Status of the PK-4 project

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Knowledge for Tomorrow

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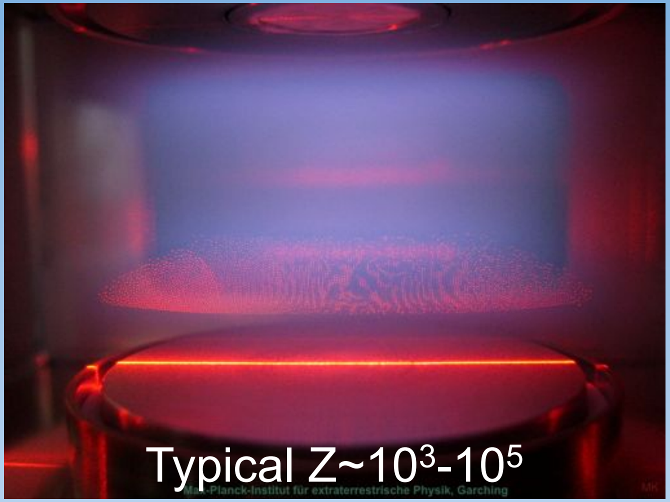
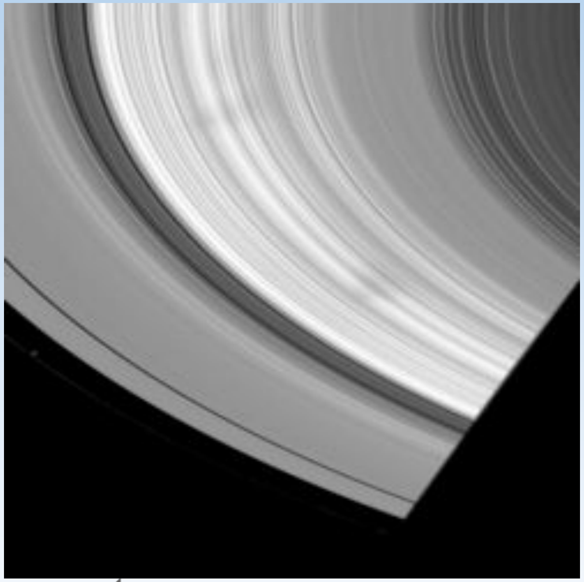
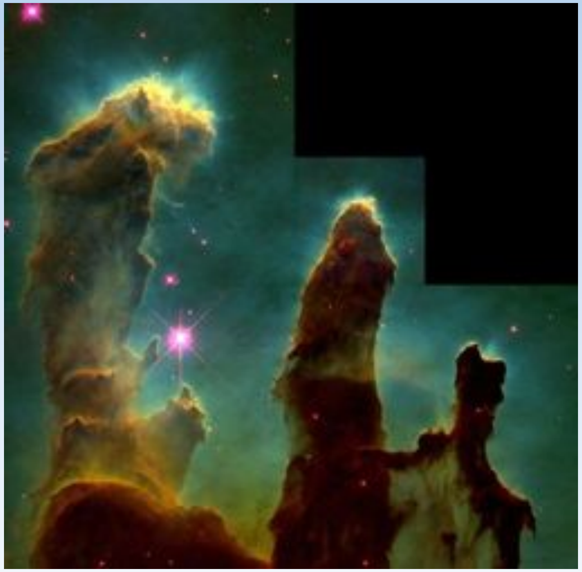
Introduction

Dusty plasmas

Dusty plasma — quasineutral medium, containing electrons, ions, neutral molecules, radiation and dust → Dust unavoidably gets charged.



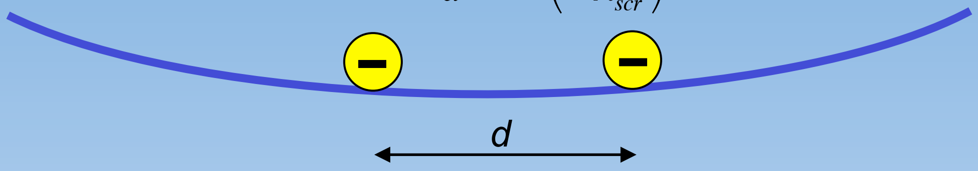




Justification of complex plasmas

φ_{conf}

$$\varphi_{\text{int}} = \frac{Ze}{d^2}\exp\left(-\frac{d}{\lambda_{scr}}\right)$$



Coupling parameter

$$\Gamma = \frac{Z^2e^2}{Td^2}\exp\left(-\frac{d}{\lambda_{scr}}\right) >> 1$$

Generic condensed matter physics
can be potentially modeled!

Stretched space- and timescales

$$d \sim \lambda_{scr} \sim 0.1\, mm$$

$$\omega \sim 1 - 100\ Hz \propto \sqrt{\frac{Ze}{M}}$$

Very easy to observe!

Complex plasmas – dusty plasmas designed for the modeling of generic condensed matter phenomena

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Dusty and complex plasmas

Dusty plasma research

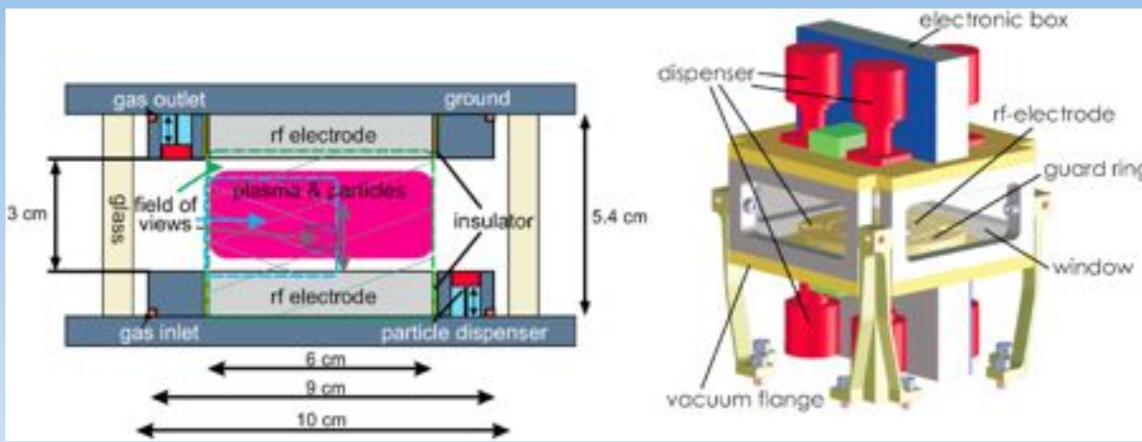
Technological applications

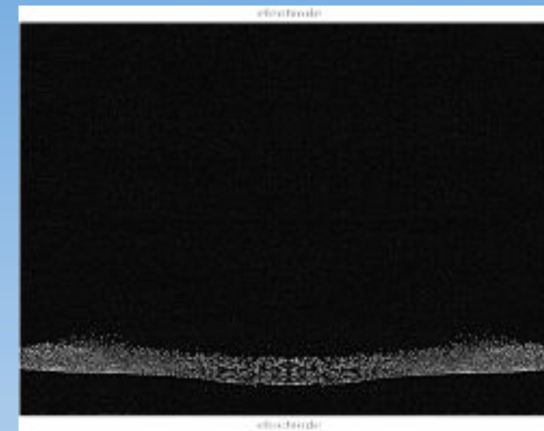
New plasma physics (dusty plasma)

Interdisciplinary (complex plasma): modelling of condensed matter at a kinetic level

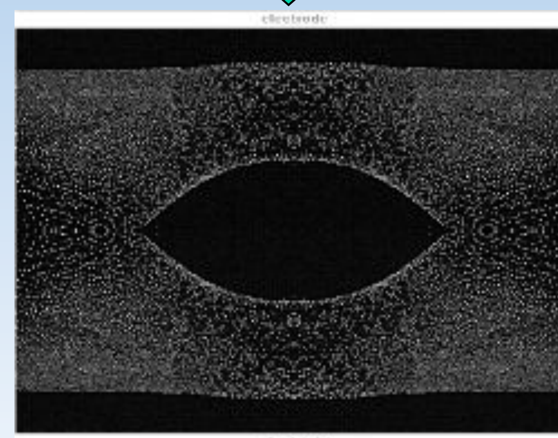
Need for microgravity

PK3-plus





Laboratory



μ-g

PK-4

Instrumental publication

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Plasmakristall-4: New complex (dusty) plasma laboratory on board the International Space Station

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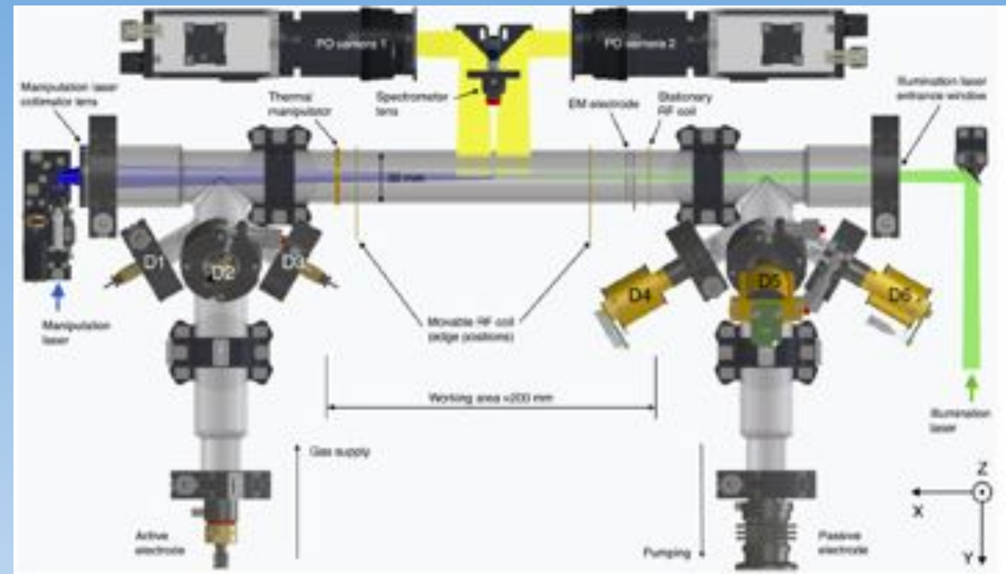
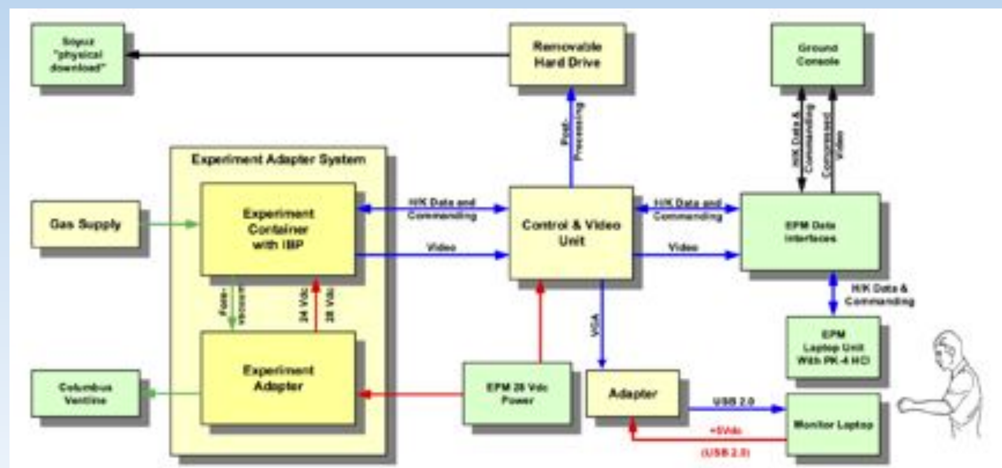
New complex-plasma facility, Plasmakristall-4 (PK-4), has been recently commissioned on board the International Space Station. In complex plasmas, the subsystem of μm-sized microparticles immersed in low-pressure weakly ionized gas-discharge plasmas becomes strongly coupled due to the high (10^3–10^4 e) electric charge on the microparticle surface. The microparticle subsystem of complex plasmas is available for the observation at the kinetic level, which makes complex plasmas appropriate for particle-resolved modeling of classical condensed matter phenomena. The main purpose of PK-4 is the investigation of flowing complex plasmas. To generate plasma, PK-4 makes use of a classical dc discharge in a glass tube, whose polarity can be switched with the frequency of the order of 100 Hz. This frequency is high enough not to be felt by the relatively heavy microparticles. The duty cycle of the polarity switching can be also varied allowing to vary the drift velocity of the microparticles and (when necessary) to trap them. The facility is equipped with two videocameras and illumination laser for the microparticle imaging, kaleidoscopic plasma glow observation system and minispectrometer for plasma diagnostics and various microparticle manipulation devices (e.g., powerful manipulation laser). Scientific experiments are programmed in the form of scripts written with the help of specially developed C scripting language libraries. PK-4 is mainly operated from the ground (control center CADMOS in Toulouse, France) with the support of the space station crew. Data recorded during the experiments are later on delivered to the ground on the removable hard disk drives and distributed to participating scientists for the detailed analysis. *Published by AIP Publishing.* [http://dx.doi.org/10.1063/1.4962696]

Everything you need to know about PK-4: scientific hardware, system considerations, operations

Open access!





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Hardware

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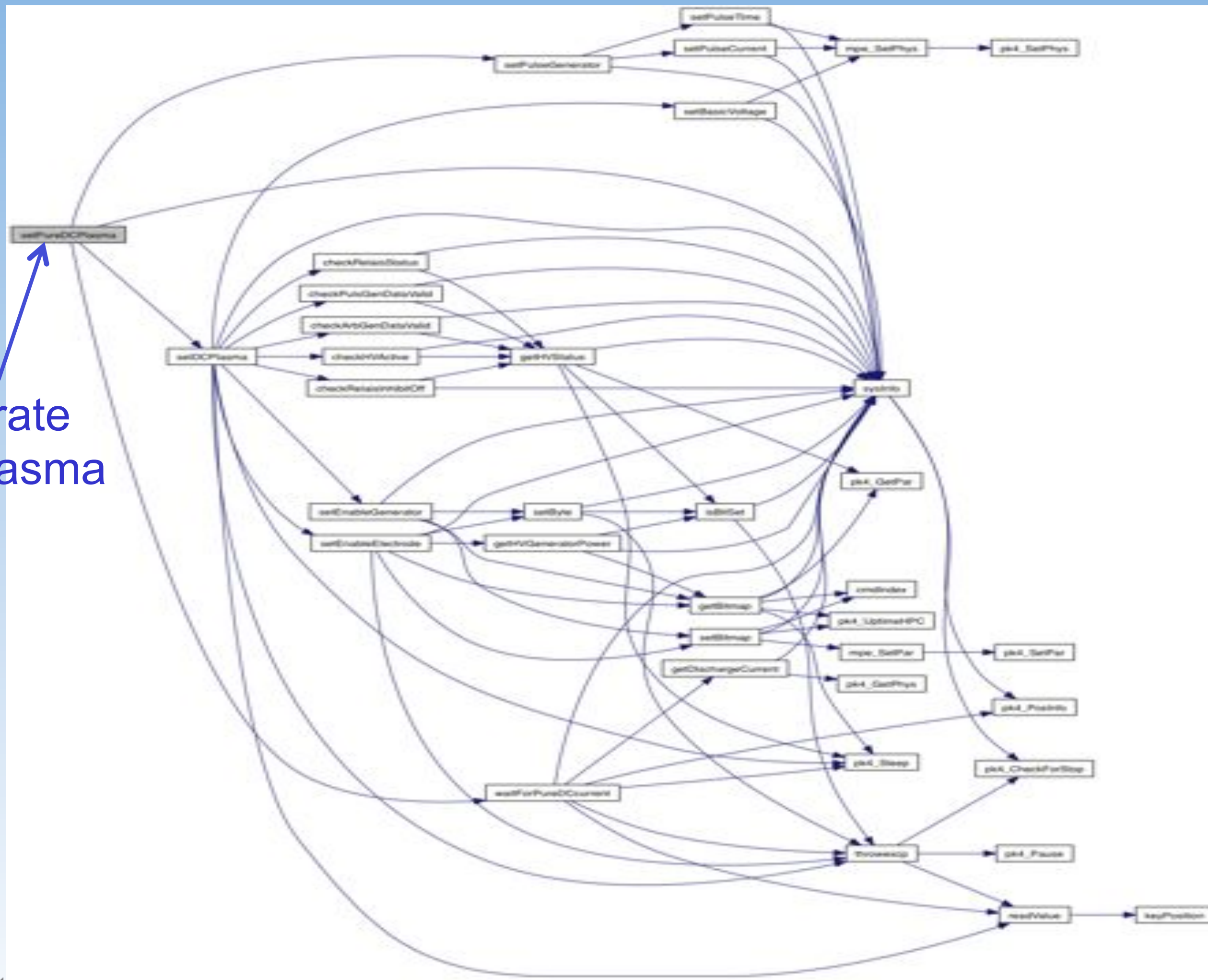
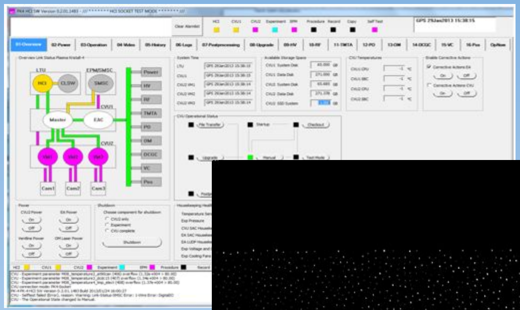
Automatization: PK-4 CSL-based programming language

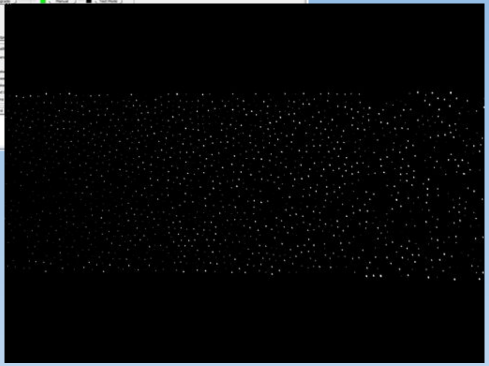
About 400 physical commands

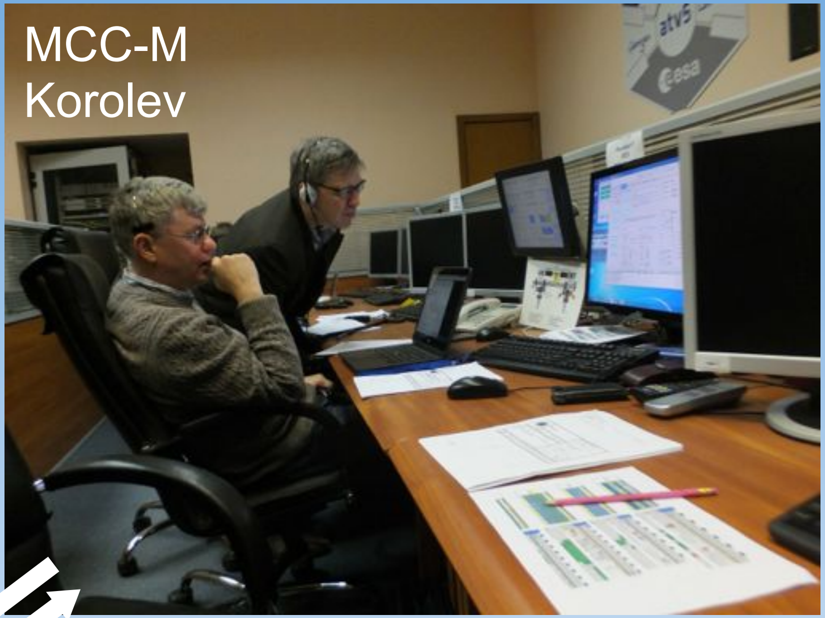


Generate
DC plasma

Operations





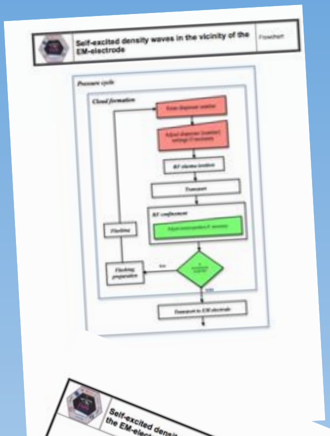


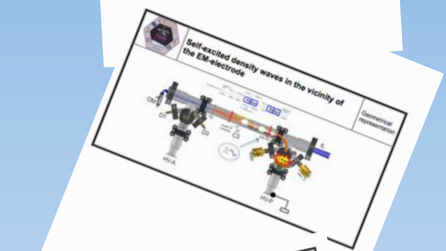
Data retrieval

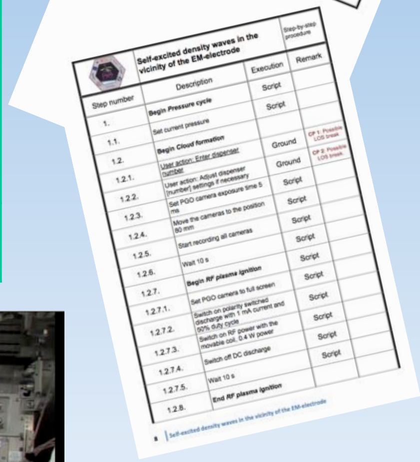
3 TB per mission!!!

History and outlook

Launch	Oct. 29, 2014
Installation (talk by A. Samokutyaev)	Nov. 27-28, 2014
Commissioning (first scientific operation)	Jun. 1-6, 2015
Campaign 01: • Charge and ion drag	Oct 25-30, 2015
Campaign 02: • Dust-acoustic waves	Jun. 12-17, 2016
Campaign 03: • Charge and ion drag • Shear flow • String fluid	Oct. 9-14, 2016
Campaign 04 (in preparation)	Feb. 12-17, 2017







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International collaborations

Scientific collaborations

Core team: immediate access to all data and 50% experiment time

ОБЪЕДИНЕННЫЙ ИВТАН

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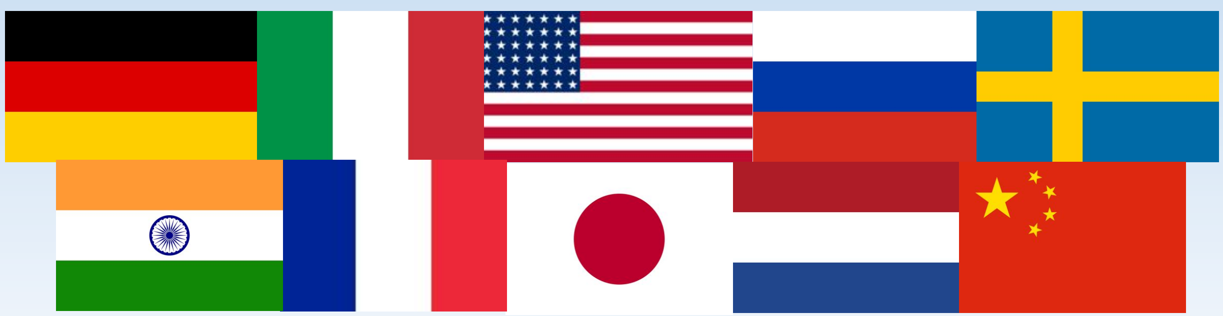
JUSTUS-LIEBIG-UNIVERSITÄT GIESSEN

ESA science team



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Space agencies and industry

- European-Russian joint project (ESA-Roscosmos special agreement)

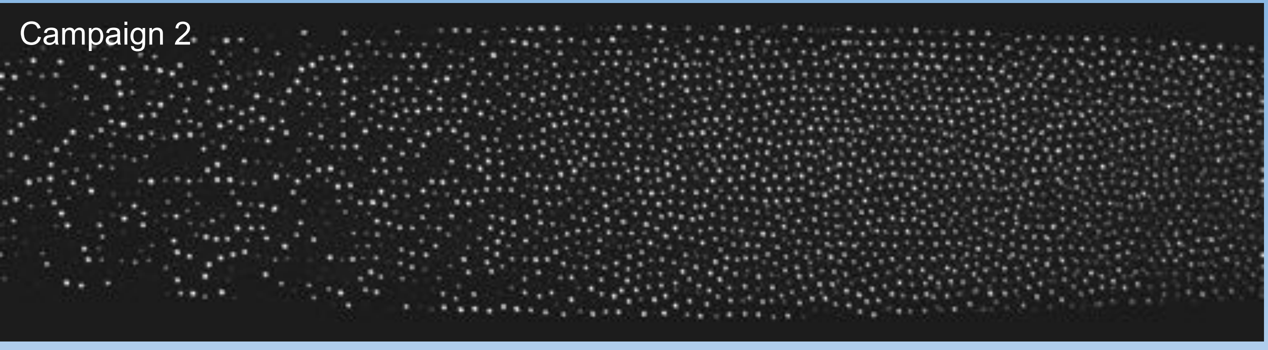
- Hardware contracted by ESA
- Accomodation in Columbus module on ISS inside the European Physiological Module (EPM)
- Control center – CADMOS in Toulouse

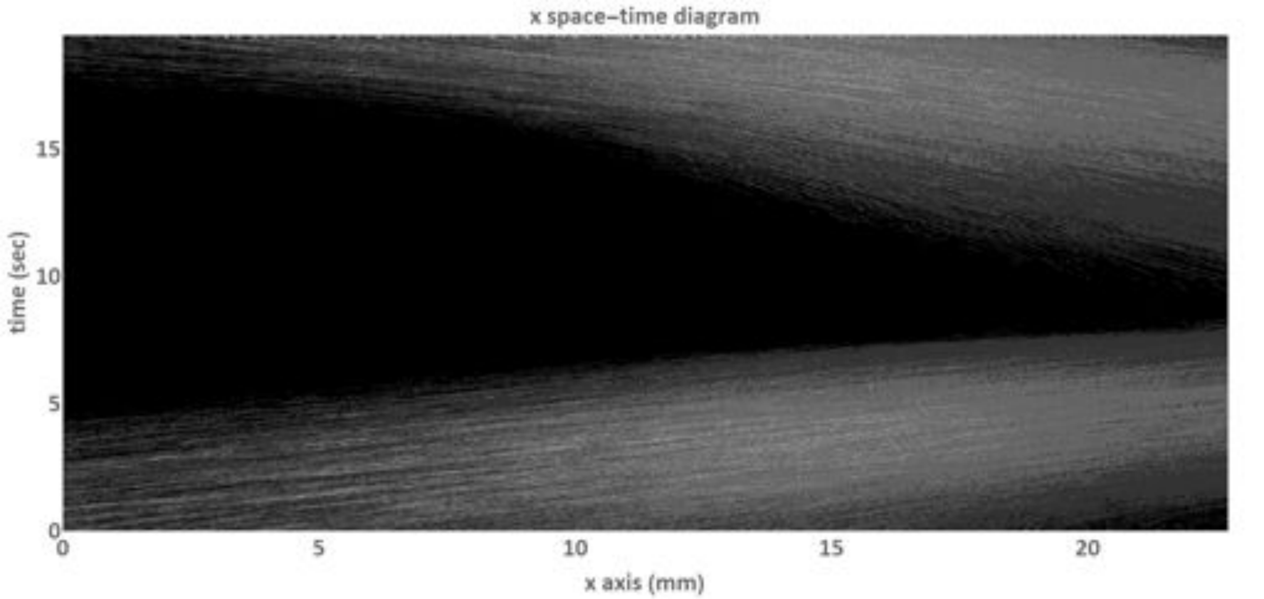
- Roscosmos: Launch and crew support

- NASA is in the process of proposal selection for PK-4 utilisation

Scientific results

Motion in dc and polarity-switched electric field



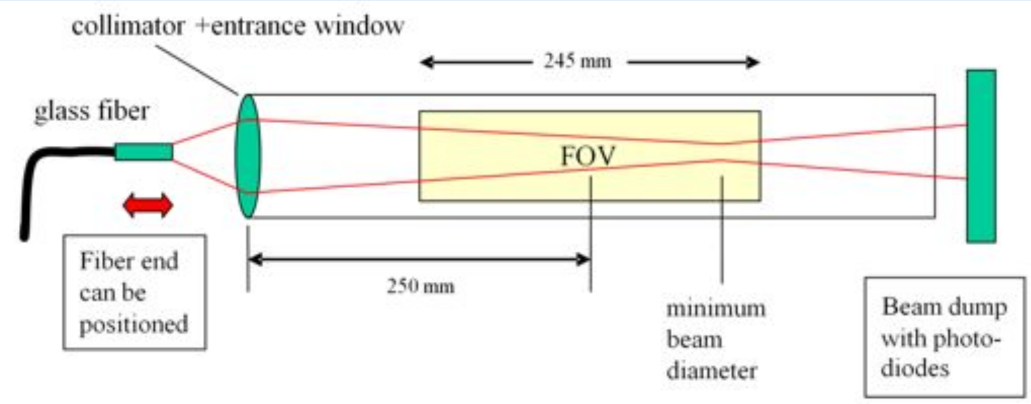


Measurement of microparticle velocities vs. polarity switching duty cycle

Talk by T. Antonova

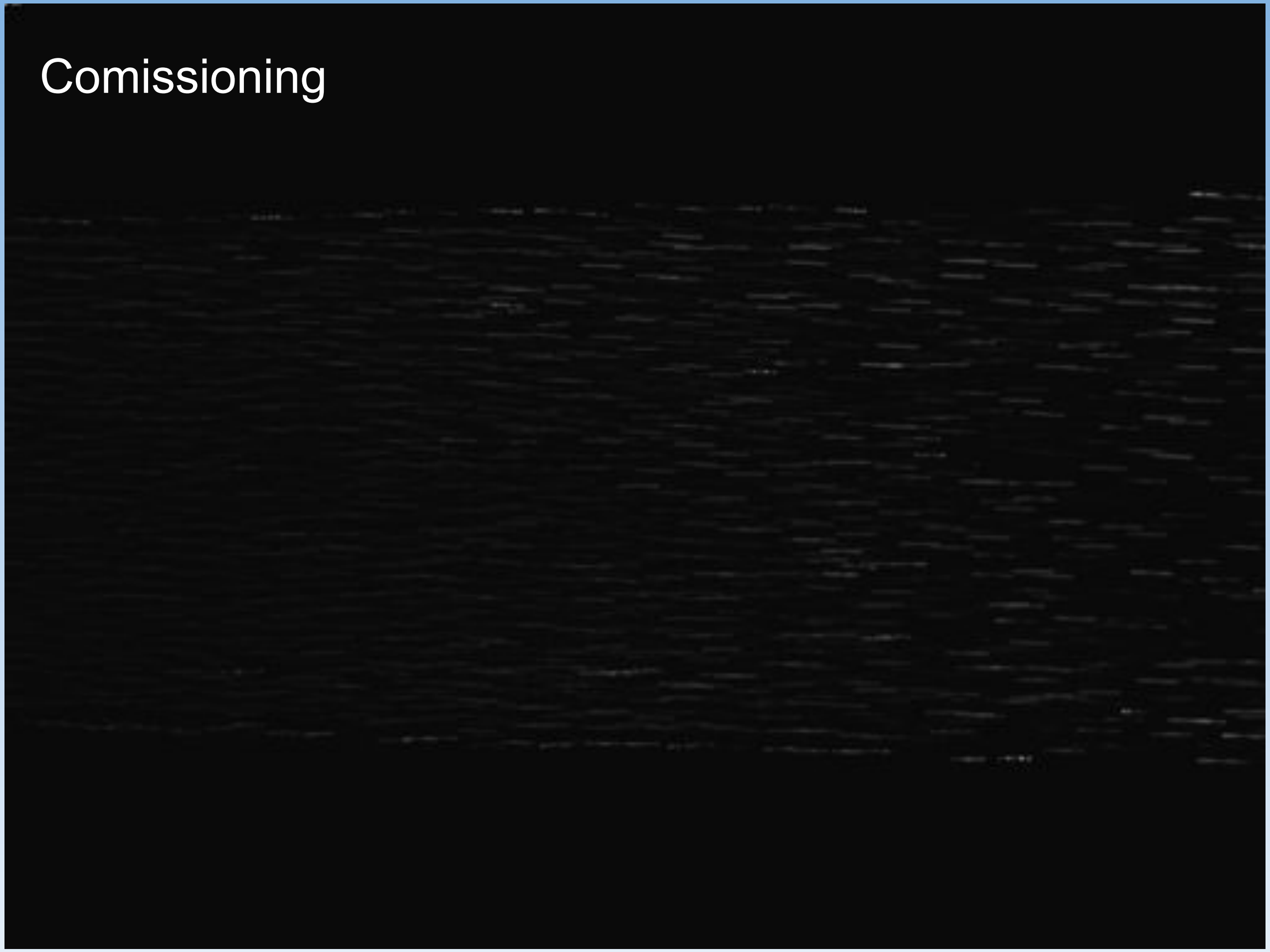
Shear flow

Campaign 3



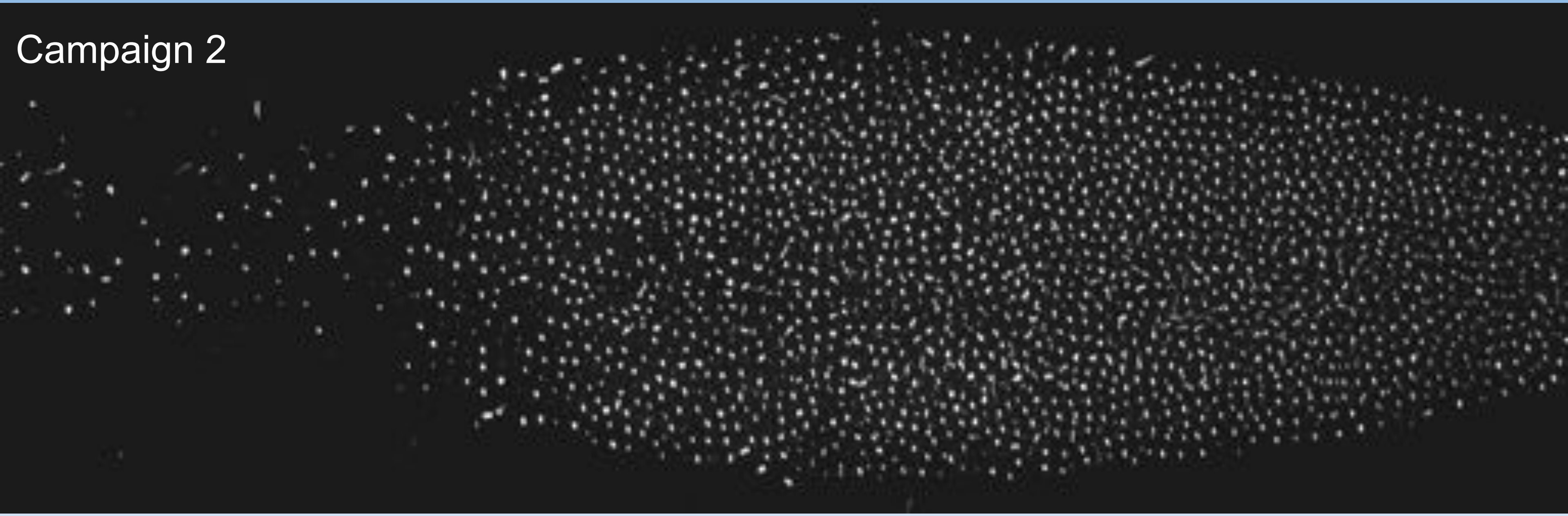
Talk by V. Nosenko

Transverse instability of a microparticle cloud

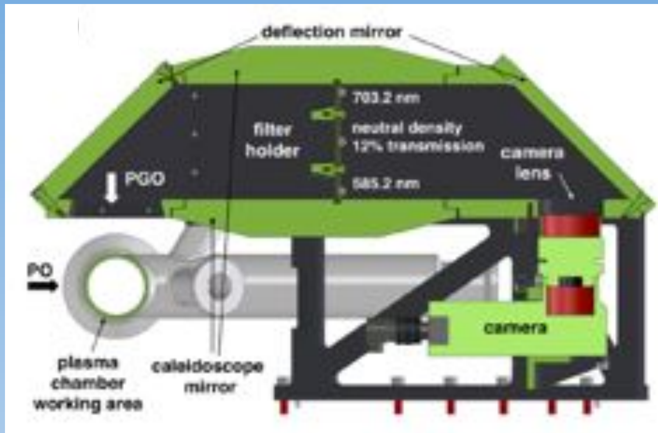


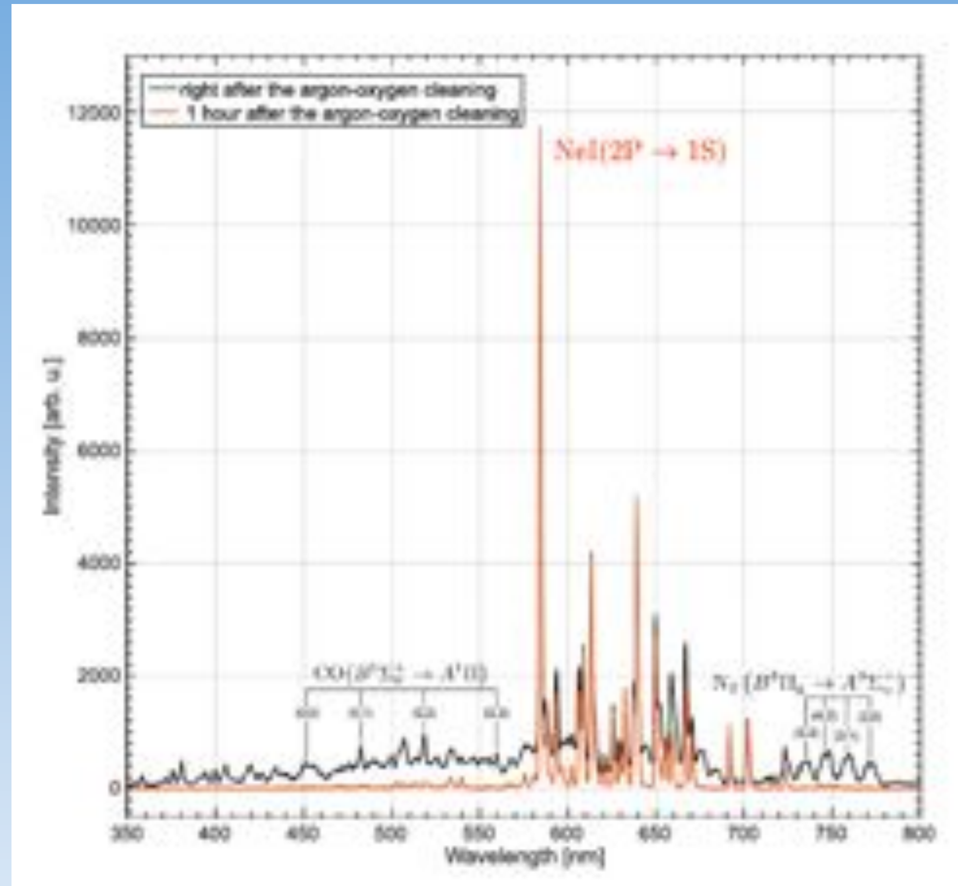
Talk by A. Zobnin

Waves excited by the EM electrode



Spectroscopic diagnostics

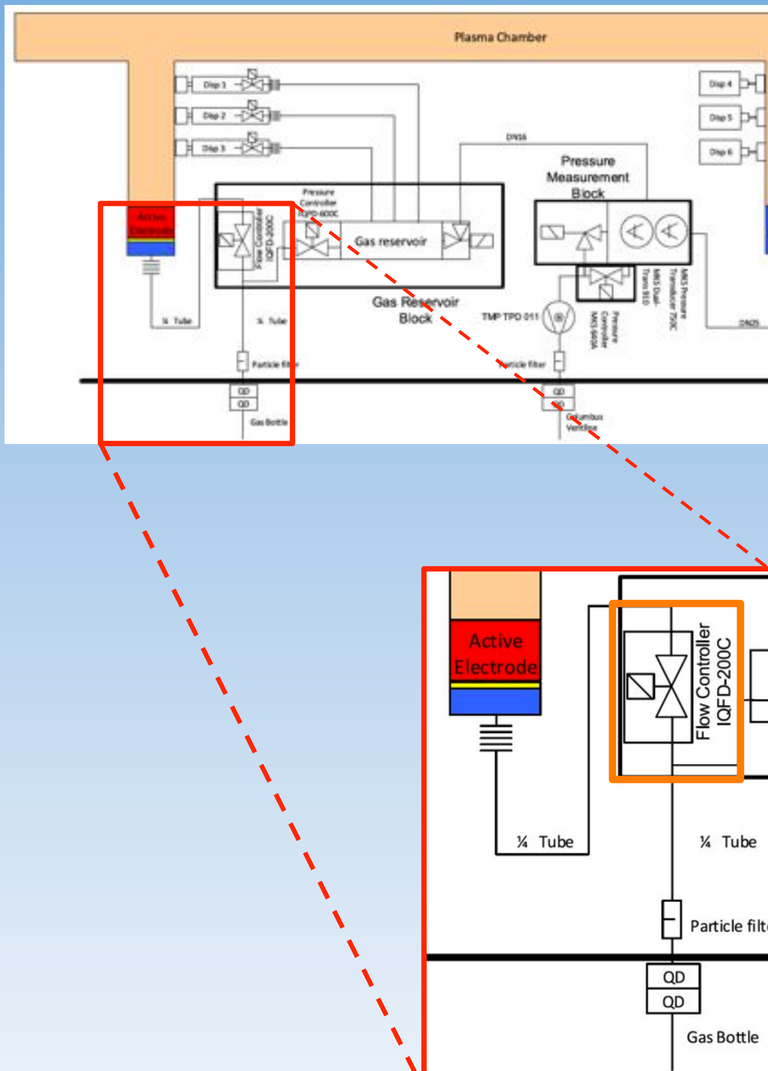


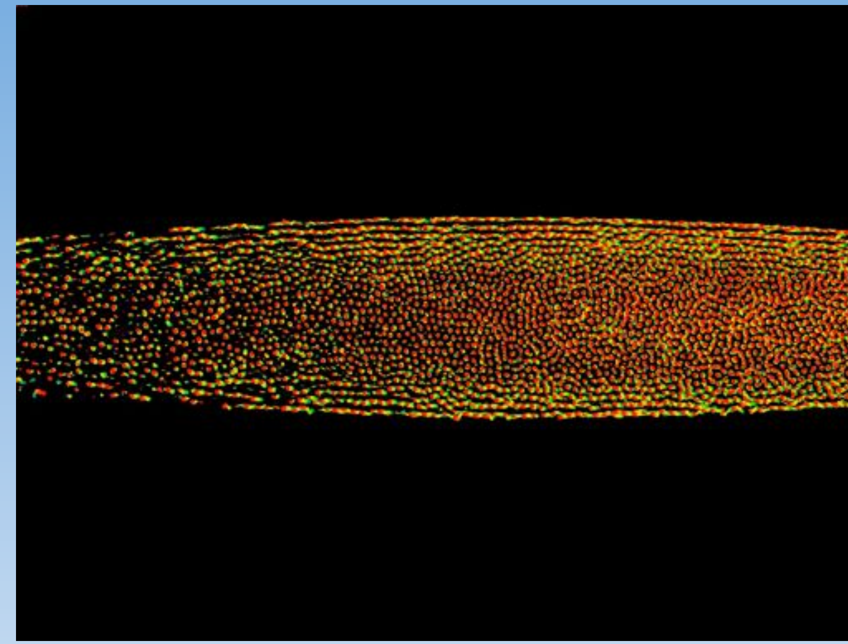


Talk by A. Usachev

Problems

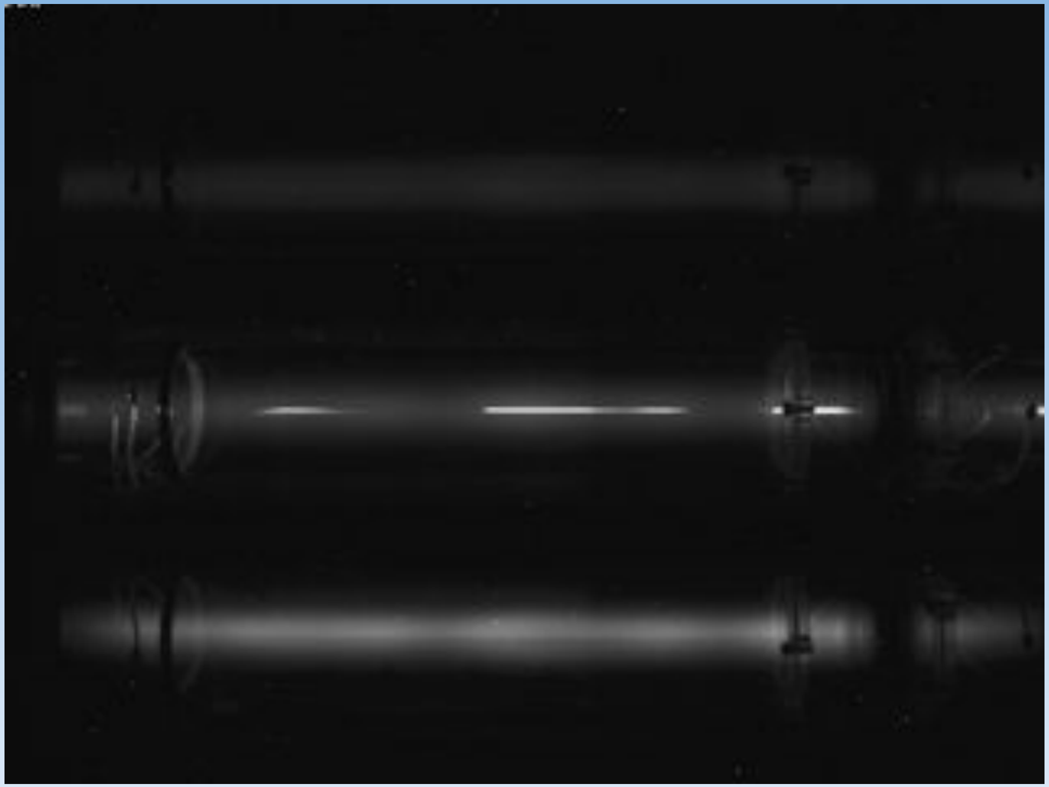
Residual gas flow





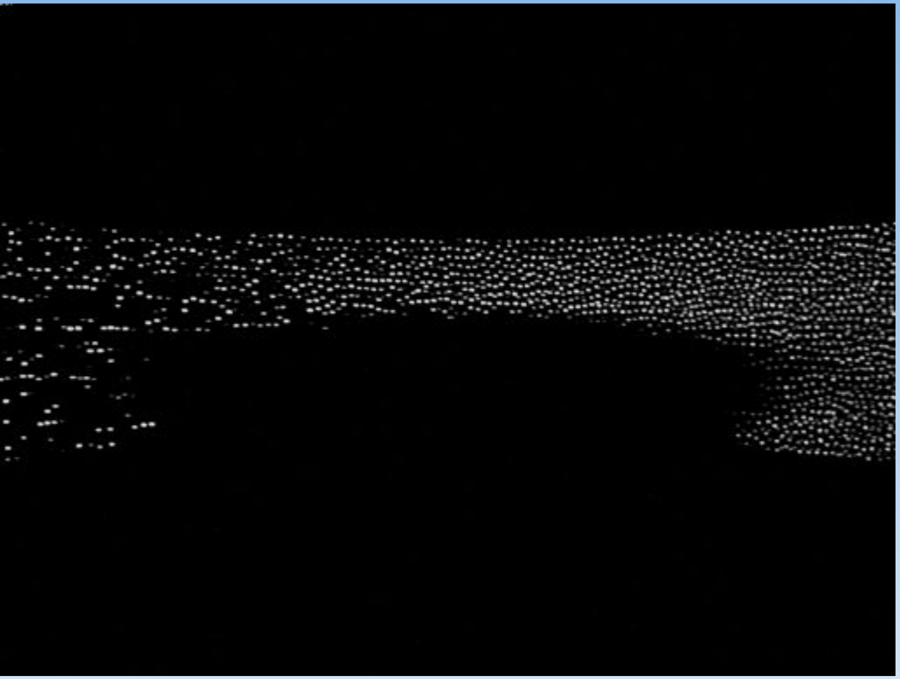
- Flow controller valve closes not as good as expected
- Leak rate 10 time higher than during the reference measurements at the launch site
- Supposed root cause – solid foreign particle stuck in the valve
- Recovery unlikely. Problem can be solved by installing an external valve.

„Stratification“



- Microparticles are confined in local “striations”
- Application of plasma parameters measured on ground questionable
- Problem under investigation, reason unclear

Temperature gradients accross the plasma chamber



• Microparticle clouds loose radial symmetry with time

• Most probable root cause is the thermophoretic force (due to the transverse temperature gradients)

• Smaller (20-30 min) experiment fragments to be separated by cooling intervals (~60 min)

• To be tested in the Campaign 4

Gas-jet dispensers

- Performance unstable
- Problem under investigation

Campaign 4: 12-17 February 2017

Campaign content

- Microparticle charge and ion drag measurements
- String fluid
- Lane formation
- Shear flow
- Laser wave excitation

- Some other tests

PK-4 Core Team

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M. Schwabe
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