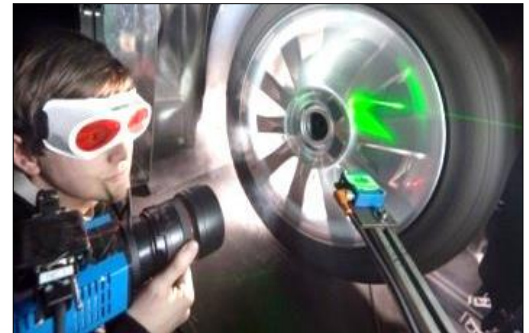




Particle Image Velocimetry (PIV)

2D/3D – Flow visualization for various vehicle technical applications

- Laser: Double pulsed laser Nd:YAG200 mJ/Puls at 532 nm, 15 Hz
- Camera: 2x 2048x2048 Pixel, 4 GB, 14 Bit, 15.56 fps, 400 ns Interframing-time
- Optic: Movable mirror arm, divergent laser 35/50/85mm AF objectives
- Equipment: Particle Generator, 1 μm
2x Tilt Adapter
X-Z traverse
- Computer: Synchronisation unit, Workstation
- Software: VidPIV + Tecplot 360



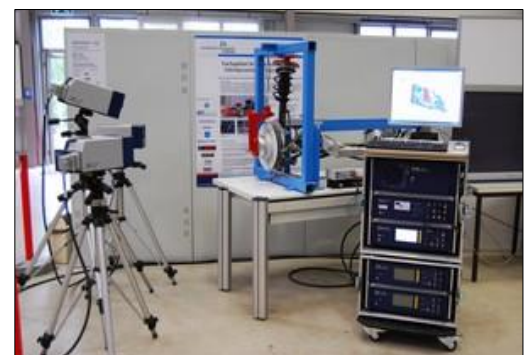
3D Laser Scanning Vibrometer

PSV 400 3D

Non-contact 3D vibration measurement technology,
Applicable also at the customer site

Specifications:

- Frequency range: 0 – 1 MHz
- Data collection: 4 canals
- Distance: > 0,4 m
- Object width: $\geq 1 \text{ mm}^2$
- Velocity: 10 m/s (max.), 2,5 MHz (max.)
0,5 m/s (max.), 350 kHz (max.)
- Signal generator 512 kHz (bandwidth)
0 – 10V, $\pm 5 \text{ mA}$
- Measurement: 2x2 up to 512x512
measurement points
- Resolution: 6400 FFT lines



Automotive Engineering

2. Measurement Systems



Real-Time Systems for Measurement and Control Tasks

PXI/Compact-PCI (Fa. National Instruments)

Autobox (Fa. dSpace):

- Prozessor-Board, DAQ-Board, HIL-Board
- 7 slots (AutoBox)
- Operation with 12V, 24V and 48V vehicle wiring

MicroLabBox (Pr. dSPACE):

- DS1202 Processor-Board
- A/D and D/A I/O Boards
- CAN Communication

Hardware-in-the-Loop Test Stand (Pr. dSPACE):

- DS1006 Processor-Board
- A/D und D/A I/O Boards
- CAN und FlexRay Communication
- Integrated control of Suspension systems



Source: dSpace

Racelogic VB3i / Video VBOX Pro

- Detection of driving condition sizes, e.g. Speed, lateral and longitudinal acceleration as well as position in combination with a 4-channel camera system for driving documentation
- Additional equipment for highly dynamic vehicle data and vehicle dynamics measurement
- Measurement wheel - Correvit Datron



Quelle: Racelogic

Specifications:

- 100 Hz DGPS
- 500 K Can-Bus-Anschluss
- Data logger
- 4xAI, 2xAO, 2xDI, 2xDO
- 4 cameras
- 2 Microphone
- Video-Overlay



Bidirectional Telemetry System

System for bidirectional data transmission between the main station and a test vehicle, which is used for vehicle dynamics development and modeling (analysis of driving behavior).

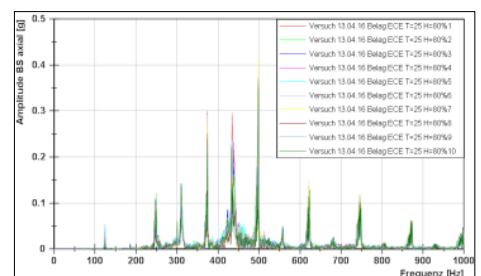
- 3km range (omnidirectional)
- Sampling rate:
48kSps (stand-alone mode)
24kSps (modules coupled)
- Bandwidth per channel:
20kHz (stand-alone mode)
10kHz (modules coupled)
- 8x Analog, 4x Digital, 8x ICP, 4x Thermocouple, 1x CAN



Vibration and Acoustics Measuring System

LMS SCADAS Mobile

- Mobile test hardware for noise, vibration and lifetime tests
- Compact size and light weight
- Robust design for extreme conditions and temperatures
- Very quiet, operation without fan
- Up to 204.8 kHz sampling rate per channel
- 24-bit ADC technology
- 150 dB dynamic range





Fuel Consumption Measurement System

Gregory Flowtronic Sensor Series S8005

Accurate measurement of the fuel consumption of internal combustion engines with high accuracy

- Can be used on engines with petrol, diesel, alcohol and biofuels
- Accurate and highly dynamic measurement of minimum flow rates (idle) and high volume flows (full load)
- Can be used in mobile driving tests as well as on the test bench

Specifications:

- Measuring range: 0.1 to 250 l / h
- Measurement accuracy: +/- 0.5%
- Volume resolution: 0.004 ml



Source: Gregory



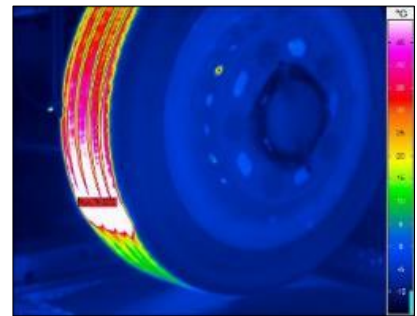
High- speed- Thermography

Thermography Camera InfraTec ImageIR 8300

| | |
|-------------------------|---|
| Detector format: | (640 x 512) Infrared-Pixel |
| Temperature resolution: | 20 mK |
| Spectral range: | MWIR, (2,0 ... 5,7) μm |
| Frame rate: | Full image: 355 Hz Half image: 670 Hz Quarter imager: 1.200 Hz Split image-line-mode: 5.000 Hz |
| Measurement accuracy: | +/- 1 K or +/- 1 % |
| Calibration: | 10 up to 850 ° C |

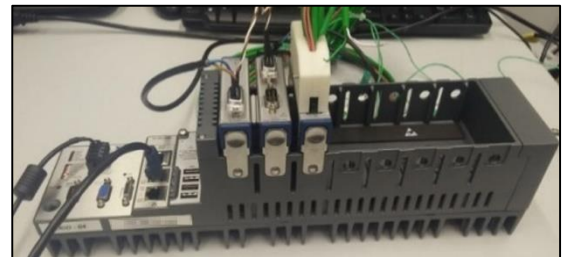


Source: InfraTec



Free-Sense HAT cRIO-9082

- Intel Core i7, 2GB RAM, 32 GB
- LabView Real-Time
- Maximum number of measuring cards: 8



Temperature Measuring Cards

NI 9213 high speed module:

- 16 channels
- Maximum sample rate 75 S/s
- Supports standard thermo-sensor types (J, K, S...)

NI 9214 precision module:

- 16 channels
- Measurement accuracy up to 0,45 °C
- Supports standard thermo-sensor types (J, K, S...)



Source: National Instruments



Computer-Tomograph for Component Analysis (μm -Range)

Ray Scan 200

- 2D and 3D material and structure analyzes
- Microstructure analysis
- Defect analysis
- Measuring tasks

Specifications:

- X-ray source: Micro focus 10-250 kV
- Burning spot: 3-250 μm
- Object dimensions \varnothing / H: 1-600 mm / 1-1500 mm
- Max. Object weight: 80 kg
- Active area detector: 410 x 410 mm²
- Detector Pixels: 1024 x 1024 (2048 x 2048 optional)
- Digitization: 16 bit
- Measurement time incl. Reconstruction: 2 - 30 min.
- Detectability: 1 μm
- Contrast: <1%
- Operating modes: 3D-CT and radioscopy



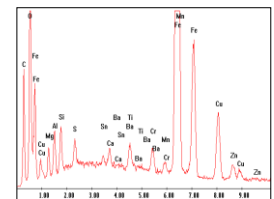
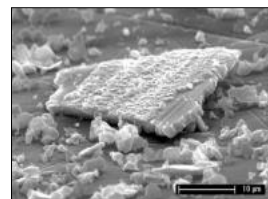
Scanning Electron Microscope with Element Analysis

JEOL JSM-6610 + EDX

Analysis of physically and chemically properties of components in nm-range

Specifications:

- Resolution of 3 nm at 30 kV
- Large sample chamber (350x340x230) mm with fully motorized sample table and a max. sample weight of 5kg
- Samples with a diameter of up to 208mm can be approached at any surface point
- Low-pressure operation with BSD allows high resolution
- Integrated element analysis (from boron to americium)
- 30 mm² active detector area
- Gold / Carbon sputter system





Laser Scanning Microscope

Keyence VK-X 3D-Laser Scanning Colour Microscope

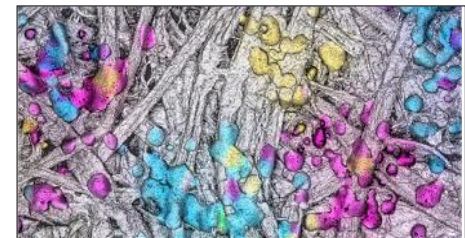
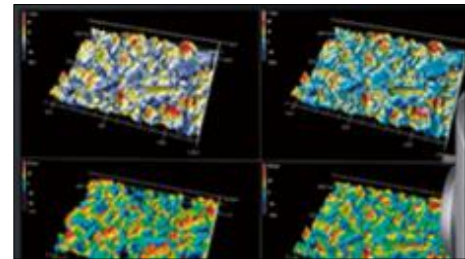
Surface analysis of tribologically stressed surfaces, roughness and ripple determination, 3D analysis of seals or friction linings and particle size determination

Specifications:

- Red semiconductor laser with a wavelength of 658 nm
- More than 3 million measurement points in each level
- 16 bit PMT, color CCD image sensor (3072 x 2304)
- 5 nm high resolution
- 8x optical zoom (laser mode)
- Scanning speed up to 120Hz
- XY image composition module with software and travel table (motorized 100x100mm)
- Comprehensive evaluation and analysis software
- Large number of different lenses



Source: Keyence



High Speed Digital Microscope

Keyence VW 9000

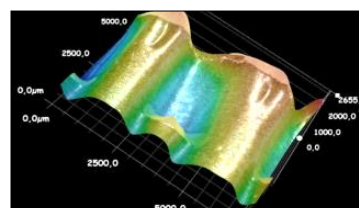
- Analysis of highly dynamic processes in the micrometer range
- 3D measurement of surfaces

Specifications:

- 4000 fps at 640x480 pixels
- Max. 230000 fps
- Microscope up to 1920x1440 pixels
- Magnification up to 200 times
- Macro zoom lens for long distance



Source: Keyence





Measuring Arm with Probe and Laser Scanner

FARO Fusion + Laser Line Probe

- 3D measurement of components, interior and body
- 3D modeling and reverse engineering
- Positioning and calibrating in the room
- anthropometry

Construction: 2,4m / 7 axes

Accuracy tactile: 51 μ m

Accuracy optical: 35 μ m



3D Midrange Laser Scanner

FARO Focus 3D X 330

- Surveying and verification of industrial plants and installations
- Testing of large moldings and components
- Architecture and terrain surveying

Range: 0.6m - 330m

Systematic error: +/- 2mm

Special features: - Integrated GPS-receiver
- Scanning in direct sun light



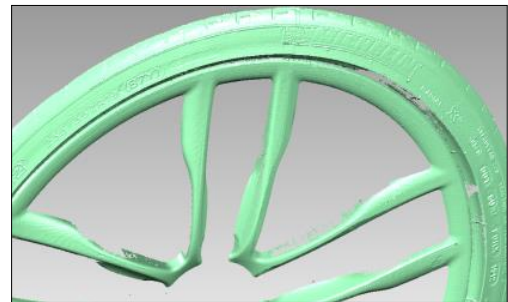
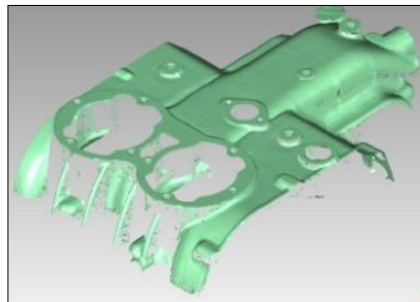
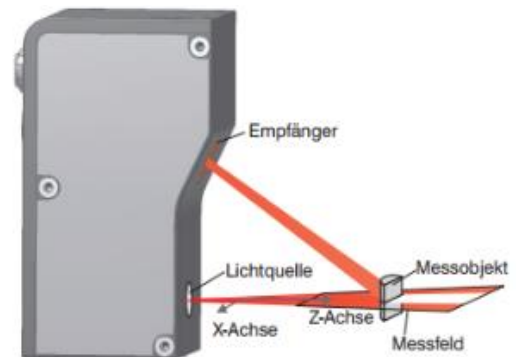
Source: FARO



Laser Line Scanner for Geometry Detection

Micro Epsilon ScanControl 2750 – 100

- Max. Profile sampling rate (test surface depended): 4000 Hz
- Typical profile sampling rate: 500Hz
- Component vibrations can be detected
- Measuring distance: approx. 500 mm
- Profile width: approx. 100mm





Wheel Alignment System

Beissbarth ML 8 R easy + Hydraulic Ramp Nussbaum UNI-Lift 3500 NT Plus

- Extensive database with setpoints of vehicles
- Measurement of individual wheel position variables
- Runout compensation
- Wheel sizes up to 24 "
- 4 measuring heads with 2 infrared cameras each
- Load capacity: max. = 4000 kg (wheel free lift 3500 kg)
- Wheelbase: max. = 4050 mm
- Width: max = 2120 mm



Robotic Handling Systems

Precision Positioning Robot

- Precision positioning robot
- Max. Payload: 34 kg
- Robotic weight: 248 Kg
- Brakes: in all axles
- Max. Speed in the center of gravity: 10.3 m/s
- Operating distance: 710 mm
- Degrees of freedom: 6
- Repeatability (typical): $\pm 0.01\text{mm}$
- Repeatability (ISO 9283): $\pm 0.05\text{mm}$
- Programming language robot control: VAL3
- Self-developed Labview interface



Source: Staubli



Actuation Robots

Pedal Actuator

- Reproducible pedal operations with high dynamics and precision
- Static and dynamic measurement of the pedaling properties and associated vehicle reactions

- Principle:** Servo-hydraulic
- Limits:** $F = 0 \dots 1500 \text{ N}$
 $v = 0 \dots 1000 \text{ mm/s}$
- Modes:** Force controlled,
Length controlled,
Ramped actuation,
Oscillated actuation,
Measurement while driving possible
- Data collection:** Pedal force, actuation path,
Hydraulic pressure,
BKV-pressure,
Vehicle velocity,
Vehicle deceleration



Steering Robot

Vehico CS-60B

- Performance of lateral test manoeuvres under reproducible conditions
- Highly automated driving

Technical Features

- Max. 60 Nm steering torque at 1200°/s angular speed
- Applicable steering wheel diameters from 250 mm to 440 mm
- Operation modes: open-loop (pure actuator), closed-loop (GPS)
- Conservation of manual steering and airbag function



Source: VEHICO GmbH



Pressure Measuring Mat

Tekscan TVR8404

- Analysis of pressure distribution of car tires in wheel-to-ground contact
- 36.608 piezo-resistive sensors on a surface of 268 mm x 317 mm allow the recording of the surface pressure distribution in the tire
- Recording frequencies of up to 106 Hz allow the measurement of dynamic processes during rolling
- Extensive analysis software



Highly Dynamic Force and Vibration Measurement System

Kistler Vibration Measurement System

- Determination of the dynamic force at the vehicle chassis connecting points
- Recording of oscillating forces and moments with up to 16 sensors

Specifications:

- Range: $\pm 100 \dots 1\,000\,000$ pC
- Frequency range: 0 – 45 kHz
- Drift: max. 0,2 pC/s
- Measurement uncertainty: <1%
- Measurement signal: 0-10V
- Storage of the measuring signals by direct reading of the measuring amplifiers (via Ethernet)





Wheel Load Sensor

Kistler RoaDyn S635

- Highly dynamic detection of wheel forces and moments
- 6-component wheel force sensor allows the measurement of multi-axis loads
- Complete assembly of the measuring wheel on the vehicle (as replacement for the standard wheel)
- Mounting on the tire trailer for the analysis of the behavior of the tire / road contact
- Mounting at the corner-module test stand for the analysis of the behavior under laboratory conditions



Measurement Range:

| | |
|--------------------|---------------|
| F _x | -35 ... 35 kN |
| F _y | -20 ... 20 kN |
| F _z | -35 ... 35 kN |
| M _{x/y/z} | -5 ... 5 kNm |

Emission Analysis Systems

HORIBA MEXA – 2100 SPCS and SMPS

- Solid Particle Counting System (CPC) + Scanning Mobility Particle Sizer (SMPS)
- Enlargement of the surface of the particles by heterogeneous condensation makes optical detection possible (the particles are passed through saturated alcohol / n-butanol)
- Counting by means of optical scattered light detection

Specifications:

- Particle count range: 10 - 2500nm (CPC - modified)
- Dilution Factors: 150: 1 - 3,000: 1 (two dilution steps)
- Size distribution by SMPS: 2.5 - 150nm and 10 - 1000nm over 167 channels



Source: HORIBA



Mobile Exhaust Measurement Systems

AVL M.O.V.E

- **GAS PEMS iS:** The AVL GAS PEMS iS is a compact, portable exhaust-gas analyzer developed for the determination of NO / NO₂, CO / CO₂ and O₂ concentrations in the exhaust gas of diesel and gasoline engines
- **PN PEMS iS:** The PN PEMS iS has been developed for continuous measurement of particulate matter emissions [# / cm³] of solids particles under real driving conditions (RDE)

Specifications:

- Sensor principle: Advanced Diffusion Charger
- Sample preparation: Catalytic Stripper
- Max. Sampling rate: 10Hz
- Dilution rate 10: 1



Source: AVL

Differential mobility analyser (DMA)

CAMBUSTION DMS500

Function:

- Particles are charged by an unipolar corona charger with relation to the particle surface
- In a classifying unit the electrically charged particles are exposed to a static electric field, which leads to deflection in direction of 22 ring electrodes
- The trajectory (impact location on a ring electrode) depends on the electrical mobility of the particles, based on which the aerodynamic diameter is estimated

Specifications:

- Range: 5 – 1.000nm (optional: 5 – 2.500nm)
- Max. sampling rate: 10Hz
- 38 size fractions



Source: CAMBUSTION



Electrical Low Pressure cascade Impactor (ELPI)

DEKATI ELPI+

The ELPI + provides real-time measurement of particle size distribution and particle number concentration within a size range of 6 - 10,000 nm. In addition the measuring system is suitable for measuring the particle charge distribution and for gravimetric impact measurements.

Function:

- Particles are charged by unipolar corona charger
- Size-selective fractionation of the particles in a cascade impactor with 14 electrically isolated isolation stages (5 separation stages in the range of PM0.1)
- Collection of the particles with the possibility of a subsequent gravimetric, chemical-analytical or electron microscopic (e.g., SEM) analysis
- Electrical determination with electrometers

Specifications ELPI +:

- Measuring range: 6 - 10,000nm
- Max. Sampling rate: 10Hz
- 14 size fractions / impactor stages



Source: DEKATI

DEKATI Thermodenuder

Application for the removal of volatile and semi-volatile substances in aerosol streams, which can eliminate unwanted transformation effects in the sample.

Specifications ELPI+:

- 10 – 20 l/min sample rate
- Heating up to 300 °C



Source: DEKATI



Particle- Measurement station

EN 16450-certified fine dust aerosol spectrometer

- Suitability tested and certified according to the latest EU requirements
- Applicable for environmental monitoring, immission measurement campaigns and long-term studies
- Continuous and simultaneous real-time measurement of multiple PM values (PM1, PM2.5, PM4, PM10)
- Measurement of particle number concentration and size distribution

Specifications:

- Measuring range (size): 0.18 - 100 μm
- Measuring principle: Optical light scattering
- Measuring range: 0 - 20.000 $\#/ \text{cm}^3$ (number) and 0 - 10.000 $\mu\text{g}/\text{m}^3$ (mass)
- Time resolution: 1 s to 24 h



Source: Palas



Condensation Particle Counter

Ultrafine Ultrafine Condensation Particle Counter (CPC) for the detection of a particle number concentration of highly dynamic processes

- Reference instrument without pre-separation, pre-dilution or thermal preconditioning
- Detection of single particles in a wide concentration range

Specifications:

- Measuring range (size): 2.5 nm (D50) - > 3 μm
- Measuring principle: Optical light scattering
- Measuring range (number): 0 - 300.000 $\#/\text{cm}^3$
- Response time: T10-90 up to < 2 s
- Sampling rate: up to 50 Hz



Source: TSI

Palas PMP-CPC 100

This condensation particle counter (CPC) is suitable for PMP applications of the EU standard ILCE

- PMP-compliant measuring system for particle count measurement
- Detection of single particles in a wide concentration range

Specifications:

- Measuring range (size): 23 nm (D50) - 10 μm
- Measuring principle: Optical light scattering
- Particle number concentration range: 0 - 1E+05 $\#/\text{cm}^3$ in single count mode and up to 1E07 $\#/\text{cm}^3$ in nephelometer mode
- Response time: T10-90 up to 2 s
- Sampling rate: 1 Hz



Source: Palas



Dekati eFilter

The Dekati® eFilter™ combines a gravimetric filter holder with real-time particle measurement technology and provides an online signal on particle mass concentration

- Applicable for environmental monitoring and exhaust gas measurements in the automotive industry
- Combination of gravimetric particle measurement (U.S. EPA) and automated real-time measurement

Specifications:

- Max. particle diameter (real time): 3 μm
- Sensitivity: approx. 1 $\mu\text{g}/\text{m}^3$ or 1000 $\#/\text{cm}^3$ for 70 nm particles
- Measuring principle: diffusion charger
- Sampling rate: up to 1 Hz



Source: Dekati

3-stage cascade impactor with ITES

3-stage cascade impactor according to ISO 23210 for the detection of the concentration in flowing gases in the fractions > PM10, PM10 and PM2.5. In addition, the ITES serves as a control and regulation unit for the isokinetic partial flow extraction

- Emission measurement/sampling according to EN, ISO and VDI standards (ISO 23210 and VDI 2066)
- Automated measuring system - applicable for environmental monitoring and exhaust gas measurements

Specifications:

- Max. mass concentrations: 200 mg/m^3
- Max. temperature range: 400 $^{\circ}\text{C}$
- orifice measuring section: 0.5 - 4 m^3/h



Source: Paul Gothe



Particle Generator

Generation of test aerosols from powders, pollen and spores

- Highest short-term and long-term dosing constancy and possibility for impulse operation
- Dispersion of almost all non-cohesive dusts

Specifications:

- volume flow: 0,5 - 5,0 m³/h
- maximum particle number concentration: approx. 1E+07 #/cm³
- Mass flow rate (particles): 0.04 - 430 g/h (at assumed plug density of 1 g/cm³)
- Particle size range: 0.1 - 100 μm
- dispersing gas: any possible (usually air)



Source: Palas



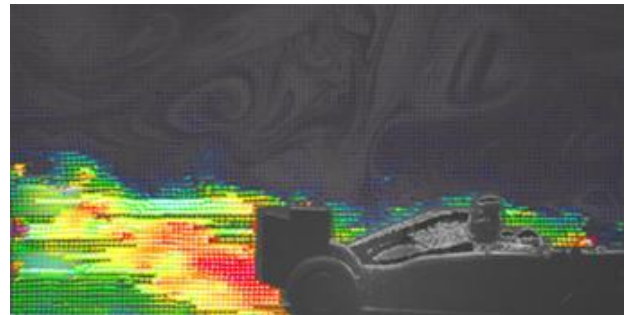
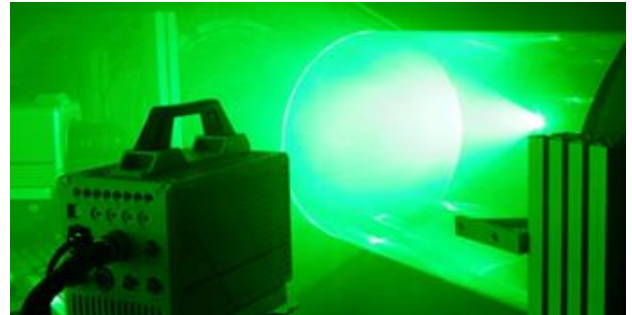
Flow measurement and Visualization

High Speed PIV

- Highly dynamic visualizations of velocity and acceleration fields at a sampling frequency of up to 10.000 Hz
- Automated traversing of illumination and image capture device

Specifications:

- camera sensor: 2048x2048 pixels
- Pixel size: max. 10x10 μm
- Frame rate: up to 20,000 Hz
- Recording time at 100 fps: 13.3 s (full frame)
- Recording time at 100,000 fps: 6.86 s (red. resolution)



Source: ILA5150

Omiprobe

- Measurement of flow vectors up to 160°
- For measurement tasks with unknown flow directions or when backflow is expected

Specifications:

- Number of holes: 14
- Temperature: 600° C
- Flow angle: $\pm 160^\circ$
- Velocities: 3 m/s bis Mach 0,95
- Velocity accuracy: $< \pm 1$ m/s
- 1 m/s



Source: Vectroflow



Precision Balance

Mettler-Toledo Balance XSR225DU (analytical balance for small loads)

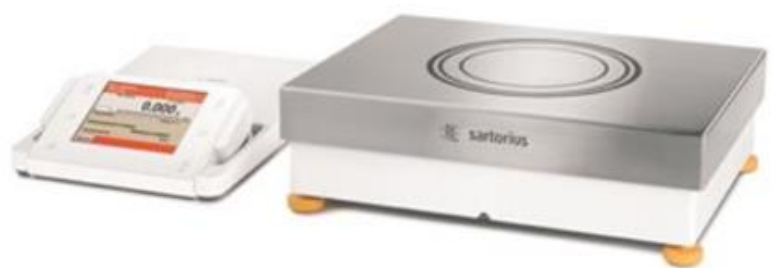
- Maximum weighing Capacity: 220 g/121 g
- readability: 0,1 mg; 0,01 mg
- Repeatability (typical): 0,02 mg (10 g)
- Minimum sample weight: 20 mg
- DAkkS Certificate
- usage: weighing of unloaded and loaded filters



Source: Mettler Toledo

Sartorius Cubis manual mass comparator MCM40K3

- Maximum weighing Capacity: 41 kg
- readability: 0,1 mg
- Repeatability (test weight): 2 mg
- DAkkS Certificate
- usage: precise mass loss determination of brake discs and tires



Source: Sartorius