



**MERIS Validation Team Meeting, JRC Ispra, 9.3.2011**

# **New calibration facility at DLR Oberpfaffenhofen**

P. Gege, DLR, Remote Sensing Technology Institute

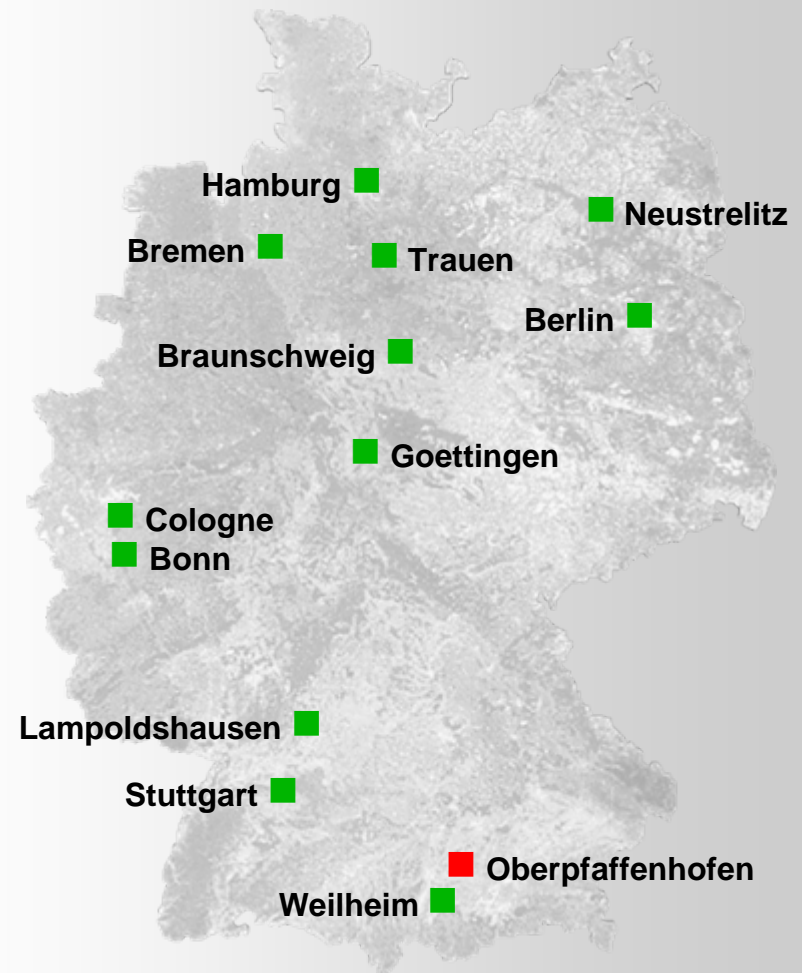


# DLR – German Aerospace Center

6700 employees across  
33 institutes and facilities at

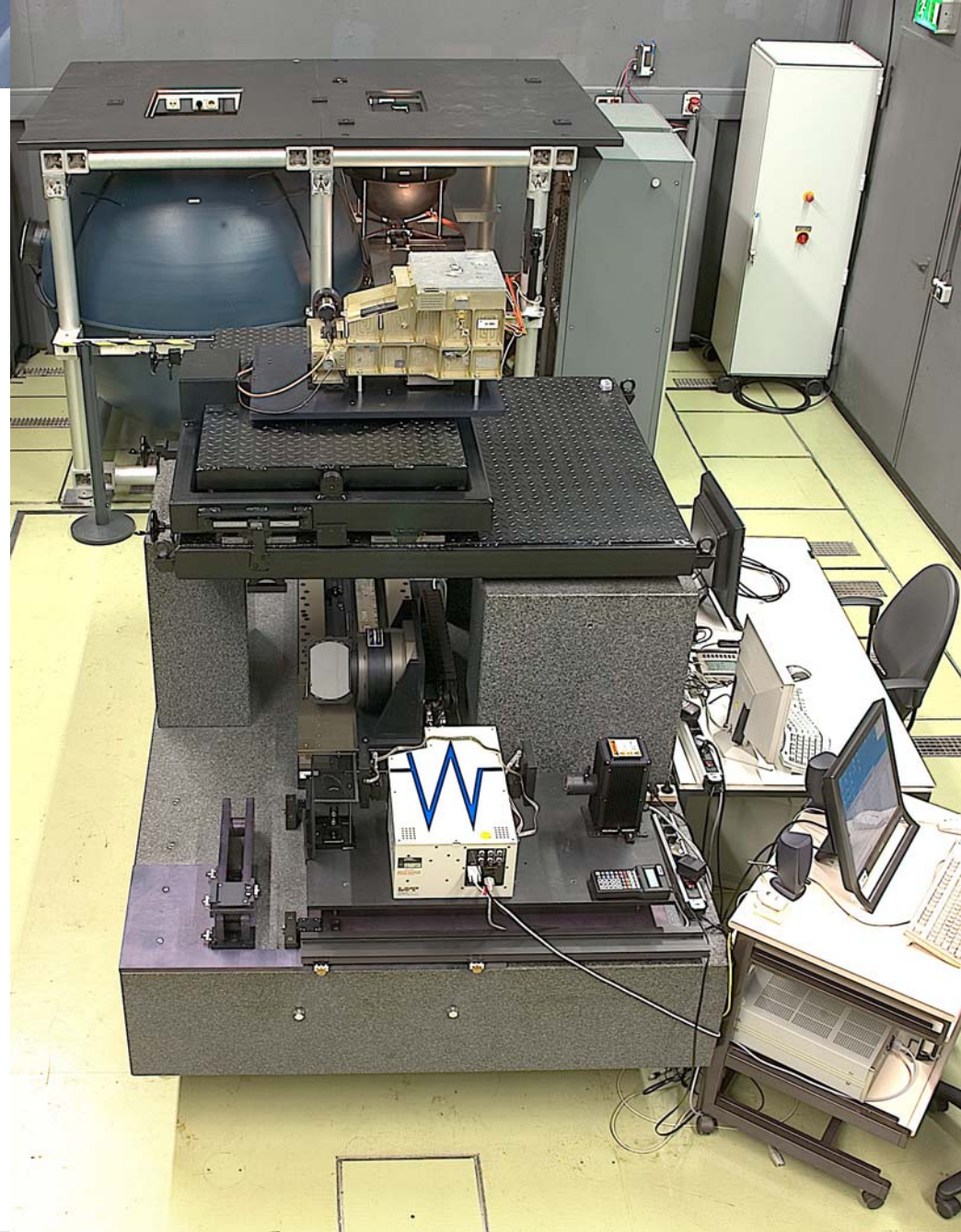
■ 13 sites.

Offices in Brussels,  
Paris and Washington.



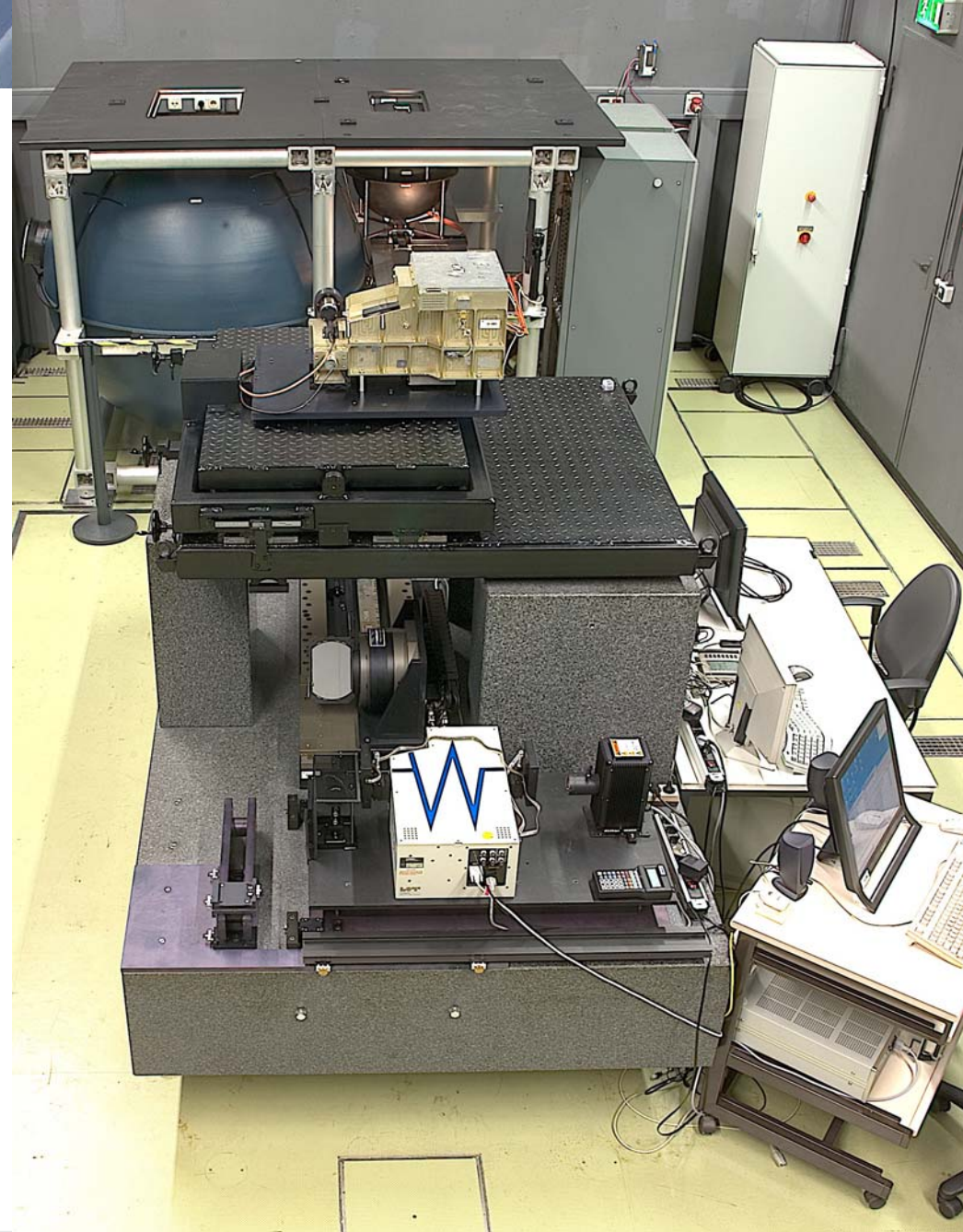
# Introduction

- Funded partly by ESA to establish **Calibration Home Base (CHB)** for APEX
- Designed for hyperspectral sensors similar to APEX
  - Mass: 170 kg (excl. adapter)
  - $\lambda$ -range: 380–2500 nm
  - Bandwidth: 5–10 nm
  - IFOV: 0.48 mrad
  - FOV:  $\pm 14^\circ$
- Operational since 2007.



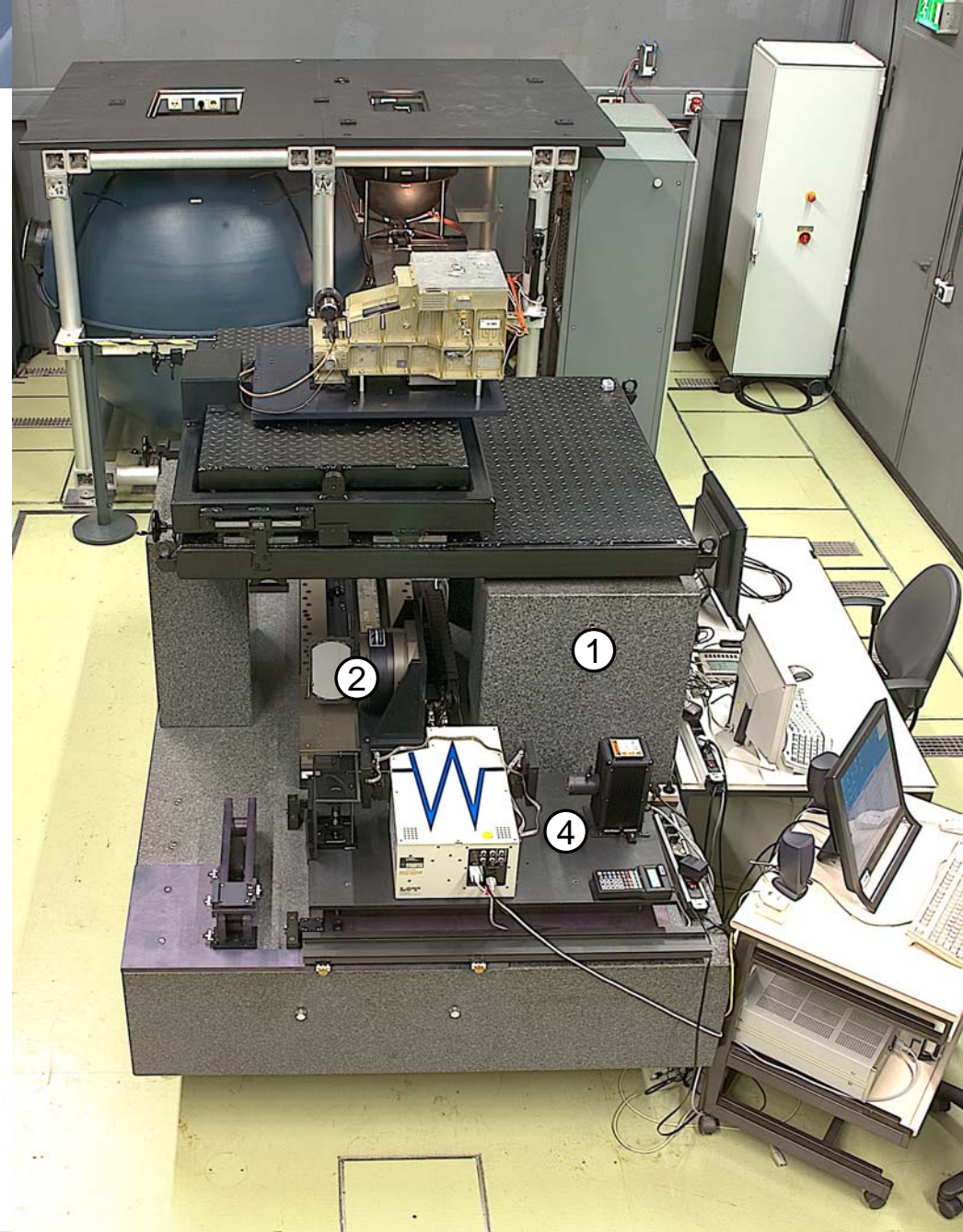
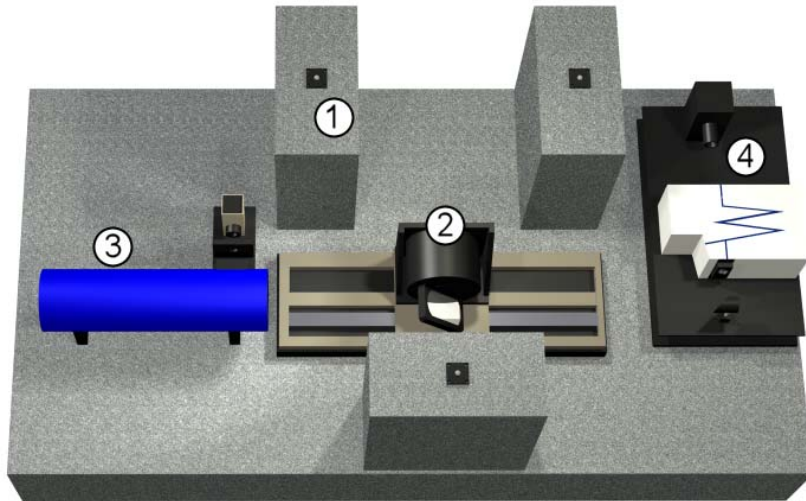
# Premises

- Close to airfield of DLR Oberpfaffenhofen
- Suited for bulky and heavy instruments up to 500 kg (incl. adapter)
- Sensor in same position as in aircraft
- Sensor stable on vibrationally isolated calibration bench
  - Spectral calibration
  - Geometric calibration



# Folding mirror concept

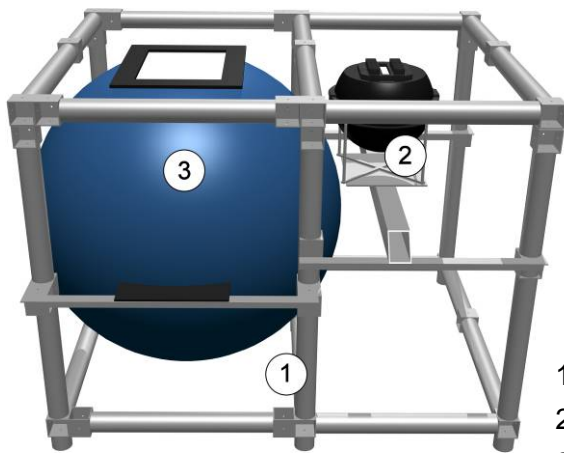
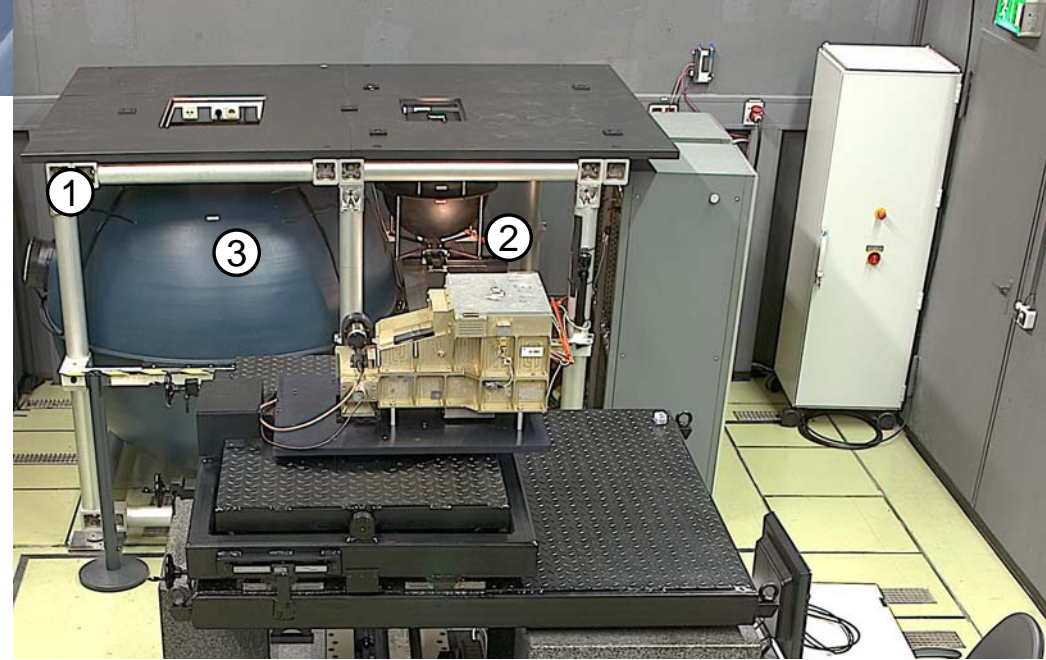
1. Pillar bearing instrument + adapter
2. Folding mirror
3. Assembly for geometric measurement.
4. Assembly for spectral measurement.



# Flat-field measurements

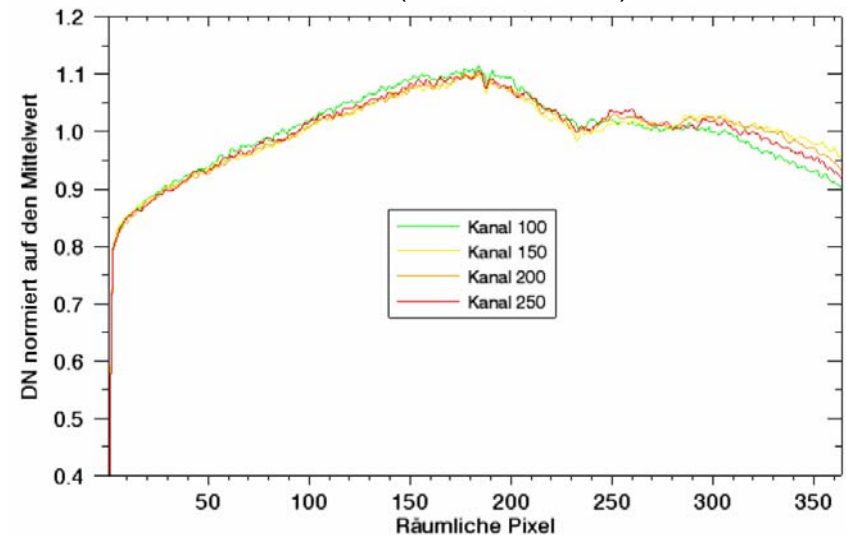
## Large integrating sphere ③

- $\varnothing$  1.65 m
- Aperture 55 x 40 cm<sup>2</sup>
- Inhomogeneity < 0.5 % rms
- 18 lamps
- Various radiance levels (57 – 1524 W m<sup>-2</sup>)



1. Frame
2. Small integrating sphere
3. Large integrating sphere

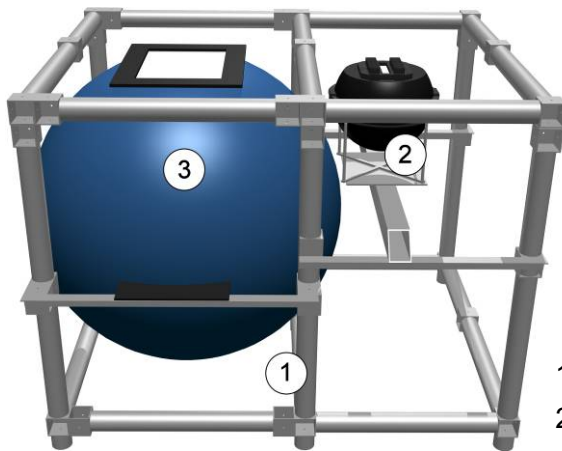
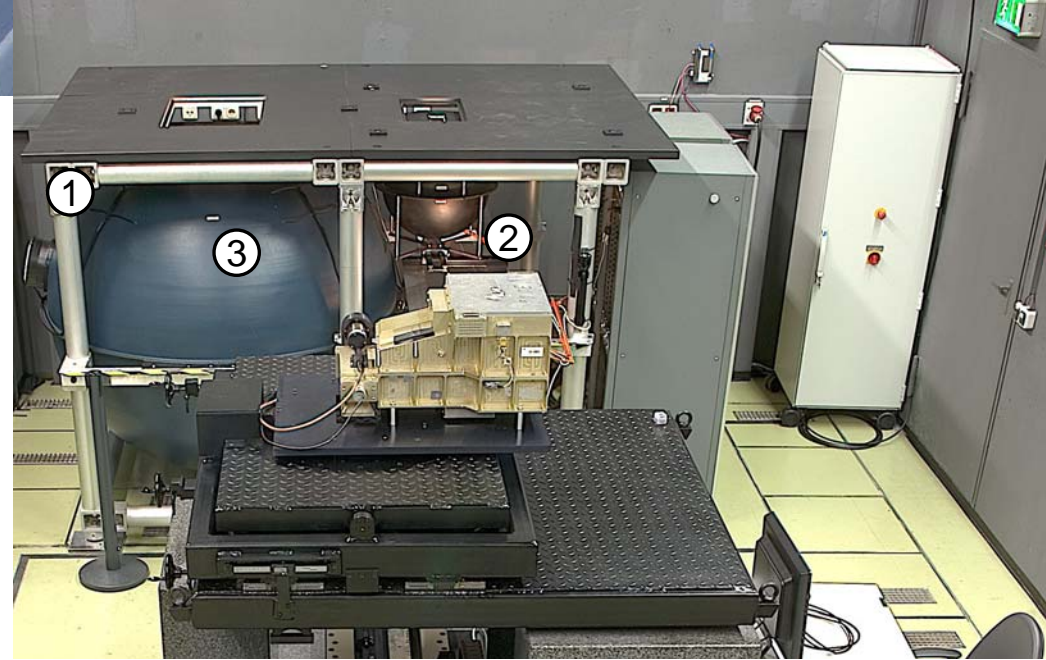
AISA (Kuhlbach 2008)



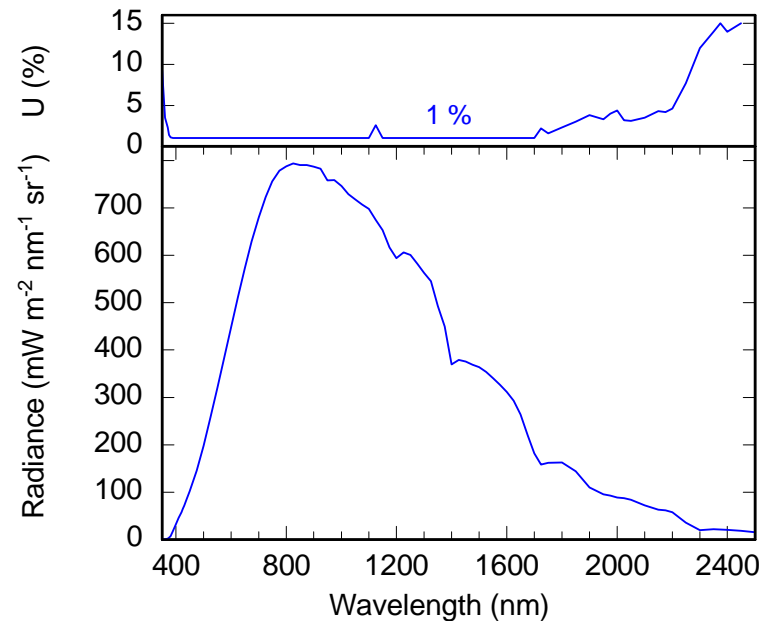
# Radiometric calibration

## Small integrating sphere ②

- $\varnothing$  0.50 m
- Aperture 4 x 20 cm<sup>2</sup>
- Traceable to PTB
- Uncertainty (k=2) 1 % in VIS



1. Frame
2. Small integrating sphere
3. Large integrating sphere



# Absolute radiometric calibration of radiance sources



## Relative radiance

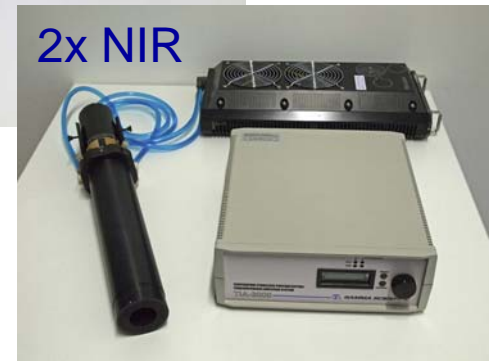
1. Calibrated halogen lamp
2. Calibrated diffuser
3. Spectrometer

## Absolute radiance

4. 5 Filter radiometers

## Uncertainty goal

- $1\sigma = 1.5\%$  at  $0.35\text{-}1.7\ \mu\text{m}$  (2011)
- $1\sigma = 2.5\%$  at  $1.7\text{-}2.5\ \mu\text{m}$  (2012)





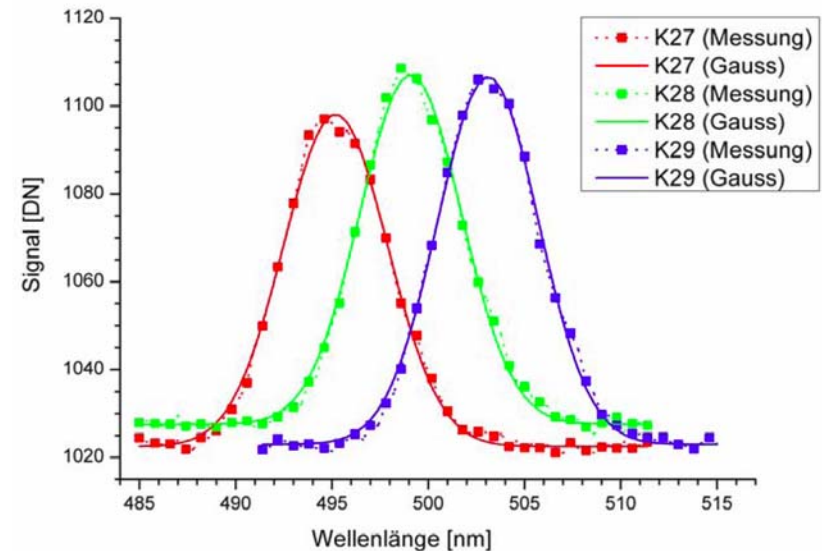
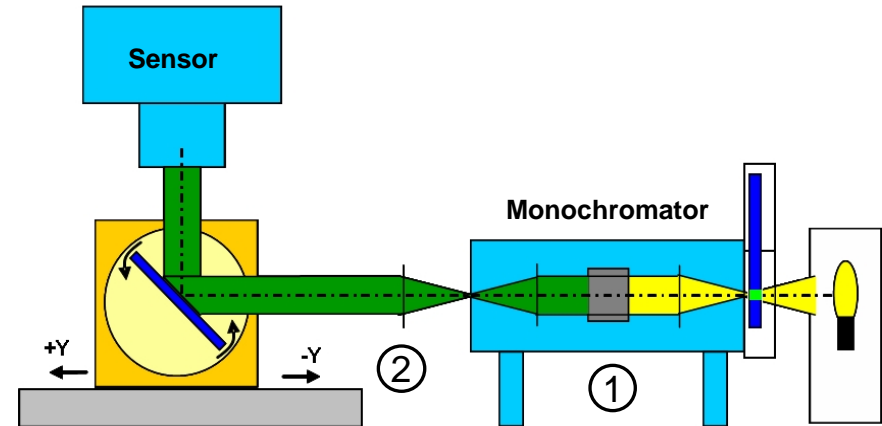
# Spectral measurements

## 1. Monochromator Oriel MS257

- Range: 0.38–14  $\mu\text{m}$  using 7 gratings
- Uncertainty:  $\pm 0.1$  nm
- Spectral bandwidth:  $> 0.1$  nm (depending on grating and slit width)

## 2. Parabolic mirror

- $f = 119$  mm
- Beam divergence  $\sim 0.8 \times 8$  mrad<sup>2</sup>
- Beam cross section  $\sim 3 \times 4$  cm<sup>2</sup>



Spectral response function of 3 ROSIS channels (Harder 2008)

# Spectral measurements: Tunable laser



## Specifications

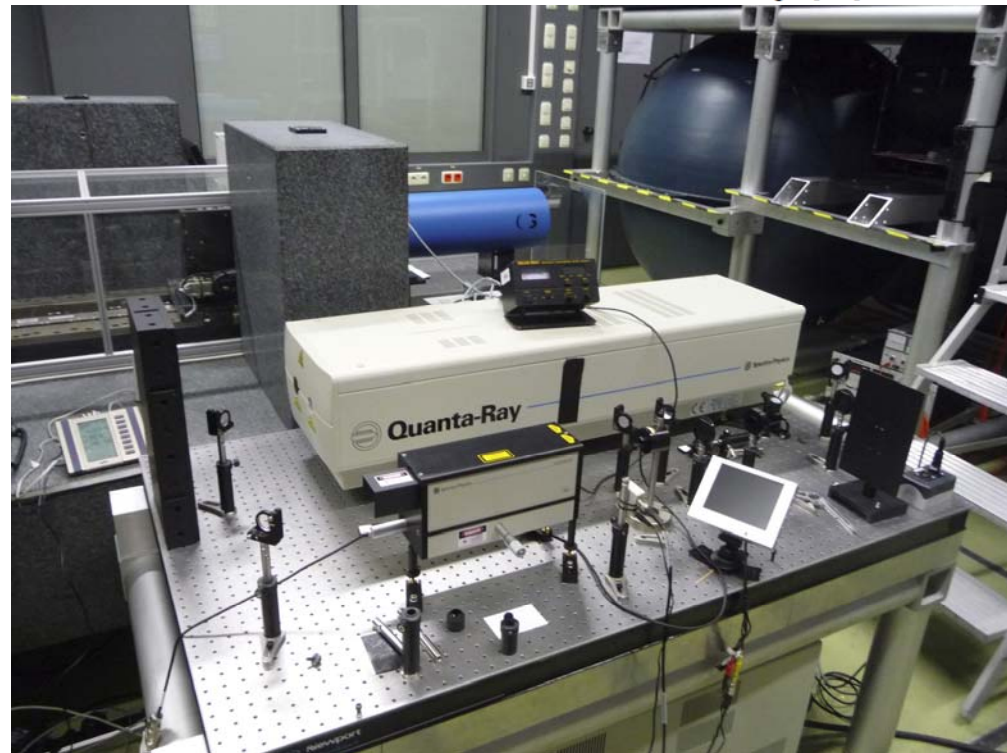
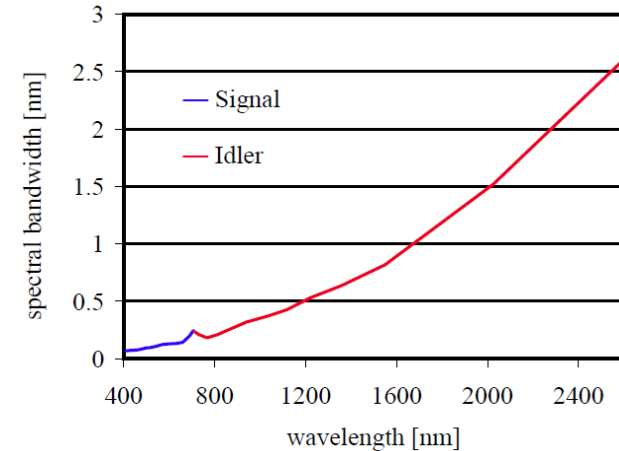
- Range: 0.4 – 2.5  $\mu\text{m}$
- Resolution: 3 – 7  $\text{cm}^{-1}$
- Repetition rate: 10 Hz

## Advantages

- High energy
- No sensor alignment
- All pixels simultaneous

## Disadvantages

- High safety requirements
- Fix bandwidth
- Pulsed (not suited for scanners)



# Geometric measurements

## 1. Slit wheel

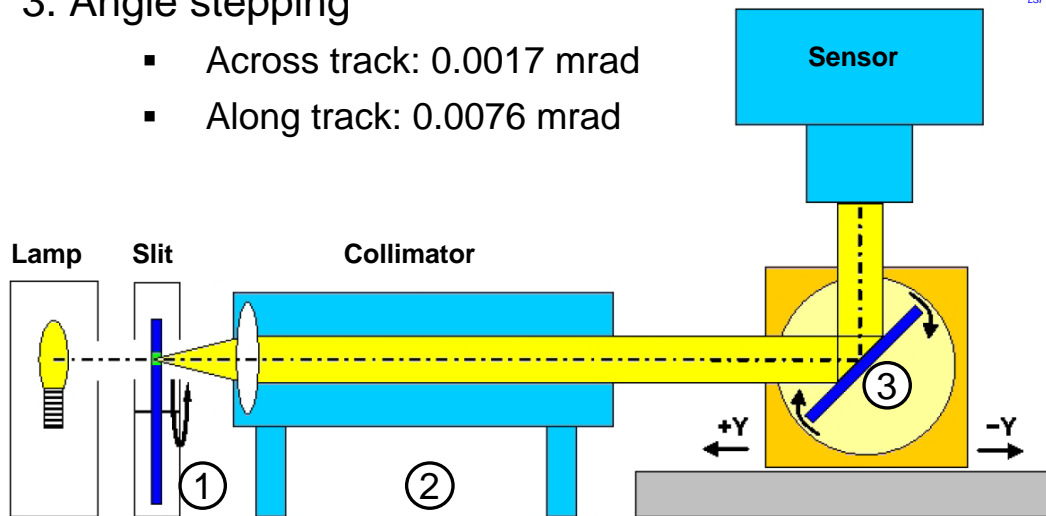
- 3 horizontal + 3 vertical slits
- Widths: 50, 100, 1000  $\mu\text{m}$

## 2. Collimator

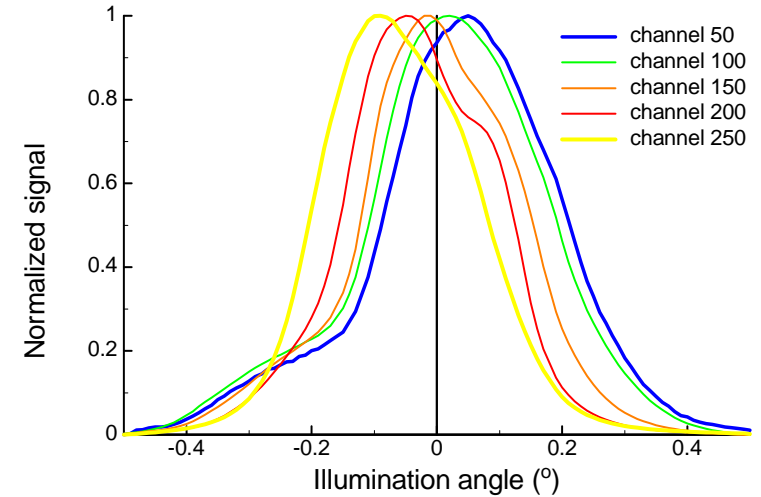
- $f = 750 \text{ mm}$
- Divergences: 0.067, 0.13, 1.3 mrad
- Beam cross section:  $\varnothing 12 \text{ cm}$

## 3. Angle stepping

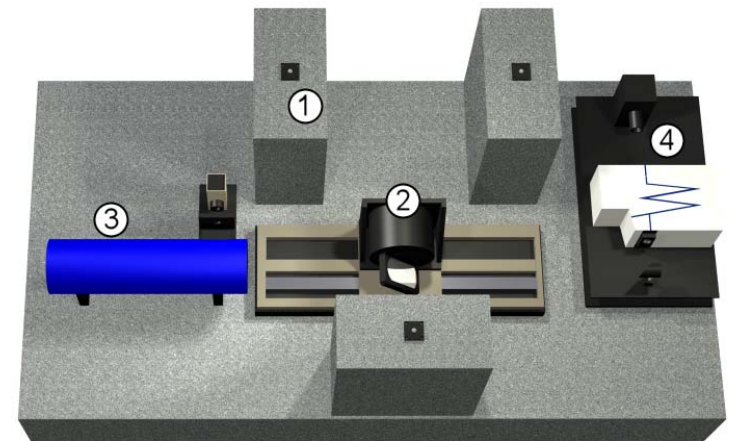
- Across track: 0.0017 mrad
- Along track: 0.0076 mrad



LSFs of AISA pixel no. 192  
(adapted from Suhr 2008)



LSF | 12.3.2009





# Auxiliary measurements

- Detector linearity
  - Small sphere and neutral density filters
- Spectral stray light
  - Monochromator
  - Small sphere and bandpass filters
  - **New: Tunable laser**
- Spatial stray light
  - From inside FOV: set-up for geometric measurements (LSF)
  - From outside FOV: large sphere and reflectance targets
- Polarisation
  - 3 linear polarisers 0.47 – 2.5  $\mu\text{m}$

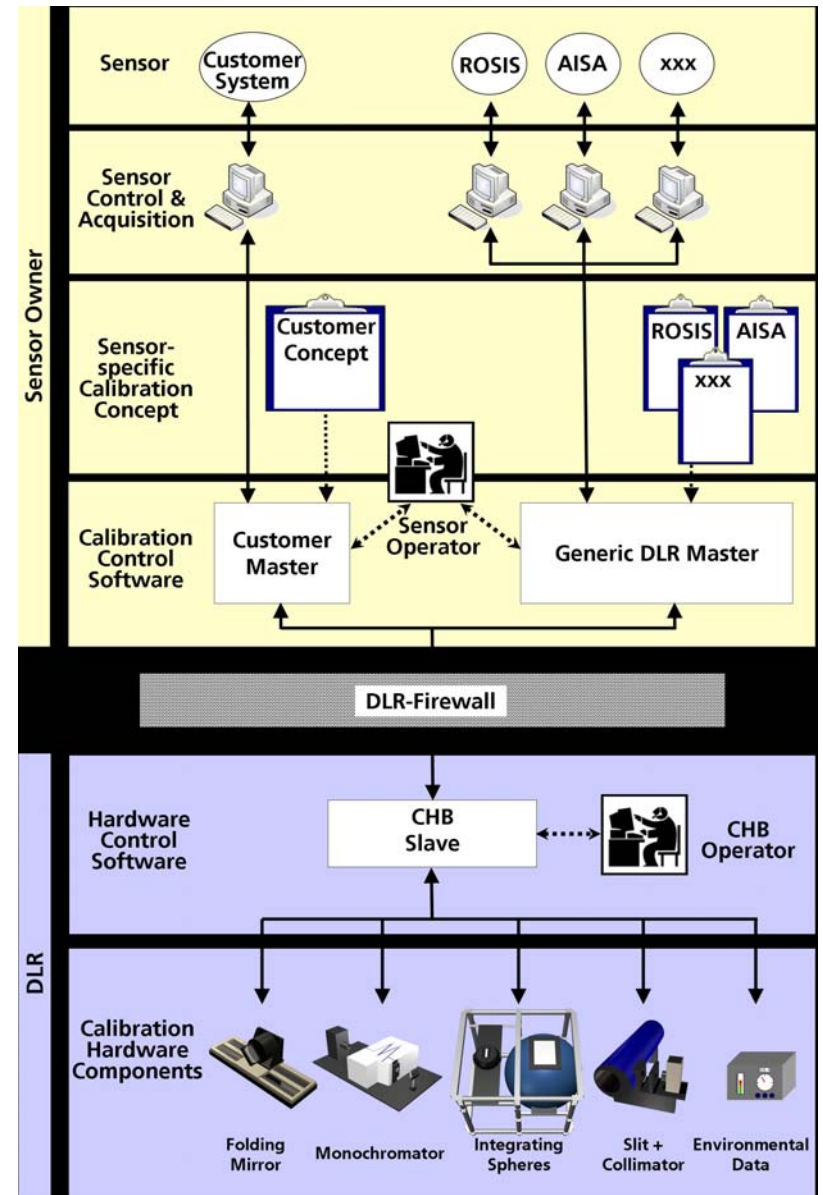
# Computer control

## ➤ CHB Slave

- Controls CHB hardware components

## ➤ CHB Master

- Measurement concept
- Commands sensor
- Commands CHB slave





# Service

- CHB infrastructure accessible to customers on request
  
- DLR contributions:
  - Consultancy (calibration concept, campaign planning)
  - Support for system adaptation (mechanics, software control)
  - CHB mobilisation, wrap-up
  - Operation of CHB subsystems during campaign
  - Tbd: scientific support (data evaluation, interpretation)
  
- Timeline:
  - Preparation phase (standard): 2-3 months
  - Campaign duration (standard): 1 week +
  
- Cost: 10 k€+

# Summary

## ➤ Facility for characterisation of airborne imaging spectrometers and field spectrometers

- Bulky and heavy instruments up to 500 kg
- Spectral range: 380 – 2500 nm
- Radiometry
- Spectroscopy
- Geometry

## ➤ Continuously upgraded

- Tunable laser
- Transfer radiometer



**CHB**  
Calibration Home Base

The Calibration Home Base (CHB) is an optical laboratory at DLR Oberpfaffenhofen for the calibration of airborne hyperspectral sensors and field spectrometers. It was partly funded by ESA to establish a calibration facility for the airborne imaging spectrometer APEX, but it is used for other optical sensors as well. It is the only facility in Europe which allows precise characterisation of the radiometric, geometric and spectral properties of bulky and heavy instruments up to 500 kg (including mechanical interfaces) in a wide spectral range from 380 nm to 14 µm.

**Principles**  
The CHB is located close to DLR's airfield in Oberpfaffenhofen and accessible to bulky instruments. It is installed in a large room (12.8 x 9.2 m, 9 m height), a crane is mounted on the ceiling for handling of heavy components. The room can be darkened. An air condition keeps the temperature at 22 ± 1 °C. Relevant environmental parameters (temperature, pressure, humidity, ambient light) are monitored and included automatically to each measurement protocol.

**Folding mirror concept**  
A folding mirror design facilitates angle-dependent geometric and spectral measurements of heavy instruments with high precision. The sensor is mounted on a massive optical bench using a mechanical interface which allows alignment of 1 axis and 2 angles. After alignment the sensor is kept in its position (downward looking like in the airplane). A flat mirror (12 x 18 cm) reflects the beam at a well-defined angle (±0.05°) most uncertainty to the sensor entrance. This 'folding mirror' can be tilted in order to set the angle of incidence, and it can be moved in horizontal direction (±7 cm) to meet the entrance aperture.

**Well-field measurements**  
The sensitivity of imaging sensors is usually not constant across the field of view due to response differences of individual pixels, variations of the entrance slit width, and vignetting of optical components. In particular for instruments with large aperture or large field of view, a large integrating sphere (1.65 m diameter) is available to measure these variations quantitatively. It is illuminated from the interior by 16 to 18 stabilised lamps and provides very homogeneous radiance for an area of 85 x 40 cm (variation < 0.3%). The radiant exitance can be changed from 67 to 1524 W/m<sup>2</sup> for adjustment to instrument sensitivity and to measure detector linearity. A photodiode inside the sphere monitors intensity changes.

**Radiometric calibration**  
Absolute radiometric calibration requires a source of well-known spectral radiance. CHB operates two sources which are certified against German national standard (PTB) for the spectral range 0.35-2.5 µm:

- integrating sphere (80 cm diameter, 4 x 25 cm opening). The uncertainty (k=2) is 1% from 390-1700 nm, it increases towards shorter and longer wavelengths.
- halogen lamp in combination with a reflectance panel (1.8 m x 0.9 m). The uncertainty (k=2) is 2.3% from 410-1700 nm, it increases towards shorter and longer wavelengths.

Both sources are monitored at each usage by means of a stable spectrometer (when the measured radiance differs at any wavelength in the range 400-600 nm more than 3% from the initial value, the source is re-calibrated at PTB).

**Deutsches Zentrum für Luft- und Raumfahrt e.V. German Aerospace Center**  
Space Sensing Technology Institute (Oberpfaffenhofen) 0-64244 Weßling

**Dr. Peter Gege**  
Phone: +49 8723 - 28 1240  
peter.gege@dlr.de

**www.dlr.de**

CHB online: [http://www.opairs.aero/chb\\_en.html](http://www.opairs.aero/chb_en.html)

P. Gege et al. (2009): Calibration facility for airborne imaging spectrometers. *ISPRS Journal of Photogrammetry & Remote Sensing* 64, 387-397. [doi:10.1016/j.isprsjprs.2009.01.006](https://doi.org/10.1016/j.isprsjprs.2009.01.006)