IMPF

International Advisory Board for the
International Microgravity Plasma Facility

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Minutes of the Meeting of the International Advisory Board
10-11 August 1999
Munich, Germany

Present at the meeting were:
Prof. John E. Allen, Prof. John Goree, Prof. O. Havnes, Prof. Lin I, Prof. A. Mendis, Prof. V. Molotkov (representing Prof. Fortov), Prof. G. Morfill, Prof. A. Nefedov, Dr. Hubertus Thomas.

Professor Watanabe was appointed as a new member of the Board.

Also present were representatives of the DLR and representatives of Kayser-Threde.

This was the second meeting of the Board. Subsequent to the first meeting, the IMPF proposal to ESA received ESA’s top rating of “outstanding.” It was one of six proposals to receive this rating.

The meeting lasted approximately 12 hours, over two days, beginning 13.00 August 10 and ending 18.00 August 11.

The purpose of the meeting was to advance the next step of the project by providing technical recommendations to Kayser-Threde, so that the firm can carry out an industrial study of the proposed IMPF facility.

<u>On August 10, the agenda included the following:</u>

1. Introductory statements by Prof. Morfill, representatives of the DLR, and Kayser-Threde
2. Talks by Dr. Thomas and Prof. Molotkov, reviewing their previous space-based microgravity experiments with dusty plasmas.
3. An inspection of the flight hardware for the forthcoming PKE experiment aboard ISS.
4. Presentations by board members of possible experiments that might be performed on IMPF.

<u>On August 11, the agenda included the following:</u>

5. Detailed discussions by the board of the configurations of the apparatus for IMPF, and plans for where it can be installed on ISS, how often it must be serviced, and how it should be operated. This was the topic which consumed the greatest amount of time, and it resulted in detailed technical recommendations

from the Board to Kayser-Threde. These recommendations are listed in the Appendix.

<u>The advisory board unanimously approved the following consensus report:</u>

a) The Advisory Board thanks the DLR for its rapid response to the recommendation (made at the first meeting of the Board) to initiate a detailed industrial feasibility study for the International Microgravity Plasma Facility (IMPF).

b) The Board notes with satisfaction that the IMPF proposal achieved the highest ranking in ESA's peer review process. The board believes that a modular and flexible facility aboard ISS will have many basic and applied scientific uses, and that it will serve a rapidly growing world-wide scientific community in one of the most exciting and rewarding areas of research.

c) The Board recommends that the industrial feasibility study should consider the detailed technical recommendations and constraints listed in the appendix to this report.

d) The Board recommends that the industrial contractor should provide the Board a preliminary version of the feasibility study in December 1999, to allow the Board to provide the contractor further guidance before the study is finalized.

e) The Board recommends to the industrial contractor that the feasibility report should be written in such a way that it can be used by DLR to approach other space agencies (including NASA, RKA, NASDA, ESA, etc.) with the purpose of obtaining international agency support for the establishment of the facility.

f) The Board recommends that the report should be public information. A summary of the report should be published electronically to the scientific community and the full report should be made available on request.

The meeting was adjourned by Prof. Goree.

The next meeting is scheduled for December 7-8 in either Garching or Munich Germany for the purpose of reviewing and responding to a preliminary version of the industrial feasibility study.

Sincerely,

John Goree
Professor of Physics, The University of Iowa
and
Chairman, International Advisory Board of IMPF

Appendix
Technical Summary of the Meeting of the International Advisory Board of IMPF
10-11 August 1999, Munich, Germany

A technical summary of the meeting is given below. In addition to this appendix, the contractor is also being provided notes that were prepared during the meeting.

The flight opportunities and funding have not been finalized at this time, although there are some encouraging prospects. It is anticipated that multiple agencies and countries will be involved in providing funds for: flight hardware and operation, funds for related laboratory studies, transport to and from ISS, space aboard ISS, and data link to ISS. In the critical matter of obtaining space aboard ISS, the Board learned that IMPF may have an opportunity as early as 2003 aboard Russian modules whereas European facilities would likely be unavailable until 2006. The availability of American facilities needs to be explored.

Plans will be made assuming that the facility will fly aboard ISS for up to 10 years. Mature experiments will fly first, while laboratory proof-of-principle experiments should be funded to develop newer concepts for flight in middle and late lifetime of the facility.

It was agreed that funding is needed for proof-of-principle laboratory experiments to develop future experiments for the facility. Funding is also needed for certain technical testing, such as developing effective methods of cleaning particulate accumulations from the inside of the plasma chamber, and recovering particles from the chamber for ex-situ analysis.

In these discussions, the board agreed that the hardware should be designed to have a modular form to reduce the amount of hardware that must be swapped when changing experiments. In descending order of frequency of swapping, the categories of hardware are as follows: Consumables and data media will be transported to/from Earth most frequently. An experimental drawer including a plasma chamber and optical bench will be swapped on a cycle of approximately 6 months. Additional modules such as the plasma power supply will be swapped when changing configurations on a cycle longer than 6 months. Certain infrastructure items such as vacuum and computer will be changed least frequently.

The board determined that the first hardware configuration should be a radio-frequency discharge with parallel plate electrodes and optical viewing from the sides. The reason for selecting this configuration first is that it is most mature and it is capable of being operated in both basic science and applied science modes by swapping only a few components. The basic science experiments will be strongly-coupled dusty plasma (plasma crystal) experiments, and the applied science experiments will be plasma processing of particulates. The latter will include: (a) etching and deposition of thin films on particulates and (b) Coulombic disagglomeration of particulates. It is anticipated that a minimum of two experimental drawers will be built for this configuration: one for basic science and one for plasma processing, and that they will be interchanged, with the basic science drawer flying first. There will be a high degree of common hardware and software for both the basic science and applied drawers. The second hardware configuration is expected to have a different electrode and optical viewing geometry, and a plasma power supply that can be operated as rf, dc, or a hybrid of both. While the exact configuration will be determined later, it is assumed that candidate configurations include coaxial cylindrical electrodes with viewing from the end and concentric spherical electrodes viewed in the radial direction.

This second configuration may employ conductive glass, rather than metals, for the electrodes, to allow better viewing; this can be accomplished by using Indium-Tin Oxide coated glass, which typically allows 90% transmission. Kayser-Threde was advised to concentrate its efforts in design and costing on the first configuration.

Beyond the second configuration, it is anticipated that in the mid- to late-lifetime of the facility, further configurations will be designed and flown. These will include configurations that cannot presently be anticipated, or configurations that do not yet have laboratory verification of proof-of-principle, for example an ion-free plasmas consisting of dust and photo-electrons detached by ultraviolet light or thermionic emission. Some of these configurations might include segmented electrodes that allow various voltages to be applied to various segments, allowing more possibilities for plasma shaping and particle manipulation.

Further details of the first configuration are presented below and in the hand-written notes provide to Kayser-Threde as part of this report.

(a) The basic science version of the first configuration will be similar to the PKE (Plasma Krystal Experiment), but with more diagnostics and manipulation of particles, and with larger diameter electrodes. Wall materials should be changed from glass to metal, using flanges to mount windows. The electrodes will be circular, and the chamber geometry should conform to the cylindrical shape of the electrodes. It is expected that not all of the additional diagnostics and manipulation schemes will be operated simultaneously, but that the drawer will be refitted from time to time on the ground. The purpose of the larger electrode is to reduce vortex formation caused by strong radial gradients in plasma parameters in the inter-electrode region. Manipulation would include a more powerful laser; in practice this should be as powerful as practical given the limitations on electric power consumption. It is anticipated that a 50 mW laser will be adequate to manipulate particles along a spherically-focused laser beam, while a power of several watts might be required to manipulate particles on a cylindrically-focused sheet or line. The latter configuration might also place greater demands on the volume used by the optics compared to other manipulation and detection schemes. Diagnostics will include a Langmuir probe, a low-pixel video monitor of the glow, and a scannable Fabry-Perot spectrometer with bandpass pre-filter for ion-Doppler measurements that might be flown on some flights as part of the particle imaging cameras.

(b) The processing version of the drawer will require baking on the ground at 100 – 200 C. One electrode should be designed so that a magnetron magnet set can be mounted behind it so that the drawer can be flown in a magnetron configuration. Such a magnet set would consist of a cyclindrical magnet and a concentric ring magnet separated by an air gap, with a magnetic field that is typically 100-200 G at the point on the electrode surface where the field is tangential to the surface. The magnets should be in air, not vacuum. In the magnetron mode, the device would be operated at approximately 500 V and 10 mA dc. An essential feature of the processing version will be sample collection and return to Earth. The samples will be the particles after they are etched, coated, or disagglomerated. It is anticipated that collection in the vacuum exhaust may be adequate, provided that the collection allows samples from different experiments to be collected separately. The processing configuration will employ additional optics using lasers similar to those of the basic science version. These optics will allow in-situ particle sizing by ellipsometry in an early implementation and laser-doppler velocimetry in a later implementation; both of these instruments will use PMT or diode detectors rather than CCD imaging. The processing version may also use a rotatable S-P polaration analyzer inserted in front of the particle-imaging camera.

It is expected that cleaning the inside of the plasma chamber will be a technical problem that may be difficult. When particles are introduced, they will collect on interior surfaces of the chamber. The most critical problem is an accumulation of particles on the electrode surfaces, and the Board recommended that the apparatus provide a means of cleaning these surfaces with a brush, cloth, or stream of gas, possibly using a retractable probe inserted from outside, and possible accompanied by vibration. Determining the best solution will require laboratory tests. Accumulation of particles on other interior surfaces will present a problem only if they later become detached from the surfaces and reintroduced into the plasma. It is known that plasma exposure can result in particle release from surfaces. This will be a significant problem especially if the particle size has been changed. Avoiding this problem might be possible only by periodic replacement of the experimental drawer, which is a reason that the Board favors swapping the drawer as frequently as once every 6 months.

The particle shaker should have one or two shakers, with exchangeable reservoirs that can be rotated into position allowing the experiment to change particles from among approximately 6 samples, during the 6-month flight of a drawer. The shaker should work well with both polymer and ferromagnetic particles. It is anticipated that after the initial flights, there may be demands by scientist users for non-spherical particles. Scientist users may also require, in future years spherical polymer particles with smaller size dispersions than are presently available. Some few-body scientific experiments with polymer particles will require a greatly reduced particle dosage controllable to less than 10 particles introduced at a time.

Gas cylinders should allow approximately two samples in the facility at a time, with storage of up to 10 elsewhere on ISS. Gas flow and vacuum exhaust to space will be required. The gas should flow at an adjustable rate and pressure, with a minimum rate that is significantly faster than a 10-minute exchange to assure sufficient purity of gas in the presence of leaks and outgassing.

The Langmuir probe must be retractable. It is desirable that it be adjustable in position in two axes, which might be accomplished by using metal bellows, which collapse for translation and twist for rotation, when used with an appropriate motorized actuator. It must employ passive filters in the probe tip. It is conceivable that the Langmuir probe shaft might be designed to serve additional purposes such as electrode cleaning. The Langmuir probe will be used to acquire low-bandwidth data for the I-V characteristic curve. It may also require an additional circuit for high-current glow cleaning of the electrode tip.

Telescience will be required, with a minimum requirement of housekeeping data plus reduced-frame-rate imaging and lowbandwidth timeseries of certain voltage measurements.

Particle imaging will be an essential diagnostic for all experiments. It is anticipated that the experimental drawers will be fitted with two lasers and two high-pixel digital cameras plus a low pixel camera for glow imaging. Assuming that laboratory proof-of-principle tests that are now underway prove successful, another optical imaging scheme for 3-D imaging will require 3 lasers and 3 CCD’s.

Kayser Threde should evaluate the feasibility of including a dc magnetic field in configuration 1 as an option for certain flights of experimental drawers. The magnetic field would magnetize electrons, and would need to be a minimum of 50 G and a maximum of 200 G.

Gases for basic science will be inert gases, plus an electronegative gas such as SF_6 at concentrations up to 10%, with total pressures ranging from 10 microBars to 10 milliBar. Gases for processing will require inert gases and O_2 in the same pressure range as above.