Instrumentation for Source-based Calibration of Space Instruments using Synchrotron Radiation at the Metrology Light Source (MLS)

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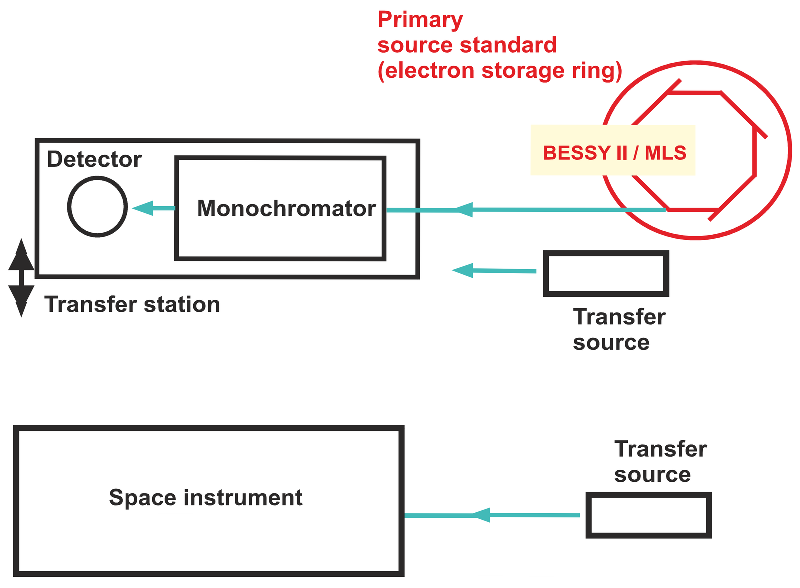
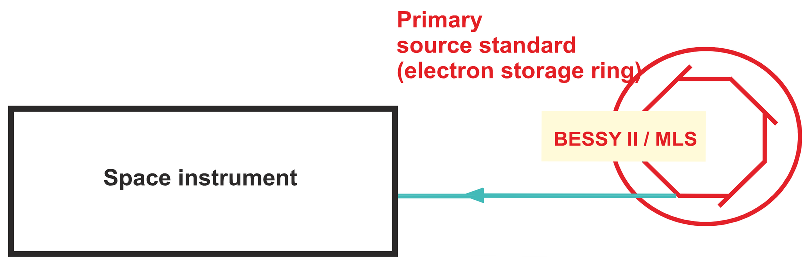
Introduction

For more than 20 years PTB has performed calibrations for numerous space missions within scientific co-operations using synchrotron radiation to cover the UV, VUV and X-ray spectral range. In this spectral range electron storage rings, the spectral radiant intensity of which can be calculated by classical electrodynamics, are used as primary sources of calculable spectral radiant intensity. At PTB, these are currently BESSY II and the MLS [1].





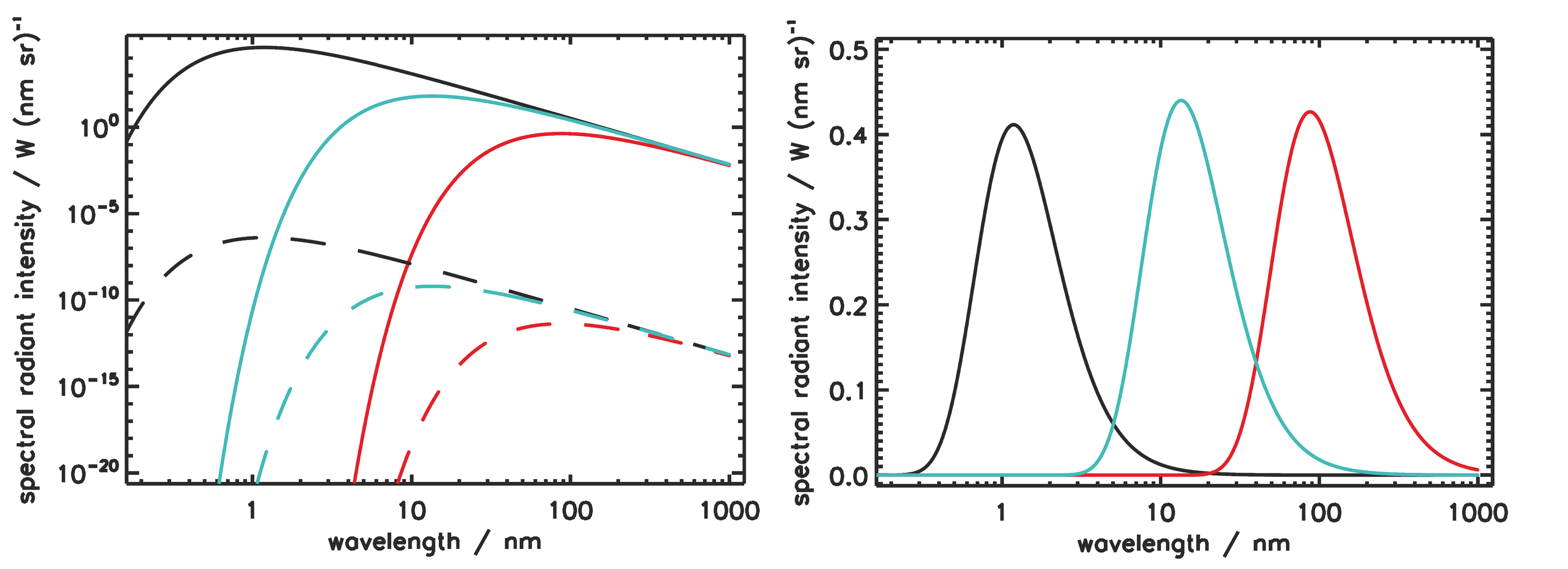
Source-based calibration schemes.

Below: Direct calibration of wavelength dispersive systems.

Right: Via use of a transfer source.

Source-based Calibrations

Source-based calibrations can then be done either by direct calibration of the instrument under test with radiation of the primary source standard (upper Fig. left scheme) or by means of a transfer source, that itself had been calibrated traceably to the primary source standard (upper Fig. right scheme). The first scheme has to be performed at the PTB laboratory at the electron storage ring, the second scheme can also be performed at the laboratory of the co-operation partner using the transfer source developed and calibrated by PTB. For the calibration of transfer sources, a new facility has been set-up at the MLS that covers the spectral range from 7 nm to 400 nm.



Spectrum and dynamic range of the calculable synchrotron radiation.

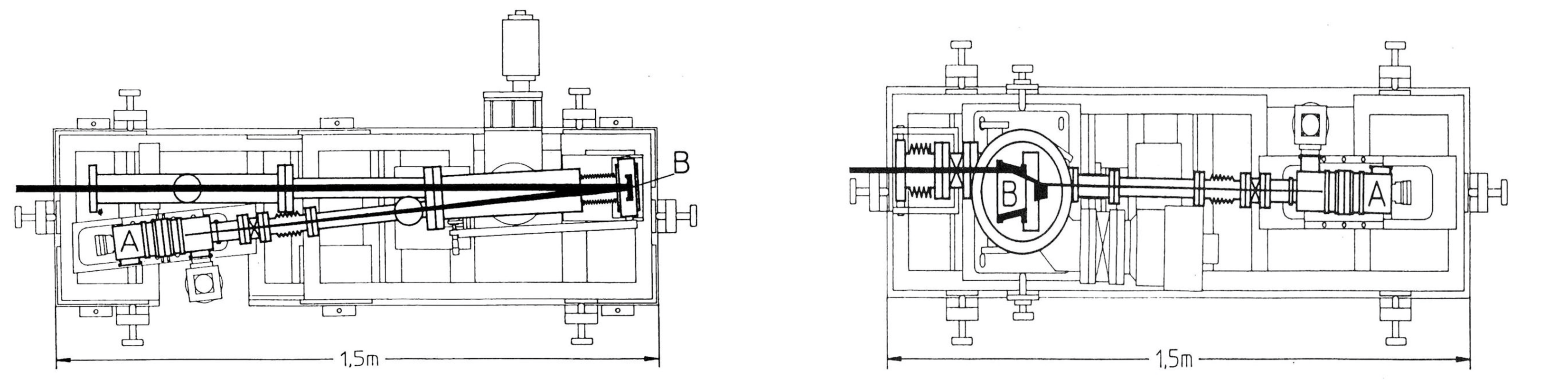
Left: The spectral radiant intensity can be altered within a dynamic range of more than 11 orders of magnitude. It is shown for an electron beam current of 100 mA (solid curves) and 1 pA (dashed curves) for different electron beam energies (black: 630 MeV, blue: 280 MeV, red:150 MeV).

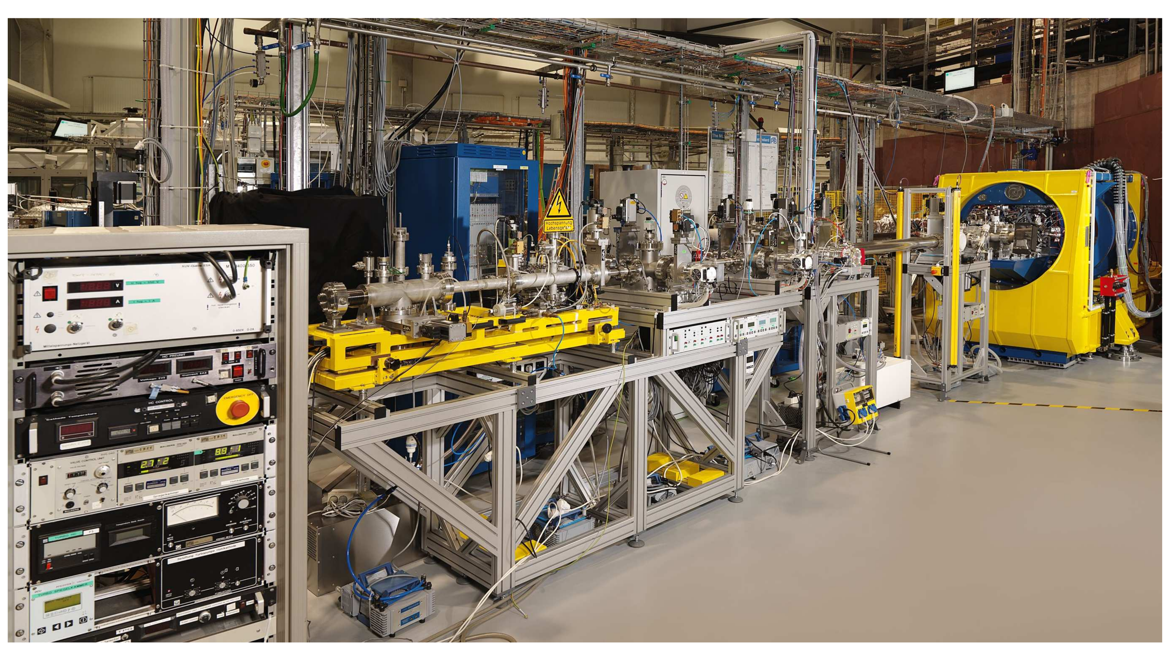
Right: Spectral radiant intensity on a linear scale for 630 MeV, 1 mA (black), 280 MeV, 700 mA (blue) and 150 MeV, 100 mA (red).

Calibration of Space Instruments

Selected missions with source-based calibrations by PTB

Year of Calibration	Wavelength Range	Instrument	Mission
1994	50 nm to 160 nm	SUMER (Solar Ultraviolet Measurements of Emitted Radiation)	SOHO (Solar and Heliospheric Observatory) launch Dec 2, 1995
1994	15 nm to 80 nm	CDS (Coronal Diagnostic Spectrograph)	
1996	15 nm to 80 nm	SERTS (Solar EUV Rocket Telescope and Spectrograph) launches Nov 18, 1997 and June 24, 1999	
2004	15 nm to 80 nm	EIS (EUV Imaging Spectrometer)	SOLAR-B launch Sep 22, 2006
2005	15 nm to 80 nm	MOSES (Multi-Order Solar EUV Spectrograph) launch Feb 8, 2006	
2007	17 nm to 37 nm	EUNIS (Extreme Ultraviolet Normal Incidence Spectrometer) launches in 2006, 2007 and 2008	
2002, 2007	180 nm to 320 nm	SOL-SPEC (Solar Spectral Irradiance Measurement)	SOLAR (Solar Monitoring Observatory / ISS) launch 2008
2015, 2016, 2018	50 nm to 100 nm	SPICE (Spectral Imaging of Coronal Environment)	Solar Orbiter





VUV transfer sources (A=hollow cathode discharge source, B=collimating optics) [3].

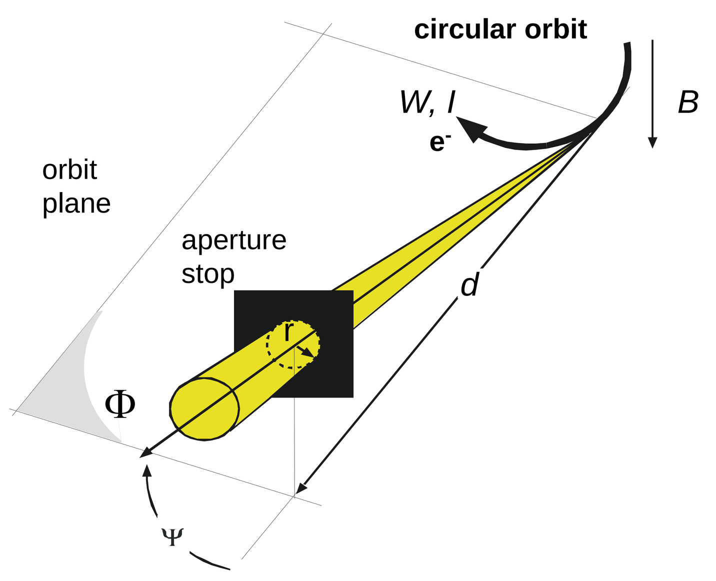
Left top: Source developed for the calibration of SUMER.

Right top: Source developed for the CDS calibration.

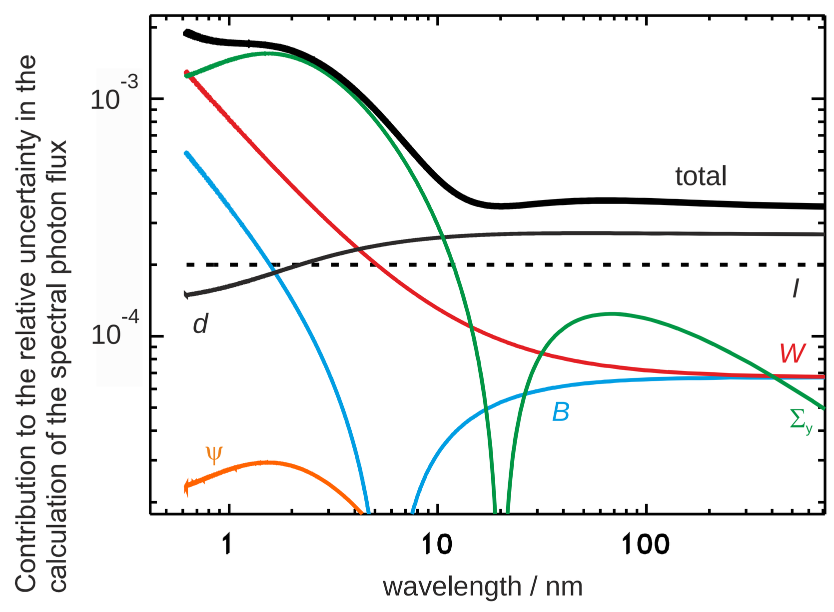
Left: SUMER transfer source with differential pumping section.

Primary Source Standards MLS and BESSY II

The radiant intensity of synchrotron radiation can be accurately calculated by the Schwinger formalism, since the parameters needed for the calculation can be determined with low uncertainty. The undispersed, calculable radiation from a bending magnet can be used either at a white light beamline, e.g. for the calibration of energy-dispersive detectors or wavelength-dispersive or selective spectrometers or, for the calibration of radiation sources (see below).



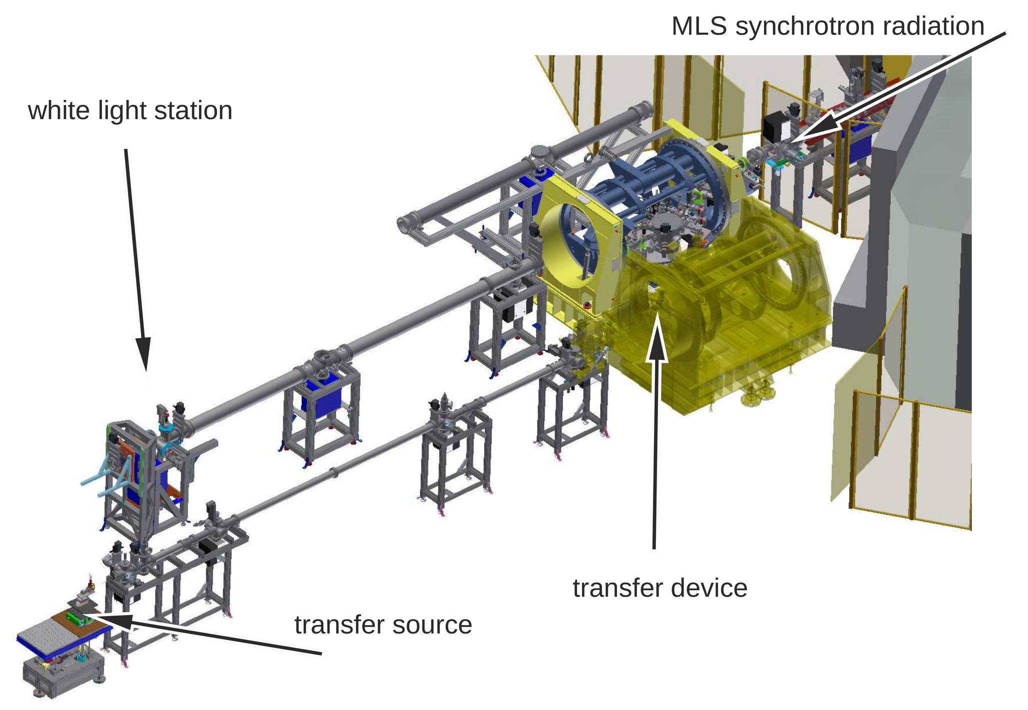
Parameters needed for the calculation of the spectral intensity of synchrotron radiation by the Schwinger formula.



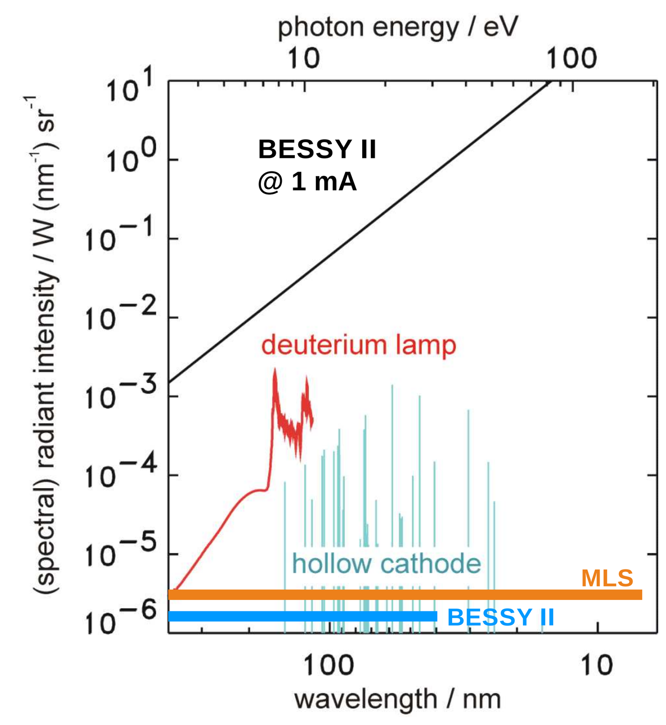
Influence of the parameters' uncertainty on the uncertainty in the calculation of the spectral radiant intensity of the synchrotron radiation.

Radiation Source Calibration

For the calibration of radiation sources a facility is operated at the MLS for the calibration of radiation sources in terms of spectral radiant intensity or spectral radiance in the spectral range from 7 nm to 400 nm [2]. At BESSY II a system for the calibration in the 40 nm to 400 nm spectral range is in operation.

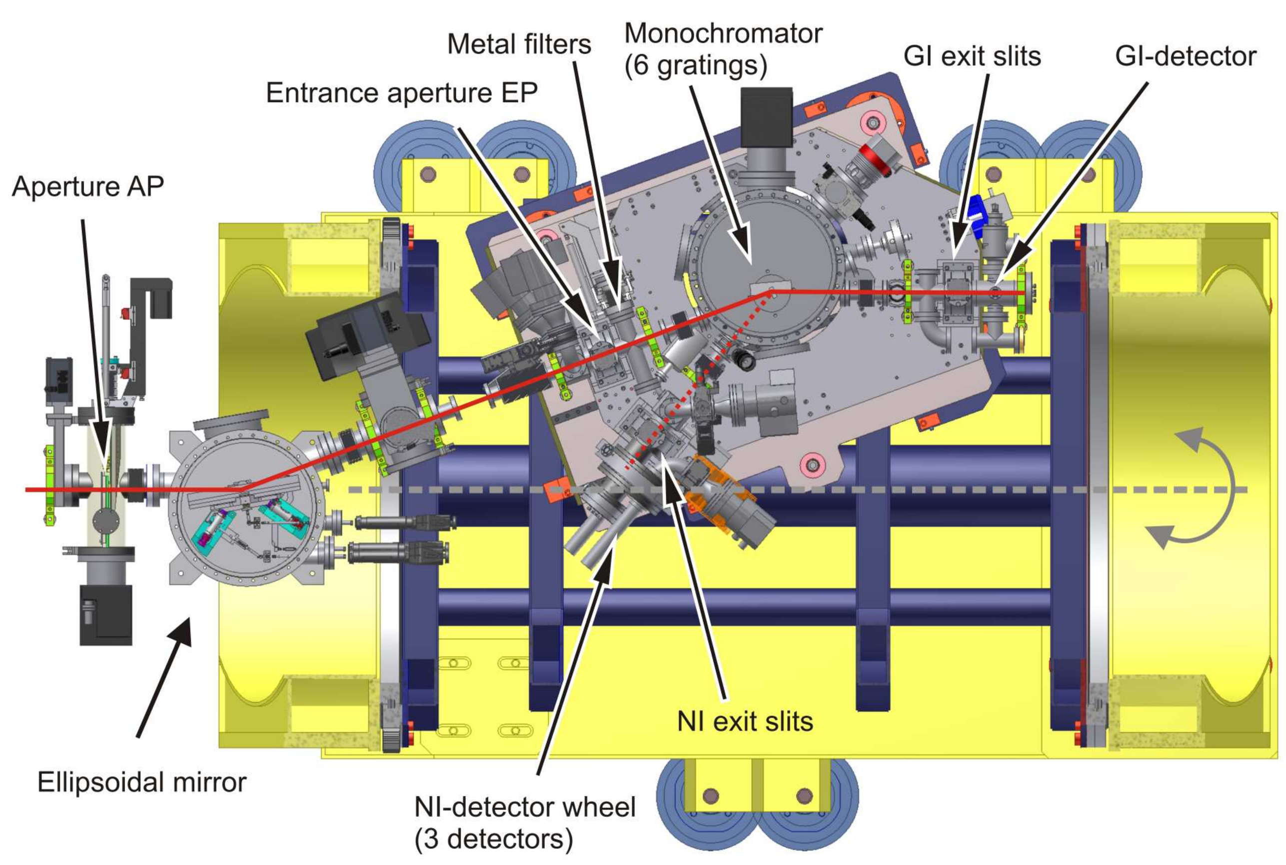


Transfer device for the calibration of radiation sources in the 7 nm to 400 nm wavelength range. The whole wavelength range is covered by six different gratings in a rotatable mounting by switching from GI to NI geometry.



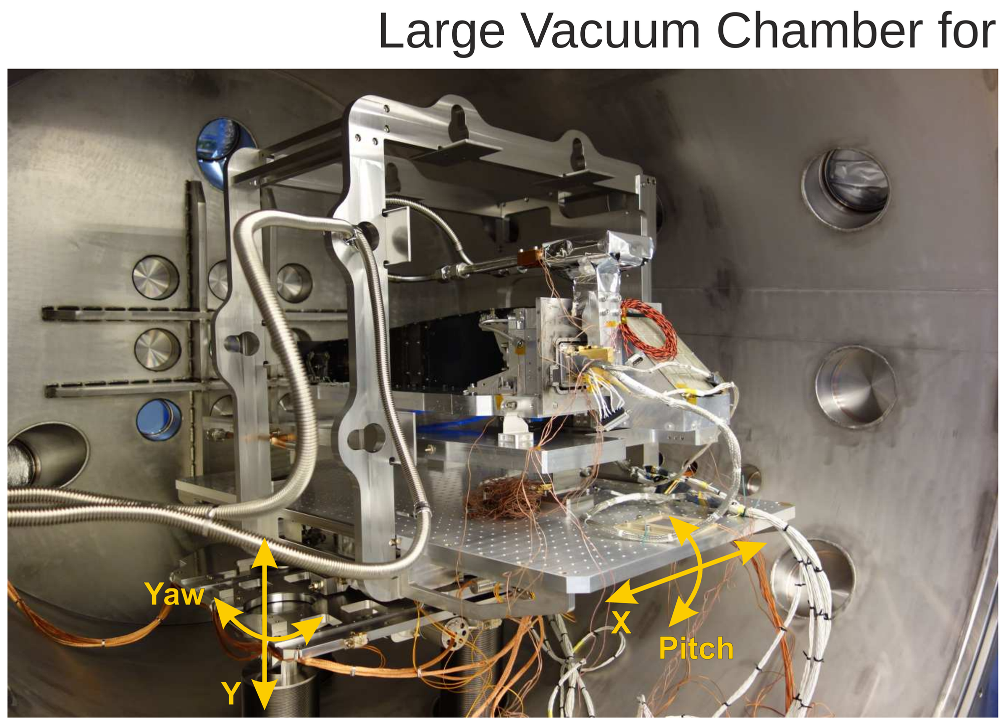
Above: Examples for calibrations of radiation source (performed at the BESSY II source calibration station). The newly set up facility at the MLS covers a larger spectral range (orange bar) as that at BESSY II (blue bar).

So the short wavelength lines of e.g. a hollow cathode discharge source can be calibrated. Hollow cathode sources are important constituents in transfer sources that have been used e.g. for the calibration of the SUMER and CDS spectrometers at the SOHO solar mission.

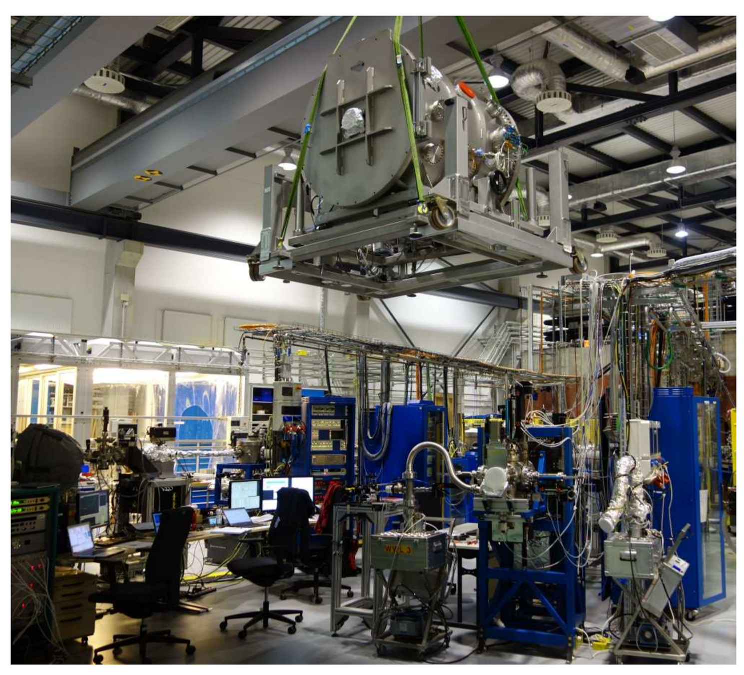


Left: Schematic view of the transfer device with its 6 gratings for normal incidence (NI) and grazing incidence (GI) geometries.

Large Vacuum Chamber for Space Instruments



Space instrument installed in the large vacuum chamber with a diameter of 1,5 m and a length of 1,6 m. The pressure inside the chamber is in the 10^{-7} mbar range).



Large vacuum chamber is transported from the clean room to the calibration beamline.

References:

[1] R. Klein et al., J. Astron. Telesc. Instrum. Syst. 2(4), 044002 (2016).

[2] R. Thornagel et al., Rev. Sci. Instrum. 86, 013106, (2015).

[3] J. Hollandt et al., Metrologia 30, 381 (1993).