so valued.

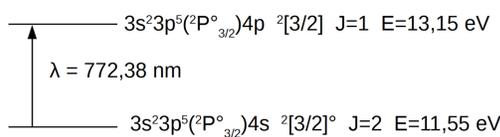
If there is a temperature gradient in a plasma, thermophoretic force acts on a microparticle. The force is proportional to the temperature gradient. Under microgravity conditions, the force can disturb the experimental environment. On the other hand, it can be used to compensate gravity in ground experiments. Also, the force can play a role in void formation.

Here, we present a method for in-situ measurements of temperature gradients based on laser absorption spectroscopy and investigate whether microparticle suspension affect the temperature gradients in a discharge.

The PK-3 Plus Setup



Absorption



$$I(\nu, x) = I(\nu, 0) e^{-k(\nu)x}$$

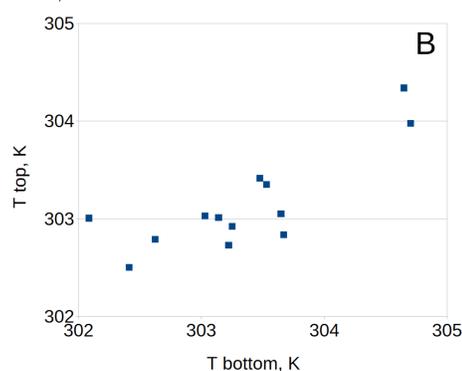
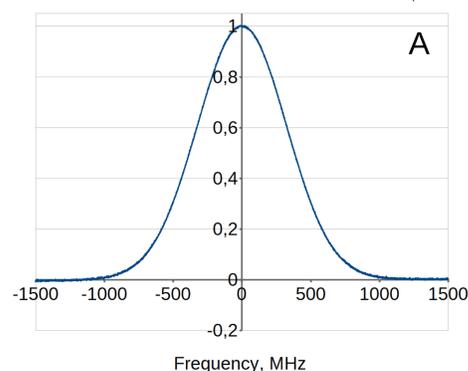
$$\int_0^\infty k(\nu) d\nu = h\nu_0 B_{i,k} \langle N_i \rangle$$

Doppler shape: $k(\nu) \sim \exp\left(-\frac{Mc^2(\nu - \nu_0)^2}{2kT\nu_0^2}\right)$

Every measurement includes:

- $I(\nu)$ — frequency dependent intensity of the laser beam passed through the plasma;
- $I_{\text{laser}}(\nu)$ — frequency dependent intensity of the laser beam passed through the chamber without the discharge;
- I_{plasma} — plasma emission intensity;
- I_{dark} — dark signals of the photosensors.

Absorption profile: $k(\nu) \sim -\ln\left(\frac{I - I_{\text{plasma}}}{I_{\text{laser}} - I_{\text{dark}}}\right)$

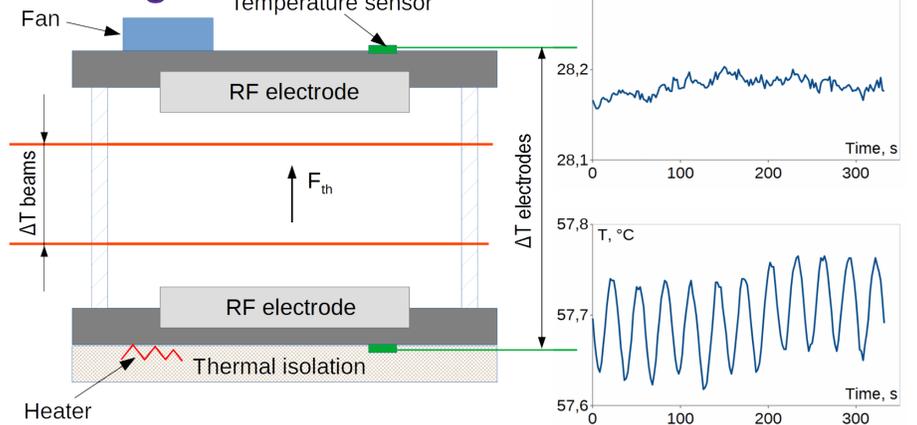


Results example:

A — Normalized absorption profile fitted with a Doppler profile

B — Temperatures, measured without heating

Heating

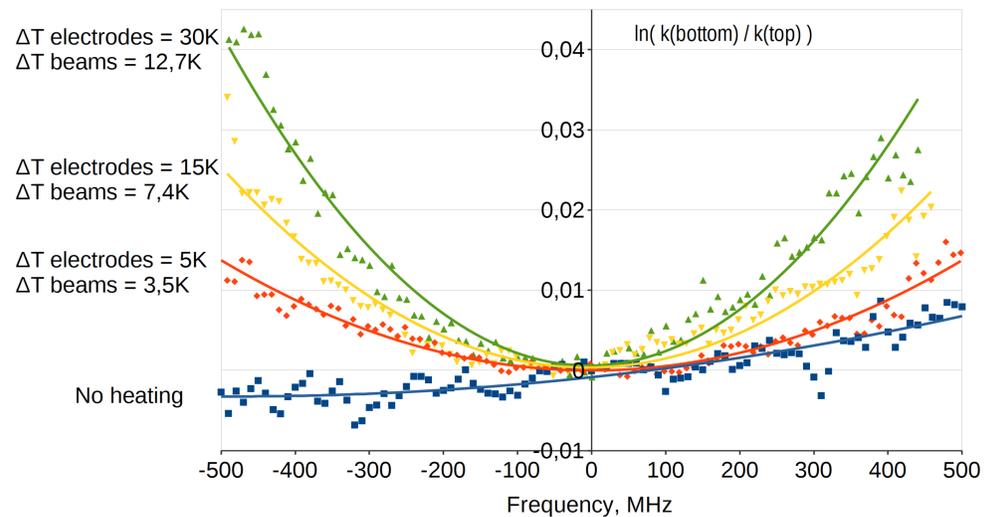


Temperature control in the PK3-Plus chamber

How to find the temperature difference between the beams?

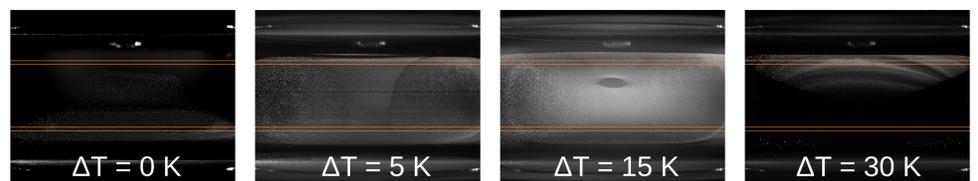
1. Find the temperatures separately and subtract one from another
2. Find the difference from the profiles ratio:

$$\ln\left(\frac{k_1(\nu)}{k_2(\nu)}\right) = -a \frac{T_2 - T_1}{T_1 T_2} (\nu - \nu_0)^2 + const$$

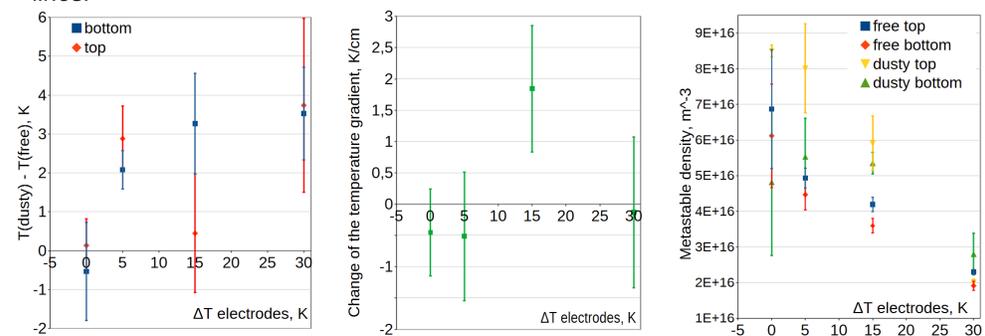


Examples of the profiles ratios.

Influence of the dusty structures



Shapes of the microparticle suspension. Pressure = 0,38 mbar; power = 400 mW; particles — MF Ø 1.95 µm. The beams positions are marked with orange horizontal lines.



Dust influence on the temperature, temperature gradient, and metastables density

Summary

- We developed a technique to measure temperature gradients in a discharge chamber with the tunable diode laser absorption spectroscopy.
- Microparticle suspensions influence local gas temperatures if the bottom electrode is heated. Physical mechanism of this effect needs further investigation.
- If the suspension occupies whole discharge volume, it increases the metastable densities for both beams, in other case, the density decreases inside the suspension and increases outside.