NPP 2024

NON-IDEAL PLASMA PHYSICS

DUSTY PLASMA IN AN INDUCTIV RF DISCHARGE

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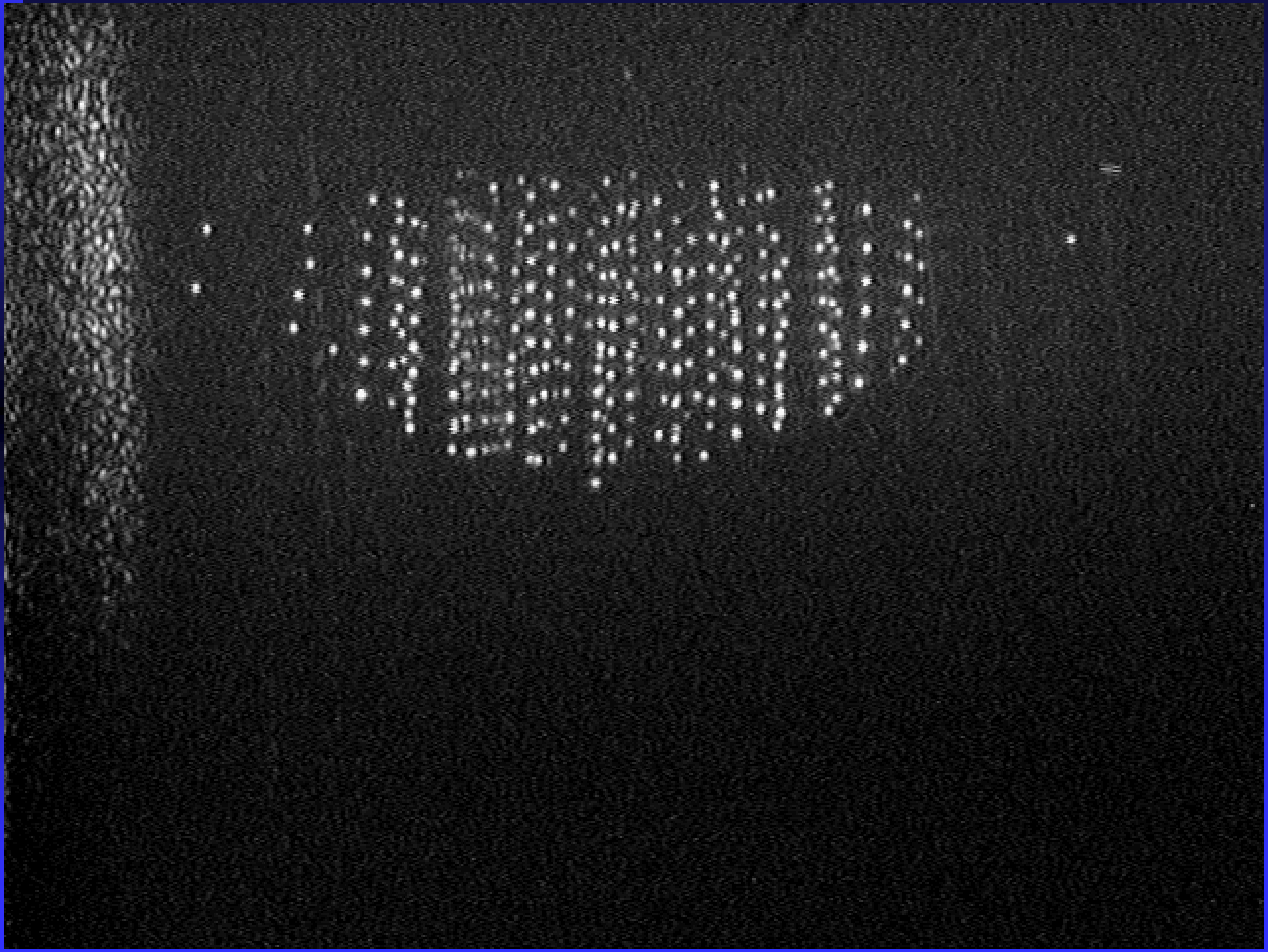
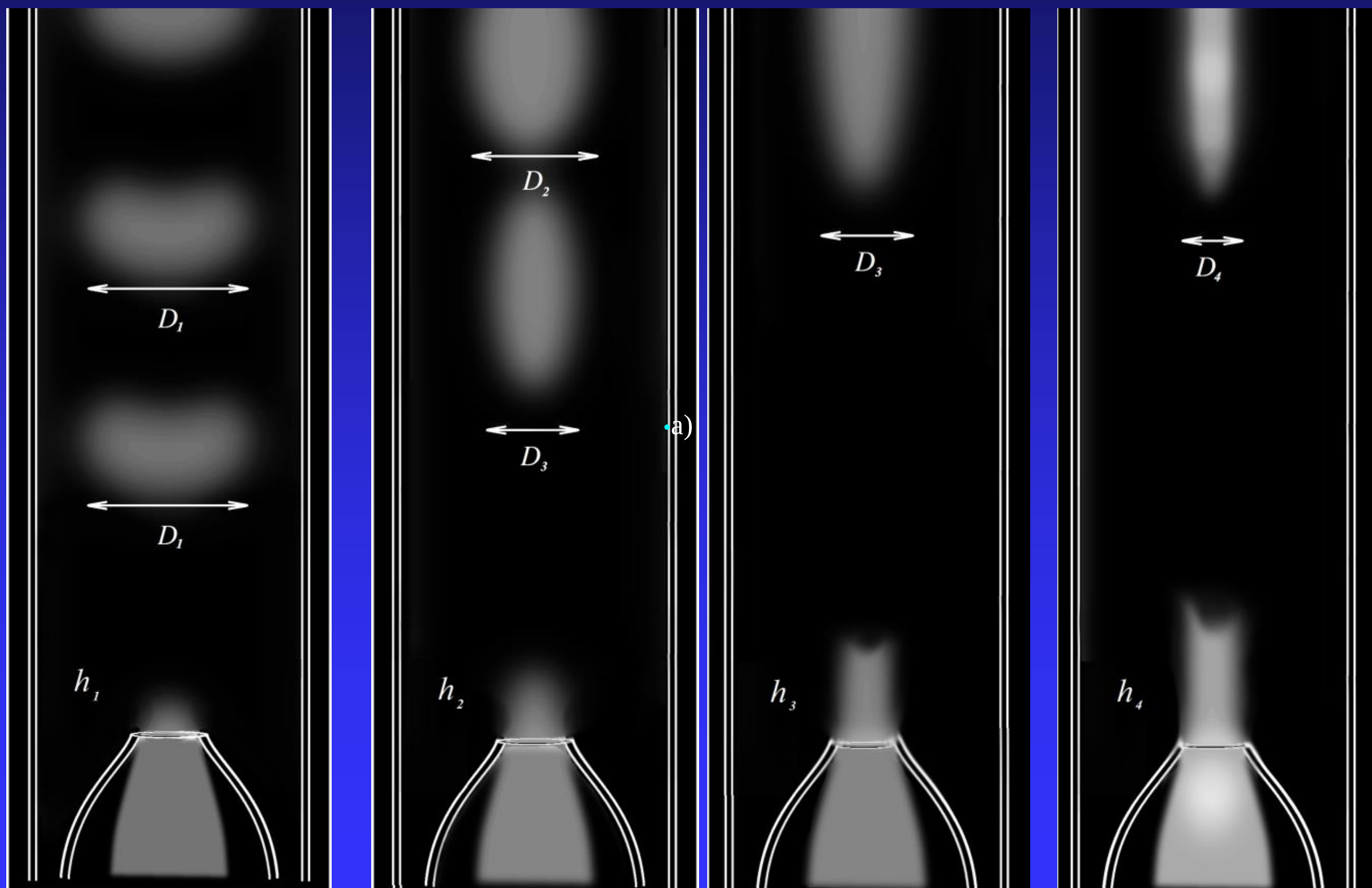
outline

- Motivation. Volumetric dust structures in a magnetic field, trap instability
- Levitation of dust particles in an RF discharge. Particle selection in VFI.
- Dependence of structure formation on the radius of the discharge tube.
- About double structures in RFI.
- Dust structure in an RF discharge in a weak magnetic field.
- Parameters achieved in the experiment in a magnetic field. Features of rotation in neon, argon, helium.

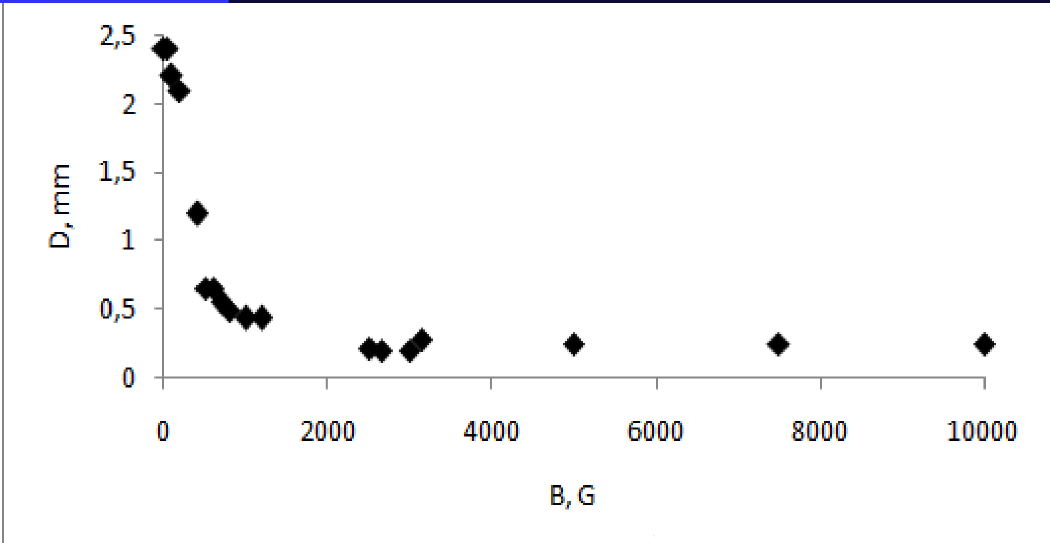
Dusty plasma rotation in dc discharge



Schematic representation of the discharge at different magnetic fields. a) 0 G, b) 10^3 G, c) $5*10^3$ G, d) $2*10^4$ G.



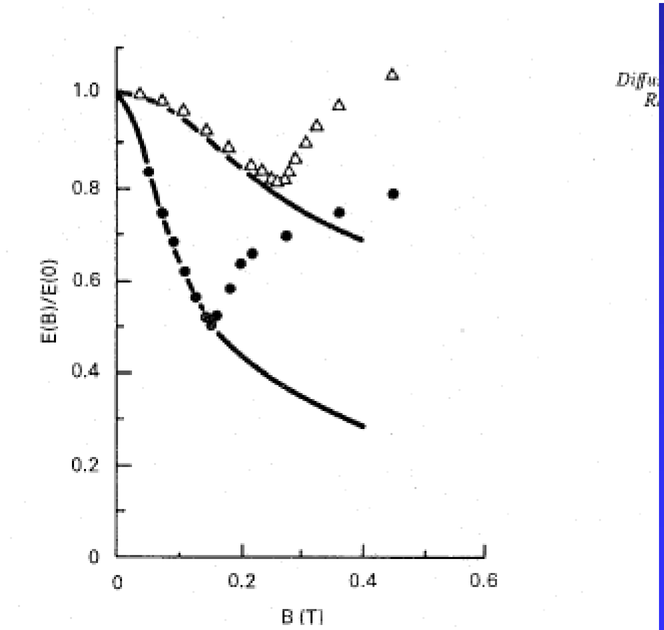
Discharge instability. Tilt of strata. Radial size



$$\omega_e \tau_e \omega_i \tau_i = 1$$

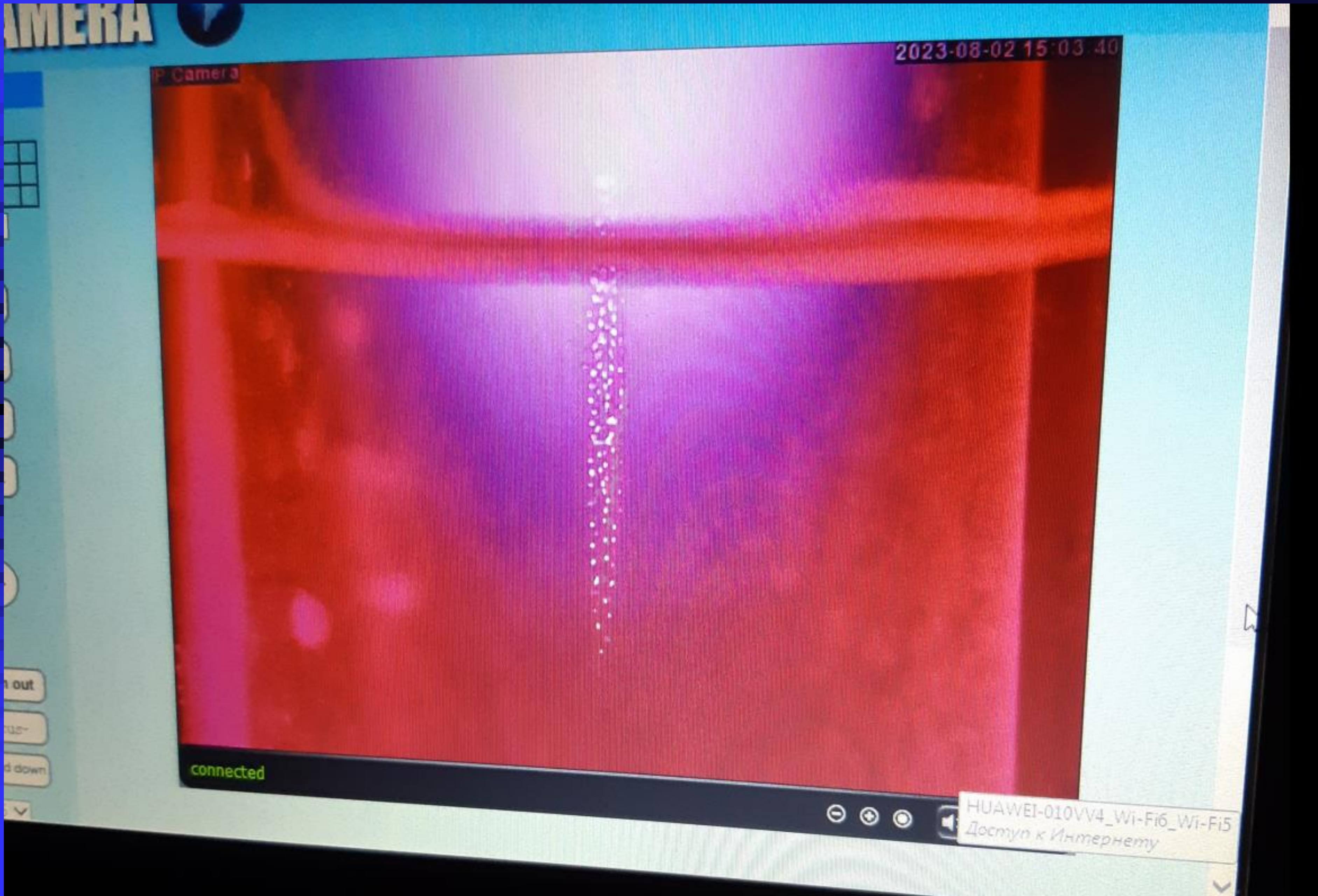
$$D_{am\perp} = \frac{D_{am}}{1 + \omega_e \tau_e \omega_i \tau_i}$$

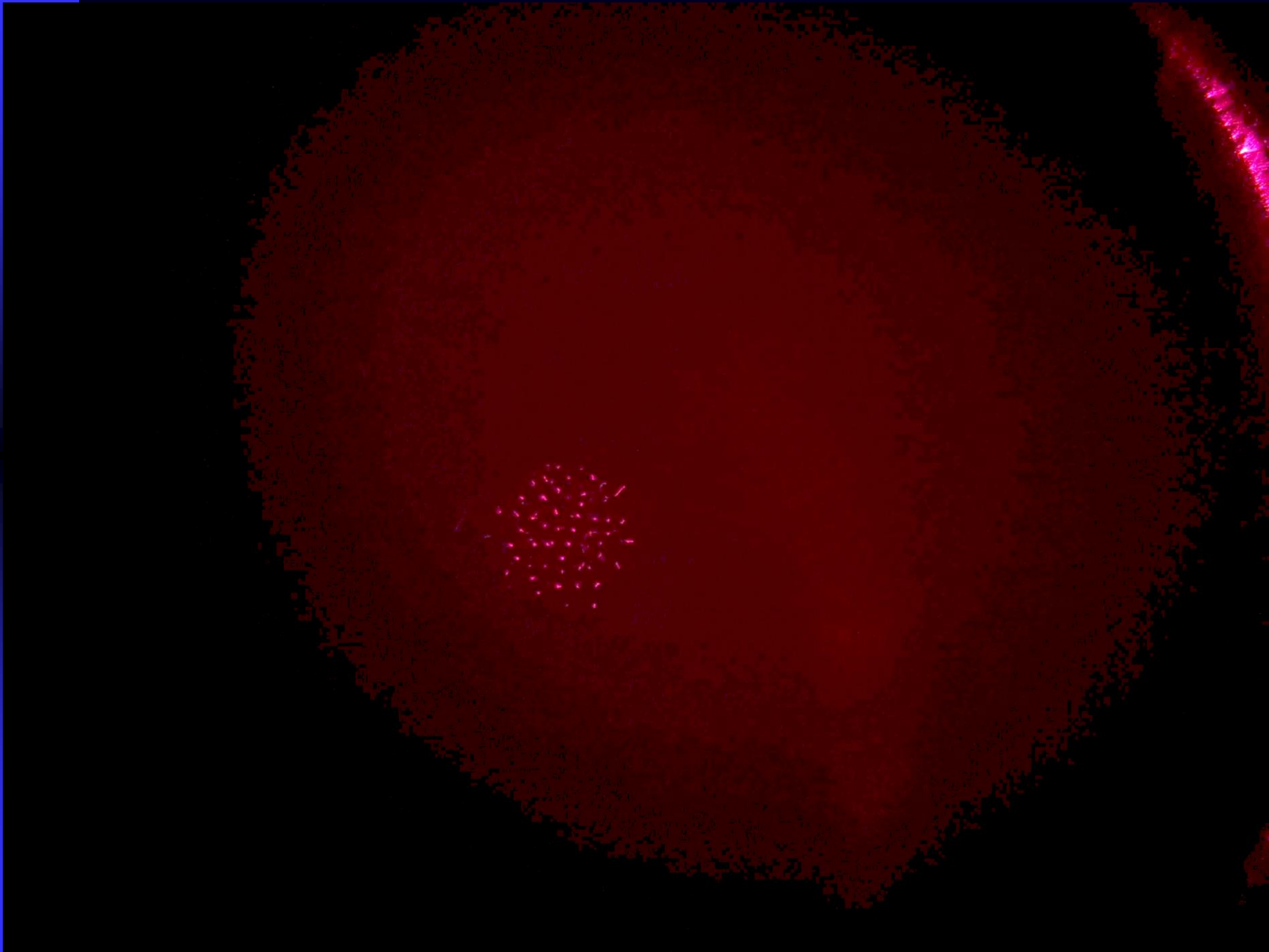
$$E_{am} = -\frac{kT_e - kT_i(\omega_e \tau_e \omega_i \tau_i)}{e(1 + \omega_e \tau_e \omega_i \tau_i)} \frac{\nabla n}{n}$$



The normalized longitudinal electric field measured as a function of *B* at two different pressures. Theoretical curves are shown for comparison. [From F. C. Hoh and B. Lehnert, *Phys. Fluids* 3, 600 (1960).] FIGURE 5-15

RFI discharge





Particle selection

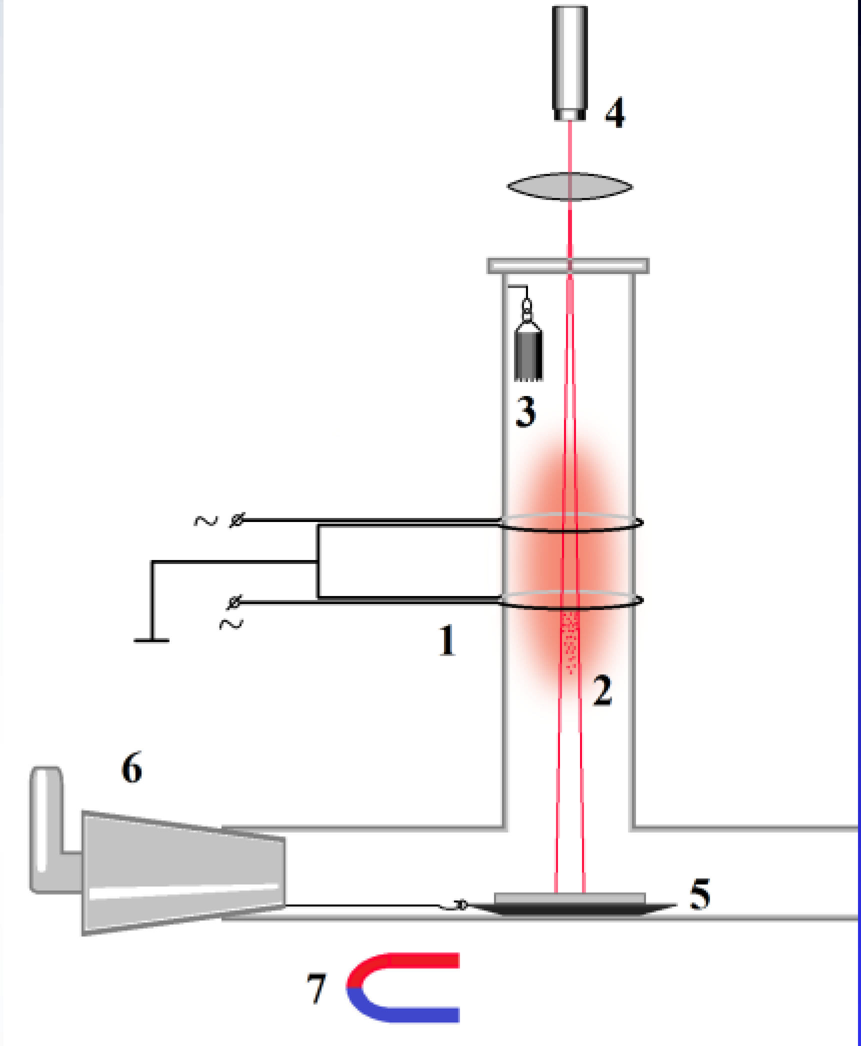


Рис. 1. 1 – индуктор; 2 – пылевая структура; 3 – контейнер для инжекции пылевых частиц в разряд; 4 – система подсветки; 5 – каретка с лежащим на ней предметным стеклом для сбора частиц; 6 – вакуумный кран для извлечения каретки; 7 – магнит для передвижения каретки внутри трубки.

Extracted particles, characteristic size distribution

Рис. 3. Фото осаждённой из ВЧИ разряда пыли. Размер частиц около 4 мкм. Ширина изображения —

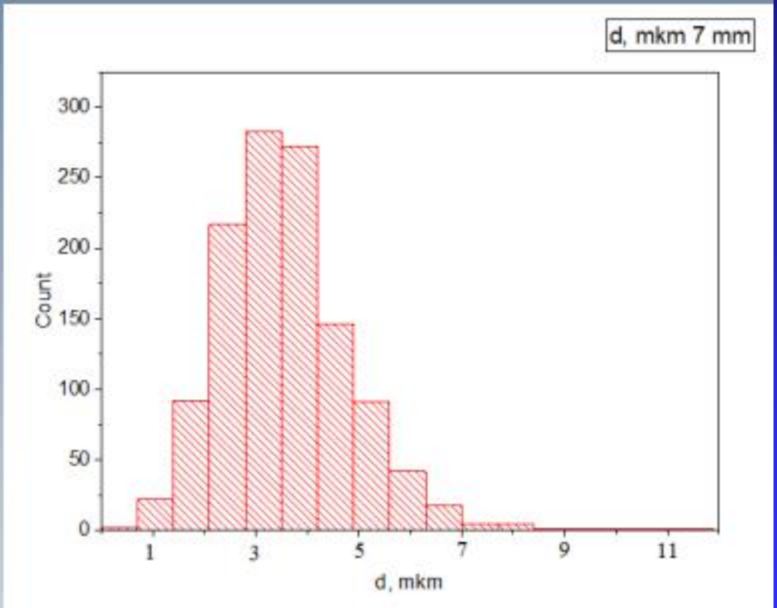
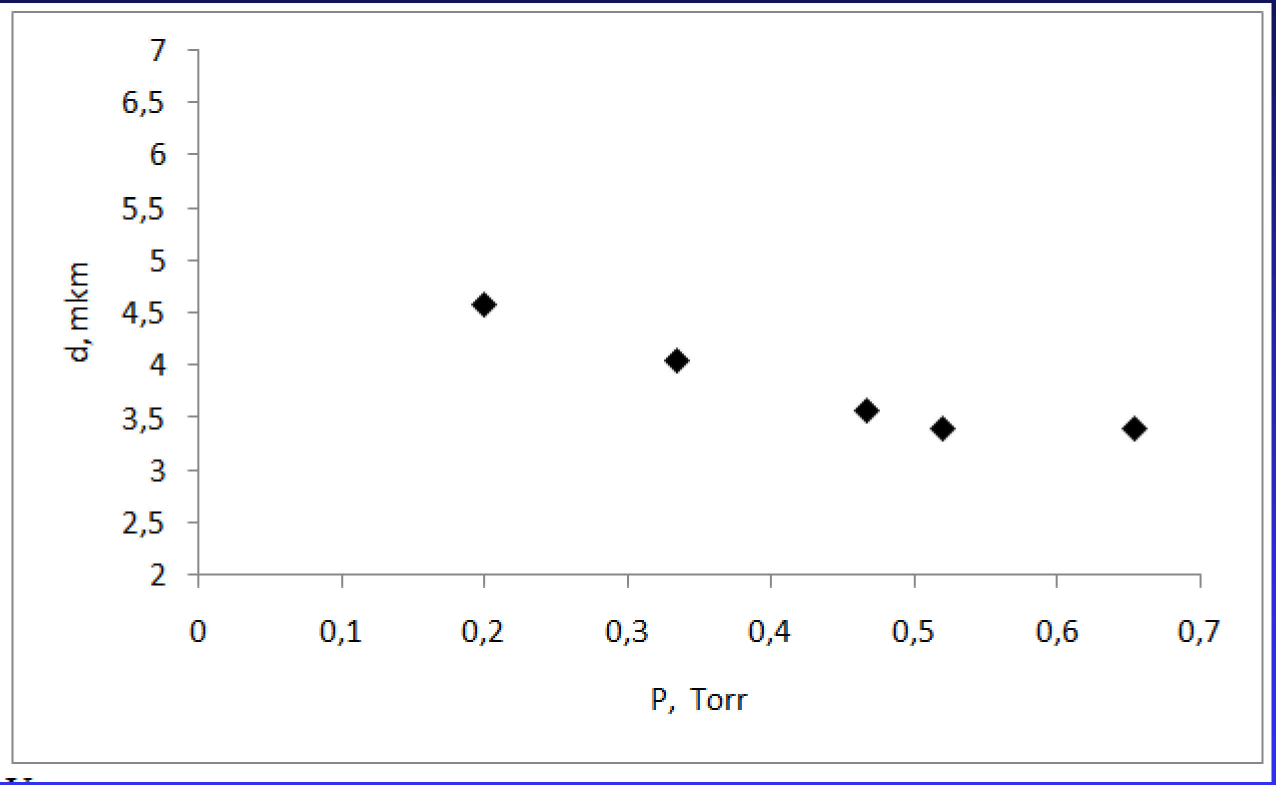


Рис. 4. Гистограмма распределения пылевых частиц по характерному размеру. Условия: Ne 0.5 Торр, 100 В, 42МГц,

Dependence of particle size on pressure



Продольное межчастичное расстоянине

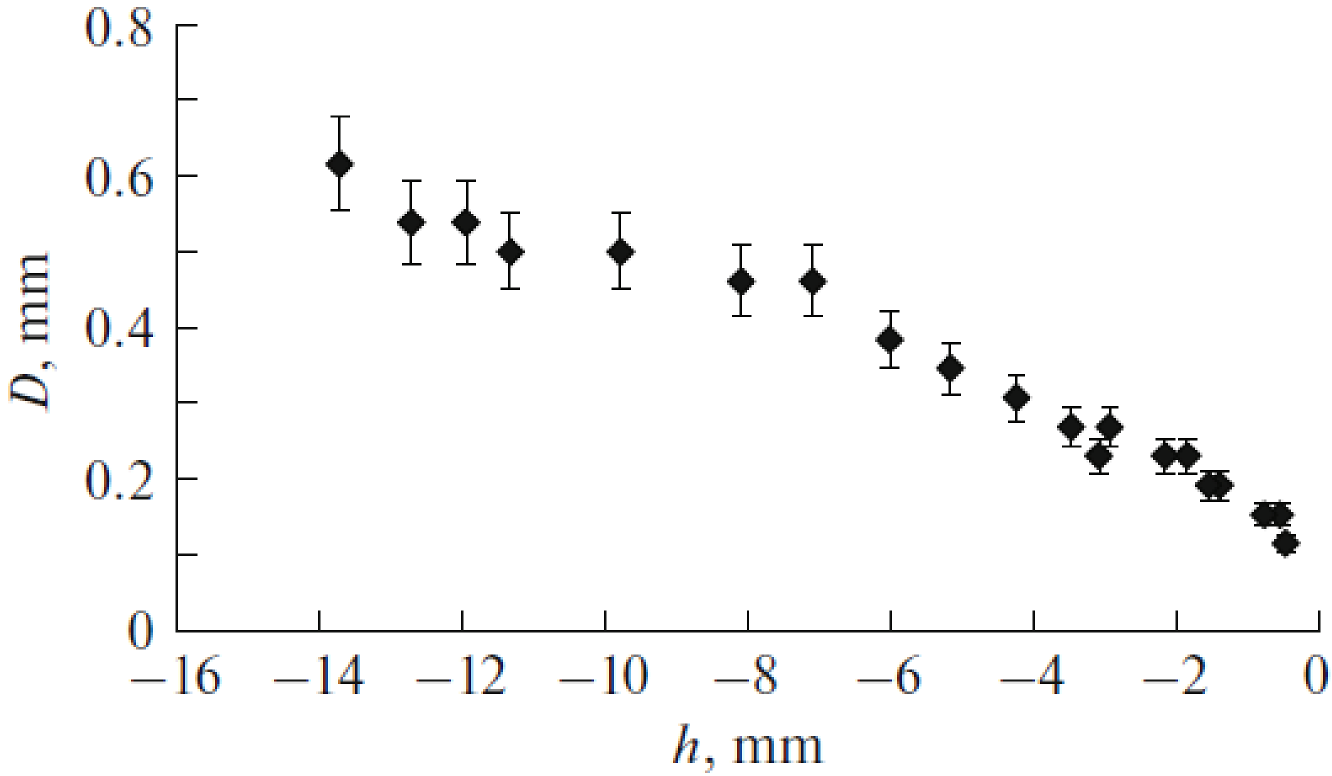


Fig. 5. Longitudinal interparticle distance as a function of

Balance

$q_d E_{\parallel} = mg + F_{id} + F_{th}$

$mg = (4/3)\, a^3 \rho g.$ $mg = 0.8$ пН.

$q_d E_{\parallel} = Z_d e E_{\parallel}$ $q_d E_{\parallel} = 1{,}3$ пН.

$$F_{id} = \frac{8\sqrt{2\pi}}{3} a^2 n_i m_i V_{T_i} V \left\{1 + \frac{z\tau}{2} + \frac{z^2\tau^2}{4}\Pi\right\}$$

0,45 пН.

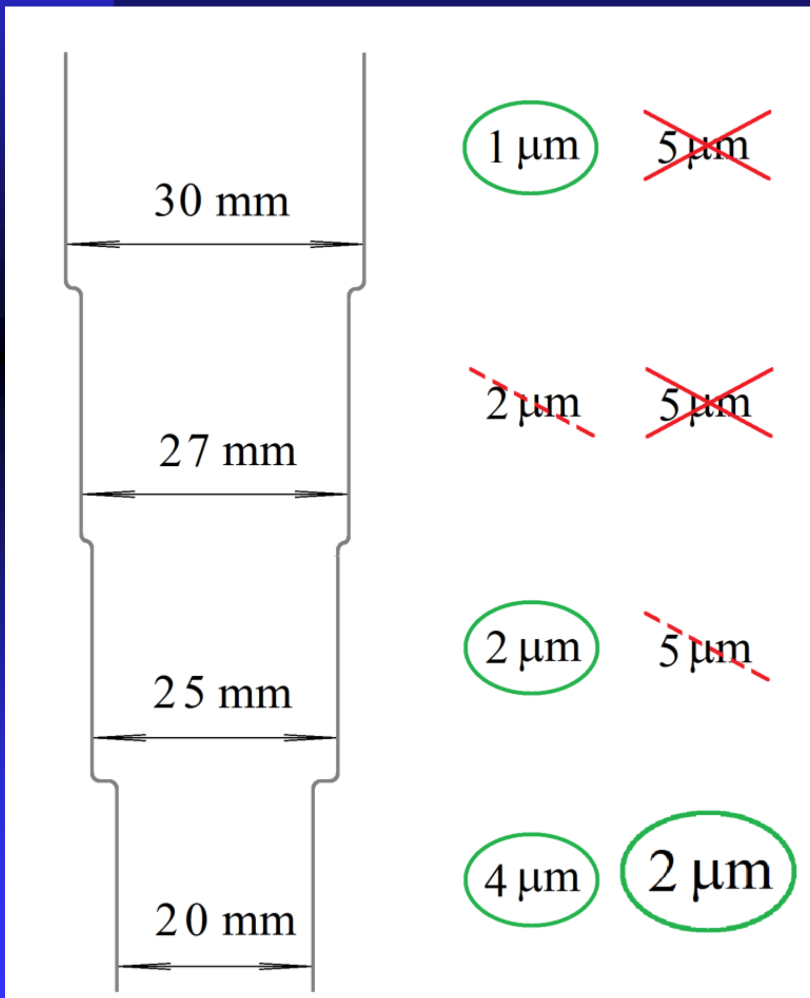
F_{th}. 0,1 пН

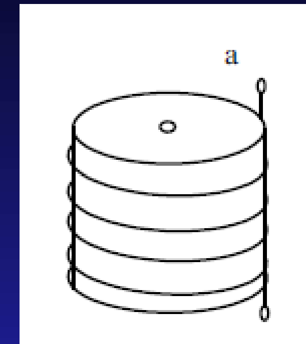
$n_e = 10^8$ см$^{-3}$, $T_e = 3{,}4$ эВ, $E_{\parallel} = 8$ В/см. Ne

$t = T_e/T_i$, $t = 3{,}4/0{,}03 \sim 10^2$ $a = 2$ мкм. 0.3 Торр

Narrow and wide tubes. Levitation of particles of different sizes

$$\delta = \frac{c}{\omega \varkappa} = \frac{c}{\sqrt{2\pi\sigma\omega}} = \frac{5{,}03}{\{\sigma\,[\text{Ом}^{-1}\cdot\text{см}^{-1}]\; f\,[\text{МГц}]\}^{1/2}}\ \text{см}.$$

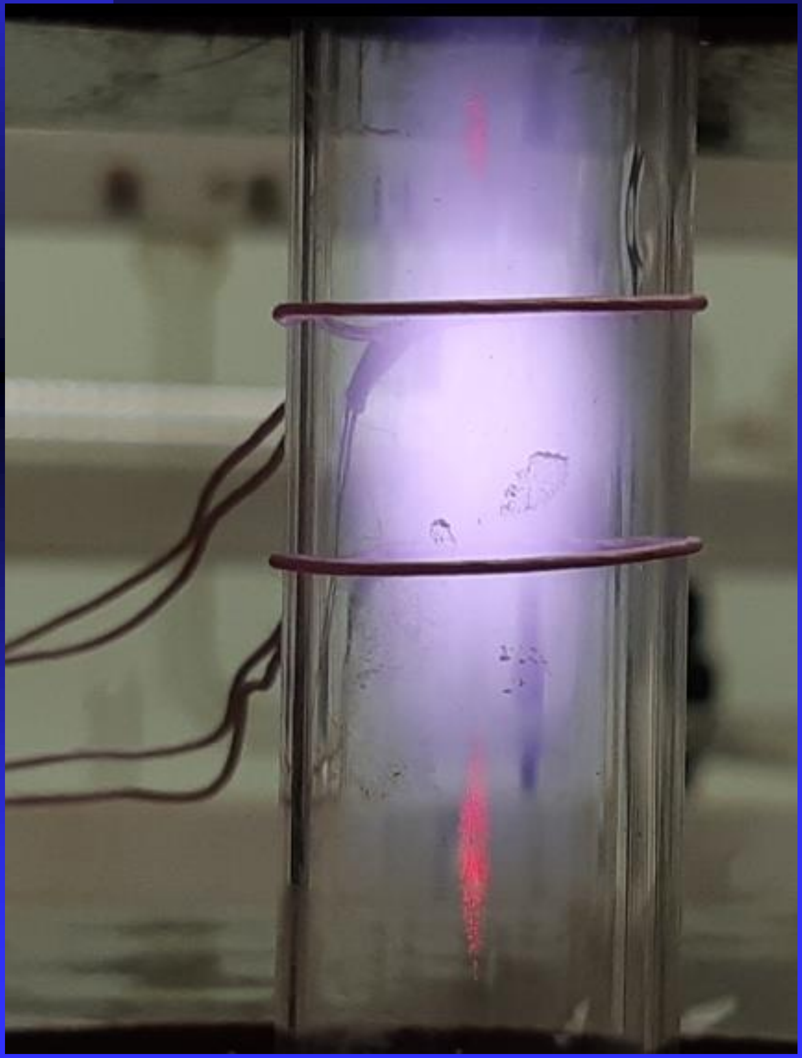


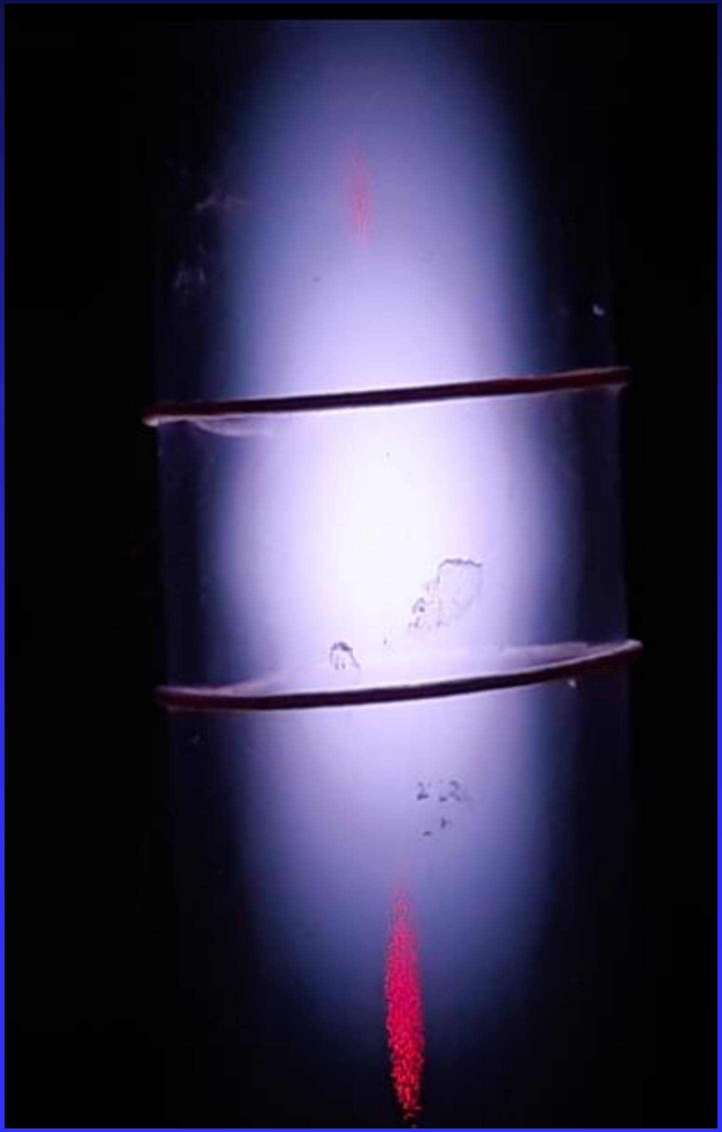


$$eEl_e = kT_e$$

$$l_e = 1\ \text{cm}$$

Two structures in a long tube





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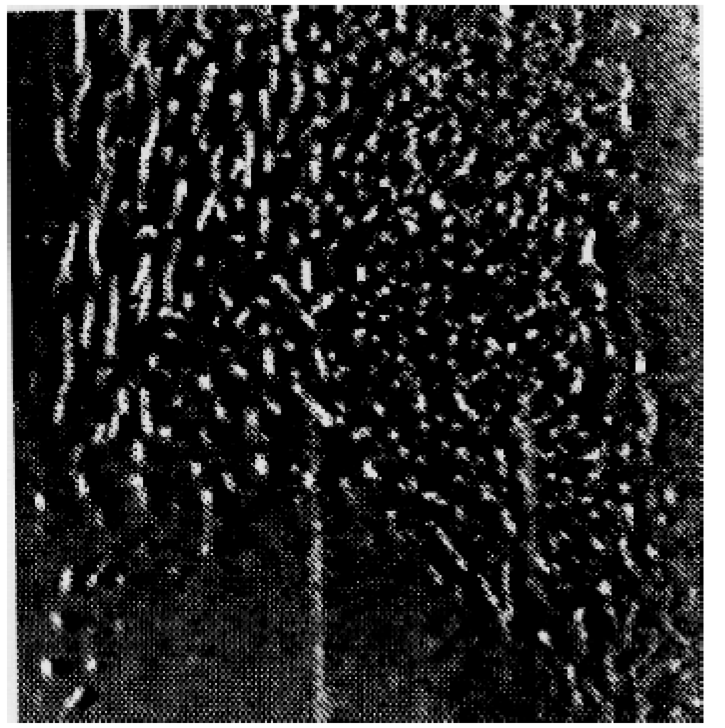
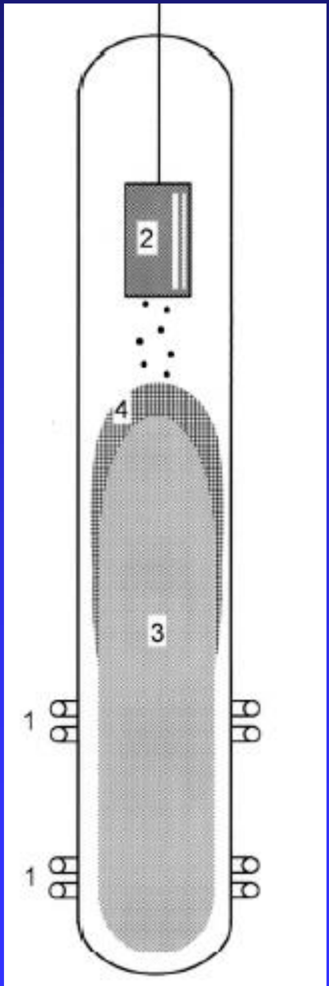
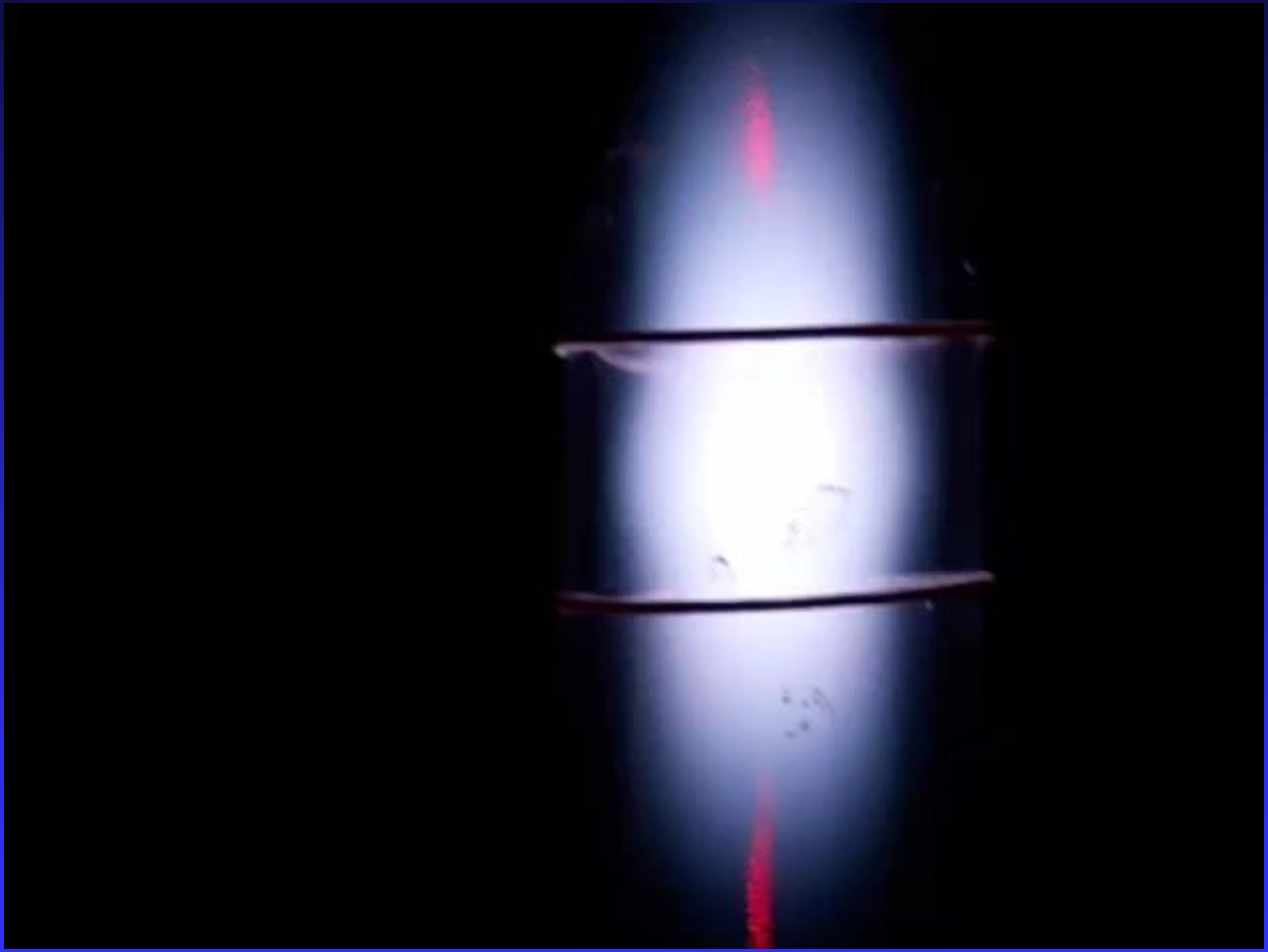
Ю.В. Герасимов, А.П. Нефедов, В.А. Синельщиков...

Письма в ЖТФ, 1998, том 24, № 19

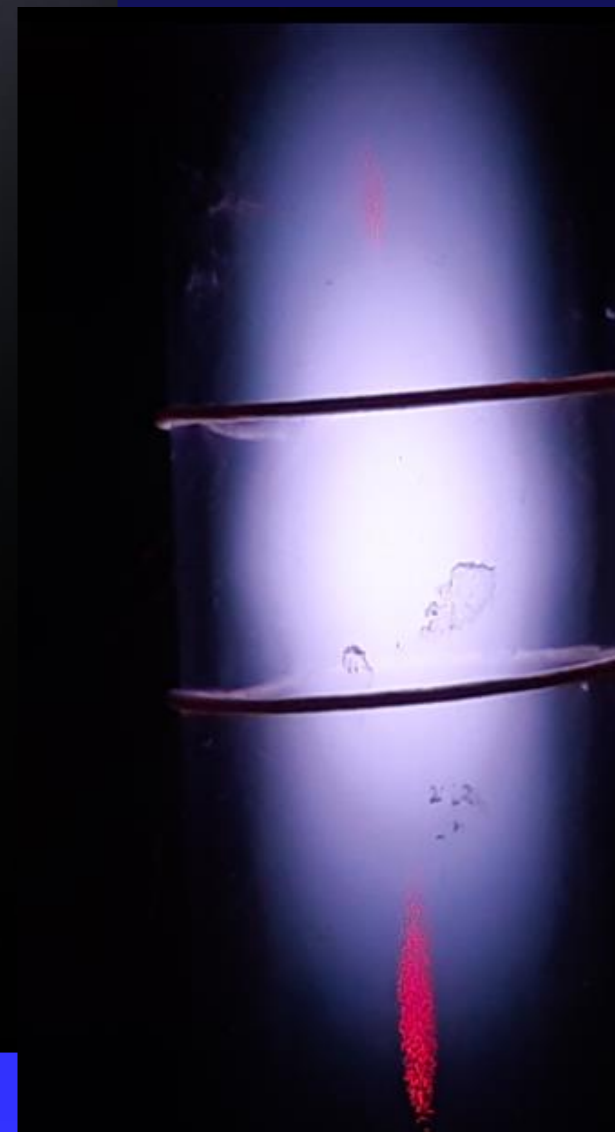






$$F_g + F_q = F_{wind}$$

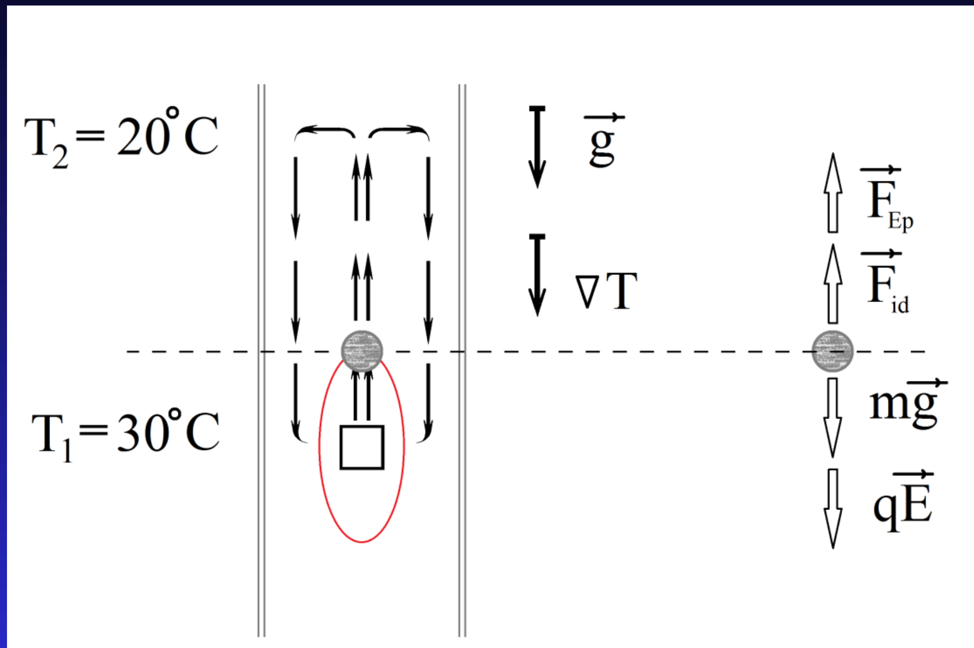
$$F_g + F_{wind} = F_q$$



Interpretation of levitation of the upper structure

- ion drag?
- thermal confinement, convection?

- thermal confinement, convection?



a=1 mkm, F ~10^{-13} N

F_{id}= 0.8

F_{Ep}= 1.0 ???

mg=1.0

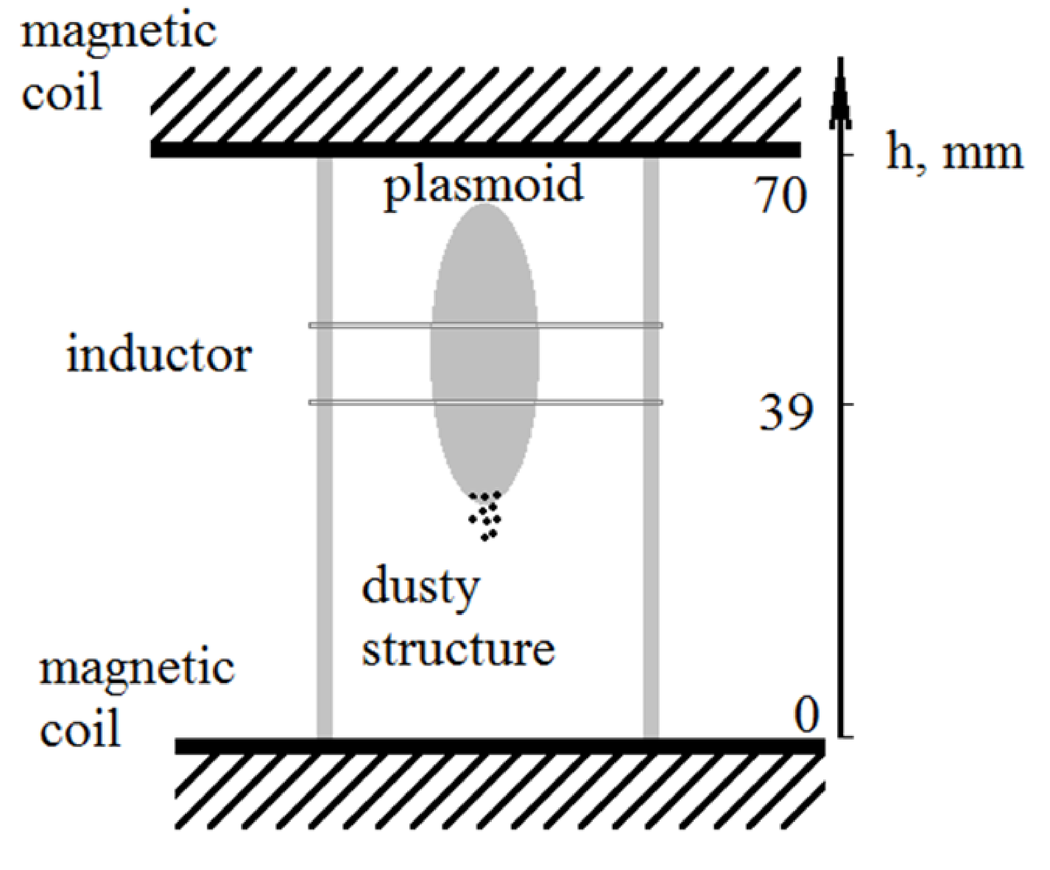
qE=0.6

$$n_1 T_1 = n_2 T_2$$

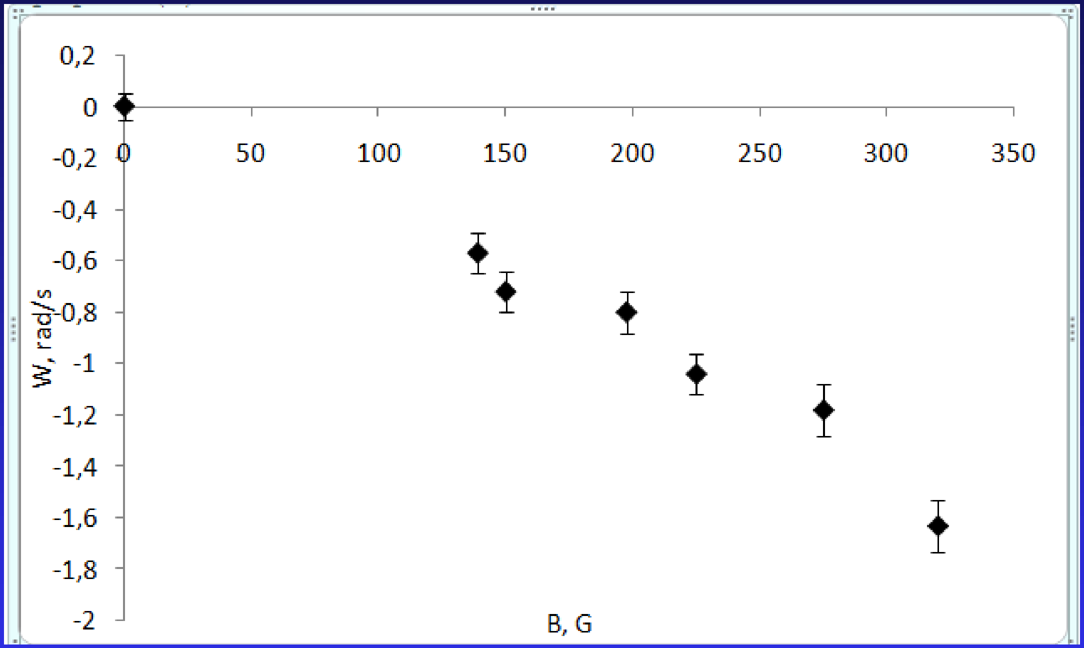
$$F^{\uparrow} = \Delta\rho g V \qquad F^{\uparrow} = 0.03\ mg$$

$$v = a^{\uparrow} t = 0.3\ m/c \qquad F_n = \frac{8\sqrt{2\pi}}{3} a^2 p \frac{v}{v_{Tn}}$$

Magnetic field



Rotation velocity in a magnetic field



$$\omega = \frac{n_i m_i \upsilon_{Tn} (\omega_i \tau_i) U_{ir} \upsilon_{Ti} \left\{ 1 + \frac{z\tau}{2} + \frac{z^2 \tau^2}{4} \Pi \right\}}{\xi p r_d}$$

Comparison of the dynamics of dust structures in a magnetic field

RF capacitive discharge

Strata

Trap in a narrow current channel

RF induction discharge

Thank you for attention!

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- St. Petersburg. Russia