Status of the PK-4 project

M. Pustylnik

German Aerospace Center (DLR), Research Group for Complex Plasmas, Oberpfaffenhofen, Germany
Introduction
Dusty plasmas

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

Typical $Z \sim 10^3 - 10^5$
Justification of complex plasmas

Coupling parameter

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

Generic condensed matter physics can be potentially modeled!

Stretched space- and timescales

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

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

Very easy to observe!

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

$\mu$-g
Hardware
Automatization: PK-4 CSL-based programming language

About 400 physical commands

Generate DC plasma
Data retrieval

3 TB per mission!!!
<table>
<thead>
<tr>
<th>Event Description</th>
<th>Date</th>
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<tbody>
<tr>
<td>Launch</td>
<td>Oct. 29, 2014</td>
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<tr>
<td>Installation (talk by A. Samokutyaev)</td>
<td>Nov. 27-28, 2014</td>
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<tr>
<td>Commissioning (first scientific operation)</td>
<td>Jun. 1-6, 2015</td>
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<tr>
<td>Campaign 01:</td>
<td>Oct 25-30, 2015</td>
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<tr>
<td>• Charge and ion drag</td>
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<td>Campaign 02:</td>
<td>Jun. 12-17, 2016</td>
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<td>• Dust-acoustic waves</td>
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<tr>
<td>Campaign 03:</td>
<td>Oct. 9-14, 2016</td>
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<tr>
<td>• Charge and ion drag</td>
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<tr>
<td>• Shear flow</td>
<td></td>
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<tr>
<td>• String fluid</td>
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<tr>
<td>Campaign 04 (in preparation)</td>
<td>Feb. 12-17, 2017</td>
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International collaborations
Scientific collaborations

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

ESA science team
Space agencies and industry

- European-Russian joint project (ESA-Roscosmos special agreement)
- Hardware contracted by ESA
- Accommodation 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
The highest efficiency laser diodes work in the near infrared. This is far away from the wavelength of the illumination laser and therefore does not influence the optical observations, which are protected by a narrow band pass filter. The laser light is carried by a 200 µm glass fiber from the laser to the collimator. This allows to accommodate the power consuming laser diode to a place where the heat can best be dumped to the structure. No active cooling will be required, since typical manipulation duration times are on the order of seconds or tens of seconds only. Typical heat load for a 5 s beam with maximum intensity is 250 Ws. The beam collimation concept is shown in Figure 49. The collimator lens itself has a fixed position and also serves as an entrance window of the discharge chamber. This reduces the optical power losses by some 10%. A collimator focal length of 30 mm is proposed. Antireflective coating will be applied to the collimator lens. The high optical power of the manipulation laser requires that an appropriate beam dump is installed able to dissipate and/or conduct generated heat to IBP. The beam geometry is changeable by moving the glass fibre end back and forth in front of the collimator. A motion range in the order of 5 mm is sufficient. The beam profile develops sharp edges (top hat profile) in the vicinity of the focus, a trapezoidal shape at few cm distances from the focus and more Gaussian profiles further away from the focus. Thus, various combinations of beam diameters and profiles are selectable in front of the observation cameras. An example for a typical beam geometry is shown in Figure 49 with the beam focus positioned to the centre of the plasma discharge tube. Some other examples for usable beam geometries are assembled in Figure 49.
Transverse instability of a microparticle cloud

Commissioning

Talk by A. Zobnin
Waves excited by the EM electrode

Campaign 2
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.
Microparticles are confined in local “striations”

Application of plasma parameters measured on ground questionable

Problem under investigation, reason unclear
Temperature gradients across the plasma chamber

- Microparticle clouds lose 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

A. Zobnin
A. Usachev
A. Lipaev
V. Molotkov

T. Antonova
T. Hagl
V. Nosenko
M. Pustylnik
M. Rubin-Zuzic
M. Schwabe
H. Thomas

M. Thoma
M. Kretschmer
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