Germany's Five Year Space Plan

N96-15622

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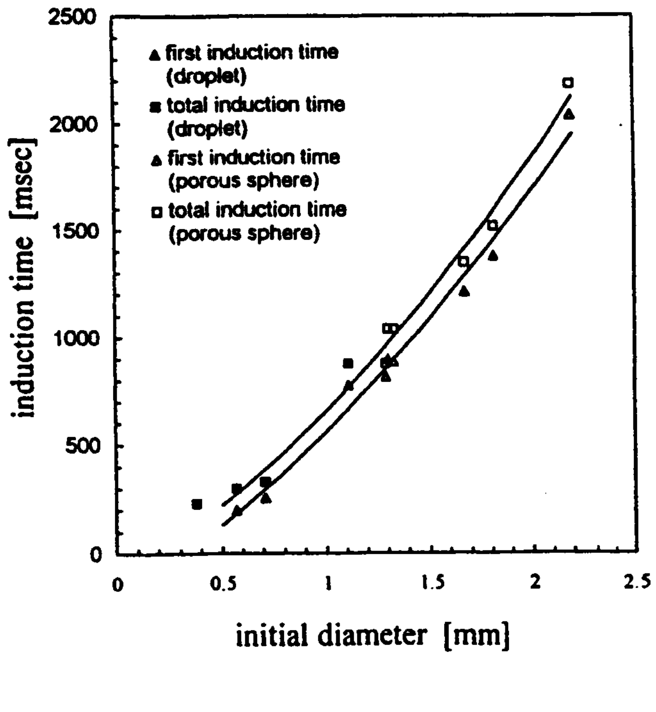
Introduction

Up to now microgravity combustion research has mainly been a powerful tool to apply on basic research items. The absence of thermal convection and thus the ability to experimentally verify simulations supposing buoyancy-free boundary conditions were ideally suited to improve knowledge about fundamental combustion processes. Beyond reasonable doubt the necessity to perform basic experiments will still be given in future in many diciplines. But the more scientists from more and more countries enter the field of microgravity combustion research and the more facilities are built for ground-based as well as suborbital and orbital research, the more application-relevant items are requested to be investigated on. Thus, the German microgravity combustion research program tries to enhance both, fundamental as well technological aspects. The four projects described in the following are utilizing or technologically advancing ground based facilities like drop tower, drop shaft and parabolic aircrafts. Which items will be the German part of the European participation on the 'International Space-Station Alpha ISSA' has not yet been decided.

Development and Research Program On Pollutant-Reduced Combustion Systems DROP-COS



n-Dodecane, Pa = 0.5 MPa, Ta = 700 K, Droptower experiments

Fig. 1: Influence of initial diameter on induction times, spontaneous ignition of isolated droplets and porous spheres

In the joint national *DROP-COS* project models describing the interactions during mixture formation and ignition in two-phase combustion systems shall be developed. These models will extend existing process simulations into the area near the injection nozzles and the pre-mixing. For this purpose, institutes of terrestrial combustion research, as well as µg-research laboratories will work together on specific questions regarding technical installations. Droplet group experiments and direct simulations will be compared with mechanisms taking place within simple plug-flow burners. Advanced laser diagnostic techniques will be applied on both, terrestrial as well as microgravity experiments.

The microgravity relevant objectives are: multidroplet- and droplet-gas phase interactions during autoignition in high temperature/ high pressure environment based on the recent single droplet two-stage ignition investigations. To match similarities to gas-turbine and prevaporized-premixed PPM combustion experiments will be made on large droplet diameter arrangements. Figure 1 shows recent results of drop tower experiments on the comparability of fuel droplet autoignition to porous sphere autoignition. Porous spheres are indispensable for large droplet autoignition experiments. The microgravity related part of the program is in co-operation with the Japanese NEDO and Japanese research institutes. Beside the Bremen drop tower, the utilization of the Kamisunagawa drop shaft as well as parabolic aircrafts is planned.

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Co-operative partners: Norbert Peters, ITM, Aachen
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Heiner Pfost, LDuG, Bochum
Wolfgang Triebel, IPHT, Jena

Support: German Space Agency, DARA, April 95 - March 98
Federal Ministry of Education and Science, Research and Technology, BMBF, March 94 - Dec. 95, to be cont.

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Development of a Laser-Diagnostic-System (LDS) for Drop Tower Use

The application of modern laser diagnostical measurement techniques for combustion research in earth-based laboratories has brought essential experimental progress. This project is to develop a UV-Laser-Diagnostic-System, which for the first time allows the application of two dimensional laser spectroscopic measurement techniques to microgravity research.

Two UV-excimer laser are used in an oscillator-amplifier configuration (Lambda Physik LPX 100i, LPX 200i) equipped with an external narrowband unit using a tunable Littrow grating. With this equipment high pulse repetition rates of 250 Hz can be combined with high energies up to 400 mJ per pulse and tunable narrowband properties to obtain high temporal and spectral resolution.

The laser system is mounted at the top of the tower attached to the inner evacuated drop tube. The laser beam follows the falling drop capsule and enters it from above through a quartz window. Details of the optical arrangement are shown schematically in Fig. 2. In order to fix the position of the laser beam within the experimental apparatus (e.g. the combustion chamber) with an accuracy in the sub-mm range, the drift between capsule and laser beam has to be compensated. Experiments in the drop tower have shown that this drift, in the range of 20 mm, is induced by oscillations in the concrete drop tower, from momentum of the release mechanism and from improperly compensated coriolis force.

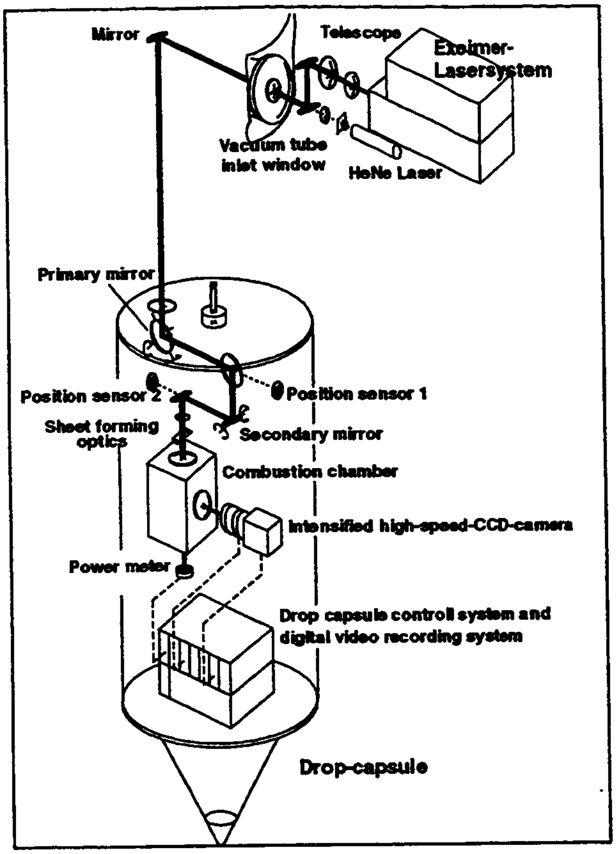

Fig. 2: Schematics of the optical arrangement at the top of the drop tower and within the drop bus

The positioning system is based on a guiding HeNe-laser beam which is coupled coaxially into the optical path of the excimer laser, and on a positioning unit at the top of the capsule. With two beam-splitter plates the HeNe-laser beam is directed on two planar position sensing detectors (PSD). A control unit drives two motorized mirrors with two axes of rotation each. Thus the lateral and the angular drift between the drop capsule and the laser beam can be compensated. With a cylindrical telescope the laser beam is focused to a suitable two dimensional light-sheet of about 30 mm height and a width of about 800 μm (FWHM).

In order to enable the investigation of rapid instationary processes like auto-ignition phenomena within the drop time of 4.74 seconds the frame rate of the laser diagnostic system is maximized to 250 frames per second. The image intensified CCD-camera with 256 x 256 squared pixels has also the capability to take 250 frames per second. By means of a compact industrial system based on a Motorola chip (MC68030) with an 8 bit A/D converter with 18 MHz sampling rate and a high speed video-interface, up to 96 Mbytes data (5s) can be stored during the drop time directly on the video-RAM. Image acquisition and data storage equipment are integrated within the capsule.

Immediately after finishing the drop experiment the image data can be transferred via radio transmission link to a large data storage outside the drop tube. From here a first evaluation of the obtained raw image data is possible, and extensive automatic digital image processing can be done.

For triggering the image acquisition system by the laser pulse a fast UV-photo-diode is used within the drop capsule. With temporal pulse to pulse fluctuations (jitter) of the laser below 3 ns, a pulse length below 20 ns, a temporal drift due to the moving capsule below 1 ns per pulse and a gate time of the image intensifier of 100 ns it is possible to trigger the acquisition of an image with the previous laser pulse.

FIRST EXPERIMENTAL RESULTS

The images on the following page show first 1g and μg experiments applying the laser system to a configuration which is comparable to the 'Emmons Problem'. The burner is a methanol drenched glass wool bed 50mm long and 20mm wide.

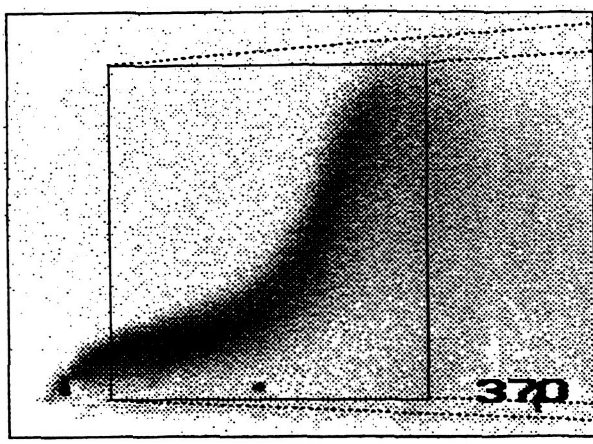

Fig. 3: Video image of a 1g methanol diffusion flame, forced air flow from left hand side

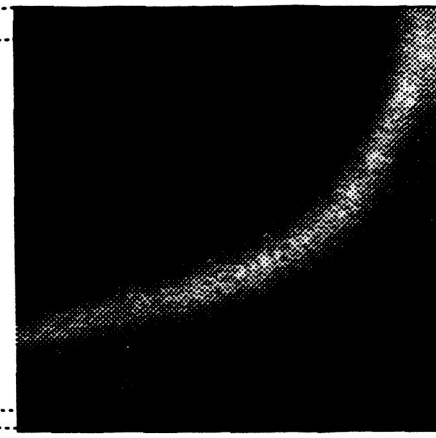

Fig. 4: OH-LIPF single shot image achieved at 120m distance from the laser, frame rate 250Hz, 248nm, exitation via $P_2(8)$ transition

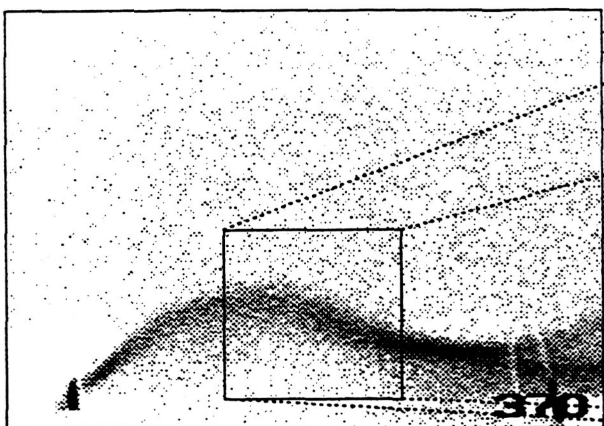

Fig. 5: Video image of the 0g flame, 0.3s after release of the capsule

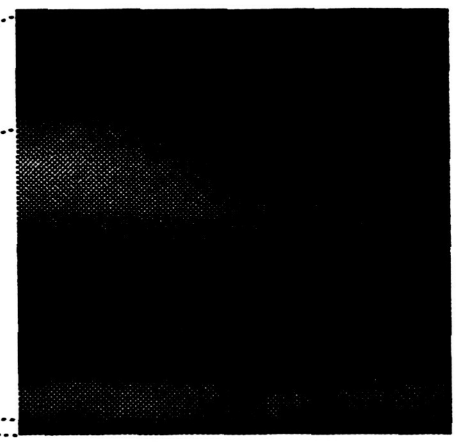

Fig. 6: OH-LIPF 250Hz single shot image of the marked area, $P_2(8)$ transition

Further applications might be:

- 2D - Measurements of the interaction of two and more droplets during ignition, flame spread and burning, which is an important step in understanding the processes of spray combustion.
- Measurement of the flame structure of premixed or diffusion flames in buoyant-free surrounding.

- 1D - Raman / Rayleigh Spectroscopy for simultaneous measurement of different major species and temperature focusing the laser sheet to a focal line and using an OMA system, where the emission wavelength is measured against the spatial coordinate with high temporal resolution.
- 2D - flow field measurements like particle tracking velocimetry or laser speckle velocimetry for various applications in fluid mechanics under microgravity conditions, where small seeding particles can be illuminated stroboscopically with the planar laser light sheet, so that the two velocity components in this plane can be measured simultaneously.
- Use of the UV laser beam for photochemical processes (e.g. photo-polymerization) under microgravity condition)

PI: Hans J.Rath, Christian Eigenbrod, ZARM, Bremen

Co-operative partner: Wolfgang Triebel, IPHT, Jena

Support: German Space Agency, DARA, (50 WP 9251), Sept. 92 - Aug. 95

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Theoretical and Experimental Investigations on Lean Flammability Limits and Laminar Flame Speeds under High Pressure and Microgravity Conditions

For reasons of safety, the knowledge of flammability limits is essential for space and nuclear reactor technology. Investigations of the lean flammability limits for fuels such as hydrogen and methane under normal gravity conditions have shown a clear dependence on the direction of flame propagation. Therefore the lean flammability limit is lower for an upward traveling flame than for a downward traveling flame. This gives the clear evidence for buoyancy effects superimposed to the flammability limits caused by reaction kinetics. These kinetically based flammability limits also have been subject to detailed numerical analysis in order to investigate reduced reaction mechanisms. These numerical results are difficult to compare with the experimental data, because the extinction process strongly depends on the configuration of the flame and the definition of flammability. To have a better insight into the kinetic aspects of flammability limits, experiments under zero gravity conditions are necessary. Figure 7 on the next page depicts the spherical high pressure combustion chamber. The inner diameter is 100mm. The chamber's pressure resistance of up to 700 bar has been tested. The premixture is loaded by means of partial pressures. Ignition is initiated concentrically, Schlieren method is applied to observe flame propagation because the lean flame is not expected to be luminous enough for direct observation.

The time being, the equipment is ground tested and 1g experiments are ongoing. First microgravity experiments are scheduled for autumn this year.

PI: Norbert Peters, ITM, Aachen

Support: German Space Agency, DARA, (50 WM 9439), May 94 - April 97

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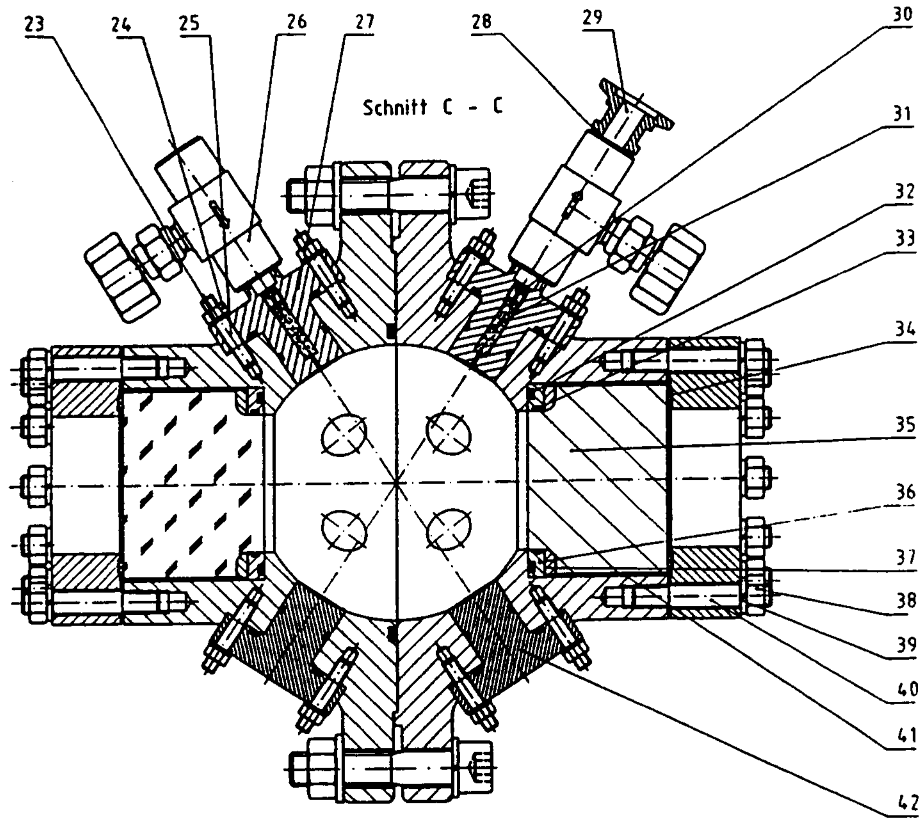

Fig. 7: Spherical High Pressure Combustion Chamber

Investigation on Laminar H_2 Diffusion Flames by Means of Solid-State-Electrolyte Sensors (Gaspotentiometric Method)

Objective of this project is to investigate flame structure of laminar H_2 - diffusion flames without the presence of buoyant effects. The experiments shall validate the numerical models describing the flame structures of different fuels without convection. The refined model will then be applied on flames influenced by gravity. Beside video observation, specially developed solid-state-electrolyte sensors will be used to detect species concentration and temperature distribution quantitatively. These measurements yield spatially and timely resolved information on flame structures and thus might help to analyse chaotic dynamics in real systems. The miniaturization of the sensors will be a side-effect of this project.

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R.Grabski, Institute of Fire-Department of Saxony-Anhalt

Support: German Space Agency, DARA, Jan. 95 - June 96

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