All-Russian Research Institute for Optical and Physical Measurements
(VNIIOFI)

CURRENT ACTIVITY OF RUSSIA IN MEASUREMENT ASSURANCE OF EARTH OPTICAL OBSERVATION

Federal Agency
on Technical Regulating and Metrology

VNIIOFI

ROSCOSMOS Russian Federal Space Agency

ЦНИИМАШ TSNIIMASH

ЭНЕРГИЯ ENERGIA S.P.Korolev Rocket and Space Corporation

11th INTERNATIONAL CONFERENCE
on New Developments and Applications in Optical Radiometry
19-23 September 2011

CURRENT VNIIOFI's ACTIVITIES

within Global Earth Observation System of Systems project

1. Establishment of high quality national measurement standard facilities for pre-flight calibration of the Earth observation instruments.

2. Performing comparisons of national measurement standards.

VNIIOFI regularly participates in int. comparisons on
- spectral radiance and irradiance
- solar irradiance
- spectral sensitivity
- transmittance and diffuse reflectance of materials

3. Development of high-stable onboard standard IR radiation source (*fixed point low temperature blackbody*) for precise in-flight stability monitoring of the instruments.

4. Implementation of the international document «Quality Assurance Framework for Earth Observation - QA4EO» in Russia.

Pre-flight calibration
of Earth calibration instruments

Standard Radiometric Facility for ground high accuracy calibration of the Earth observation instruments with apertures up to 500 mm in (0.3÷25) µm wavelength range was developed at VNIIOFI in 2006-2010.

Required radiometric accuracy and stability of Earth observation instruments

The most stringent requirements to accuracy and long-term stability of Earth observation instruments are imposed by global climatic change monitoring*

Spectral range, μm	Accuracy	Stability (per decade)
0.3÷3.0	0.5 %	0.1 %
3.0÷25	0.1 K	0.01 K

**Satellite Instrument Calibration for Measuring Global Climate Change. NISTIR 7047.*

The solution:

- within spectral range 0.3÷3.0 μm - ground calibration with the unit transfer from absolute cryogenic radiometer as a standard detector

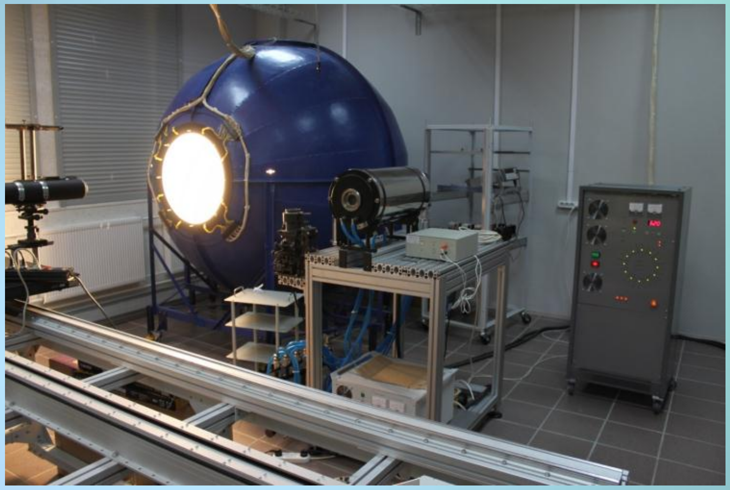
- within spectral range 3.0÷25 μm - ground calibration and in-flight stability control with the unit transfer from black body based on phase transition of eutectic alloy/pure metal as a standard source

VNIIOFI's Standard Radiometric Facility

0.3÷3 μm

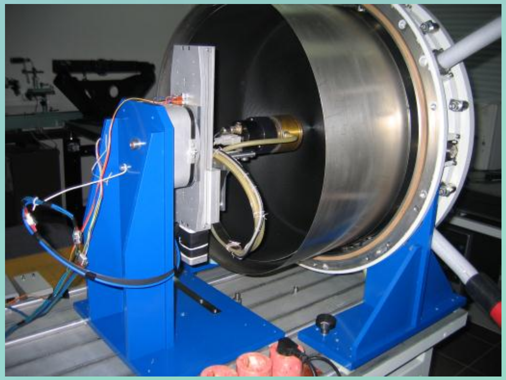
Monochromatic source

Integrating sphere,
high temperature blackbody

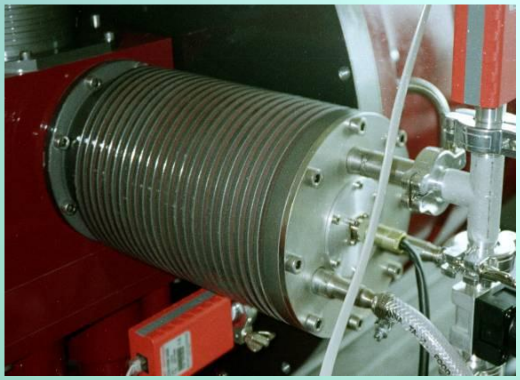


3÷25 μm

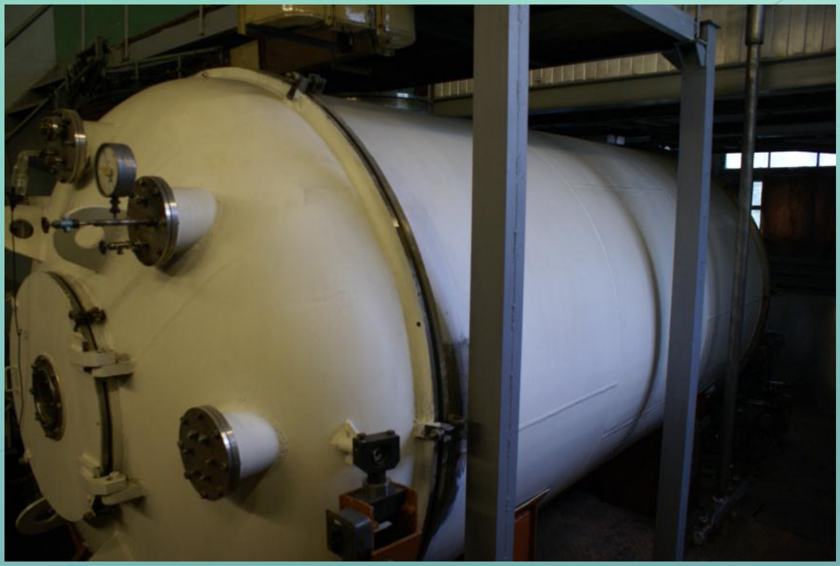
Large-area low temperature blackbody



Ga fixed-point blackbody

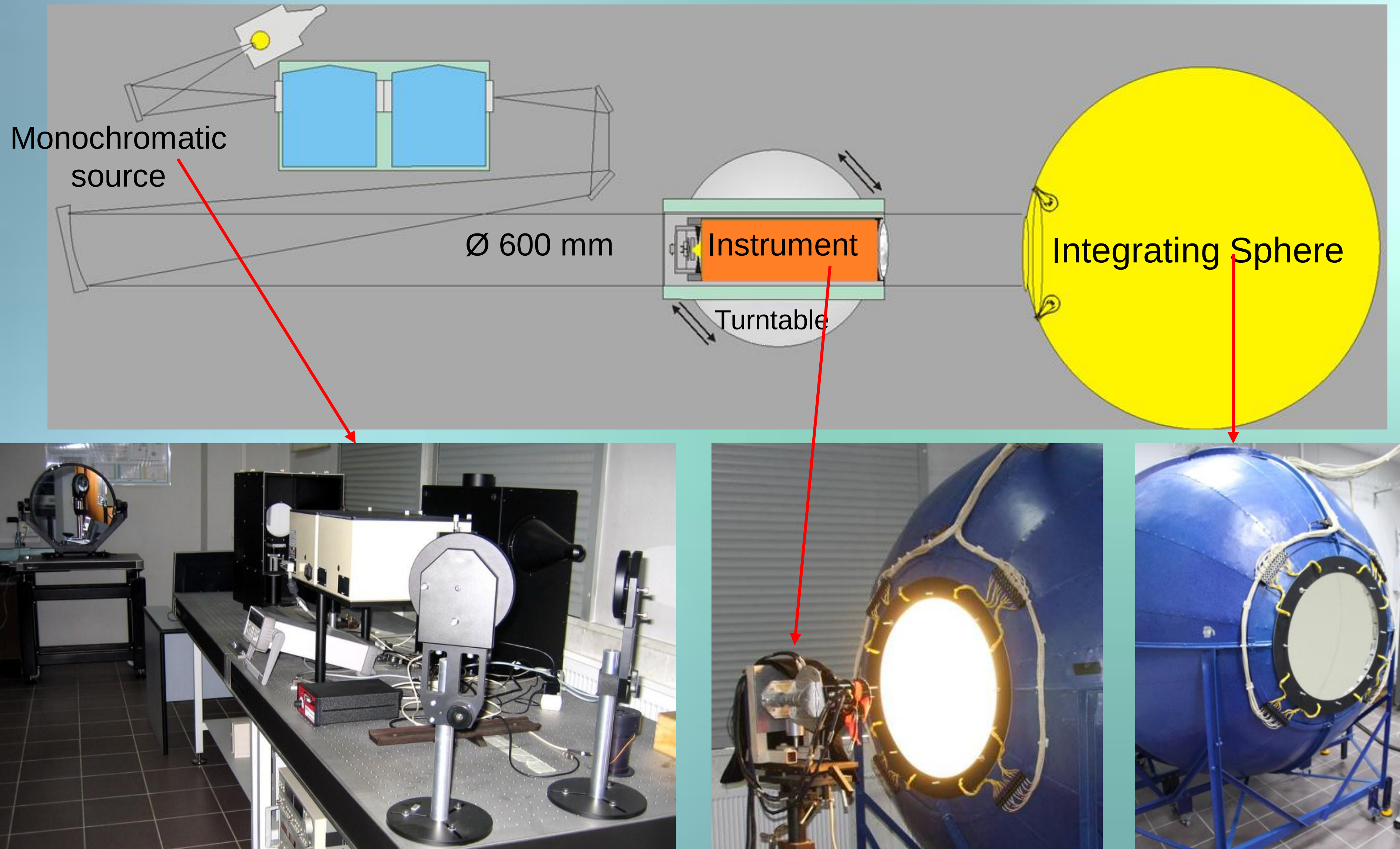


Cryogenic vacuum chamber

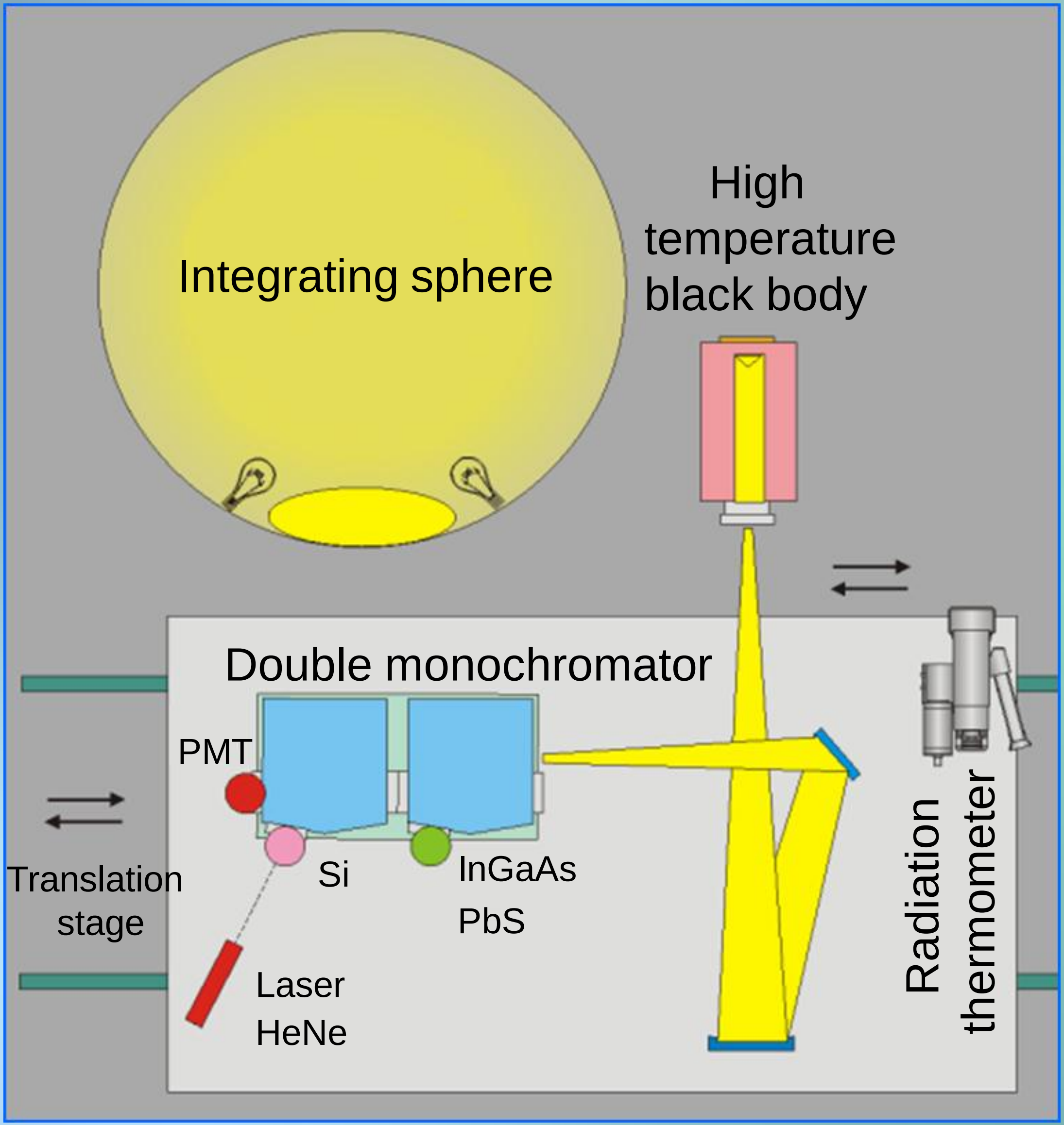


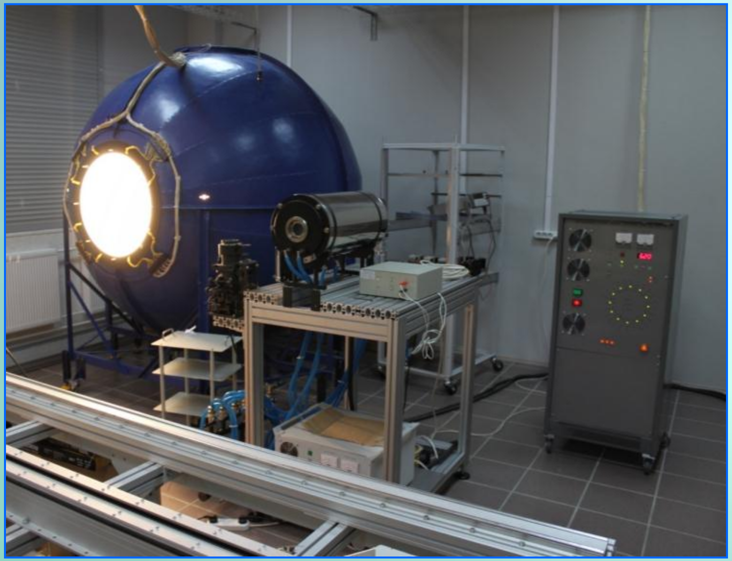
VNIIOFI's Standard Radiometric Facility

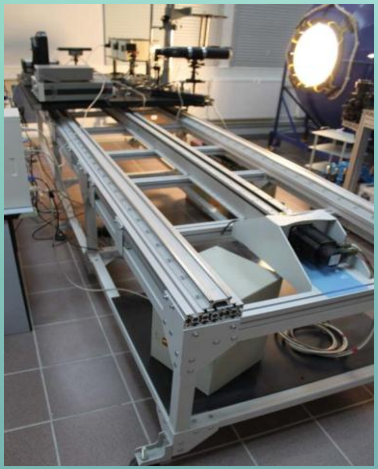
for calibration of Earth observation instruments in spectral range 0.3 ÷ 3.0 μm



Calibration of Integrating Sphere by comparison against high temperature blackbody



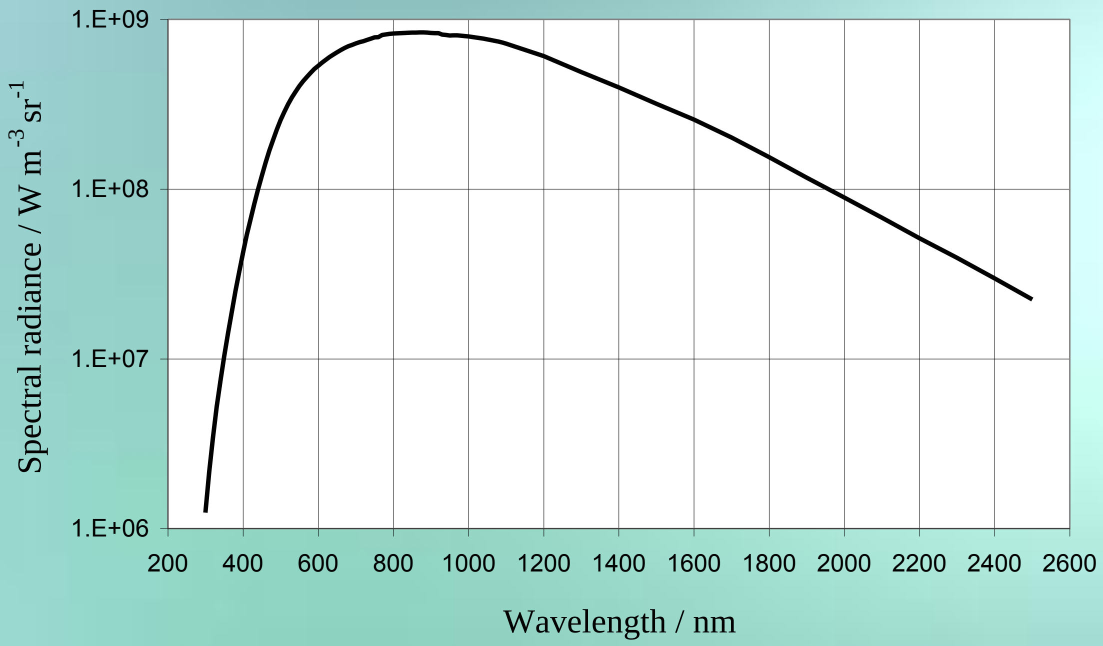




Metrological characteristics of Integrating Sphere

Uncertainty budget for spectral radiance within spectral range 0.3 ÷ 3.0 μm, %		
Type A	Standard deviation of measurements	0.2÷1.2
Type B	Size of source effect	0.2
	Scattered light	0.1÷0.6
	Non-linearity of measuring system	0.1÷0.8
	Wavelength shift	0.02÷0.2
	Nonhomogeinety over aperture area	0.2÷0.4
	Long-time stability of Integrating Sphere	0.25÷0.45
	Temperature of blackbody	0.04÷0.37
	Effective emissivity of blackbody	0.05÷0.1
Combined standard uncertainty		**0.5÷1.5**

Spectral radiance (logarithmic scale)



Wavelength (nm)	300	500	900	1100	1500	2500
Spectral radiance ($W \cdot m^{-3} \cdot sr^{-1}$)	$1.24 \cdot 10^{6}$	$2.55 \cdot 10^{8}$	$8.31 \cdot 10^{8}$	$7.87 \cdot 10^{8}$	$3.18 \cdot 10^{8}$	$2.23 \cdot 10^{7}$
Combined standard uncertainty (%)	1.5	0.6	0.5	0.7	1.0	1.5

$$i_{FR} = \frac{\pi \cdot D^2}{4 \cdot l^2} \cdot \varepsilon_{eff} \cdot \int_{\Lambda} F(\lambda) \cdot L_{BB}(\lambda, T) \cdot S_{FR}(\lambda) \cdot d\lambda$$

i_{FR} - FR signal
$S_{FR}(\lambda)$ - spectral irradiance responsivity of FR
D - diameter of BB aperture
ε_{eff} - effective emissivity of BB
$F(\lambda)$ - correction factor for diffraction

$$L_{BB}(\lambda, T) = \frac{c_1}{\pi \cdot \lambda^5 \cdot n^2} \cdot \left[\exp\left(\frac{c_2}{\lambda \cdot T \cdot n} \right) - 1 \right]^{-1}$$

Metrological characteristics of Integrating Sphere

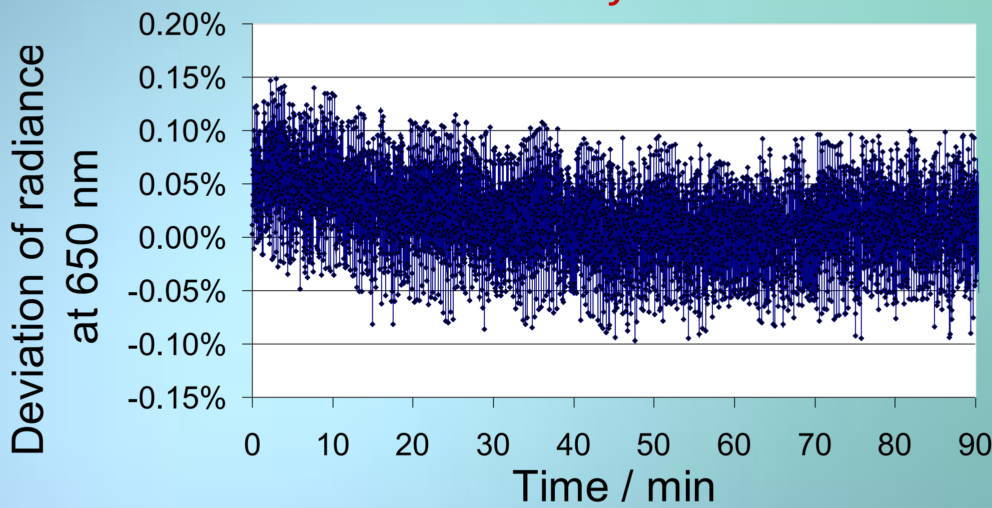
Radiation thermometer TSP-2
Central wavelength -650 nm
Band - 20 nm

Spatial uniformity

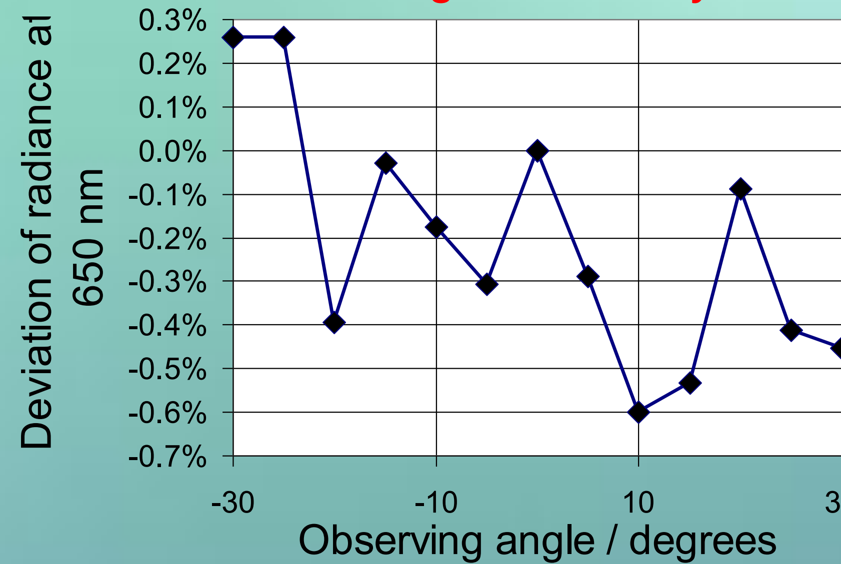
Deviation of radiance from the weighted average at 650 nm

	Horizontal/vertical coordinate with origin in center of aperture (mm)										
	-250	-240	-210	-140	-70	0	70	140	210	240	250
250						***0.77%***					
240					0.75%	0.65%	0.56%				
210				0.47%	0.66%	0.53%	0.47%	0.45%			
140			0.33%	0.54%	0.51%	0.75%	0.59	0.50%	0.66%		
70		0.46%	0.55%	0.44%	0.58%	0.41%	0.34%	0.40%	0.30%	0.38%	
0	0.01%	0.11%	0.12%	0.41%	0.31%	**0.20**%	0.20%	0.49%	-0.37%	-0.20%	-0.39%
-70		-0.14%	-0.04	-0.22%	-0.11%	-0.05%	-0.01%	0.11%	-0.43%	-0.48%	
-140			0.09	-0.01%	-0.31%	-0.30%	-0.05%	-0.12%	-0.38%		
-210				-0.97%	-1.28%	***-1.50%***	-0.96%	-1.26%			
-240					-1.20%	-1.30%	-1.06%				
-250						-1.45%					

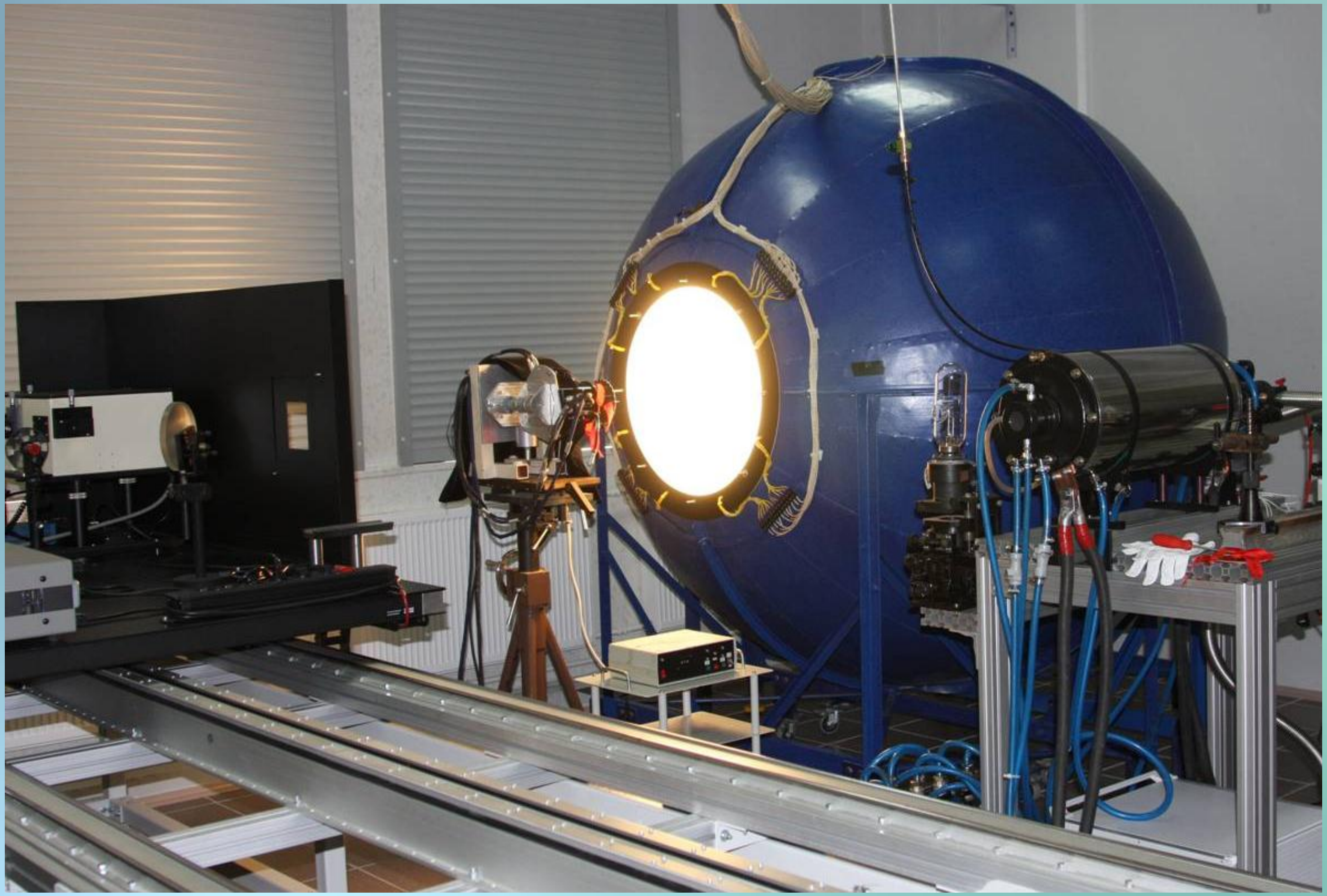
Time stability

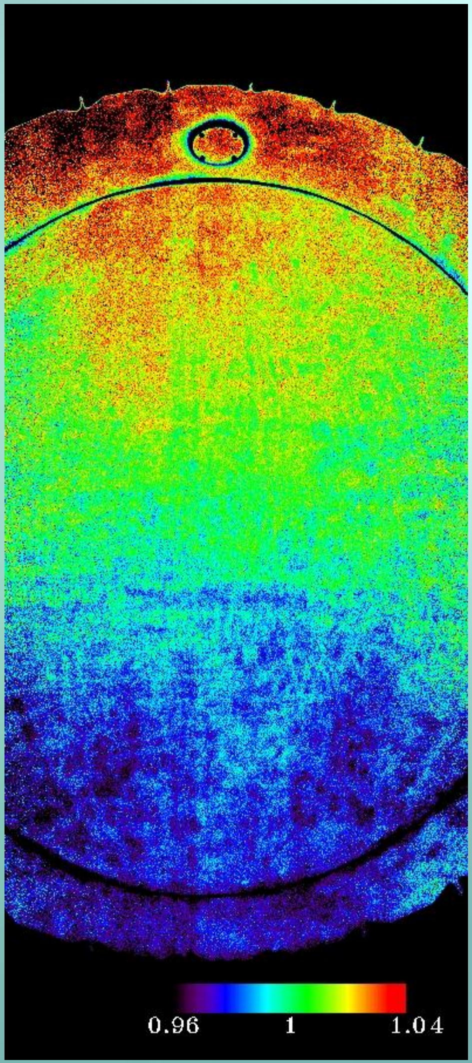


Angle uniformity



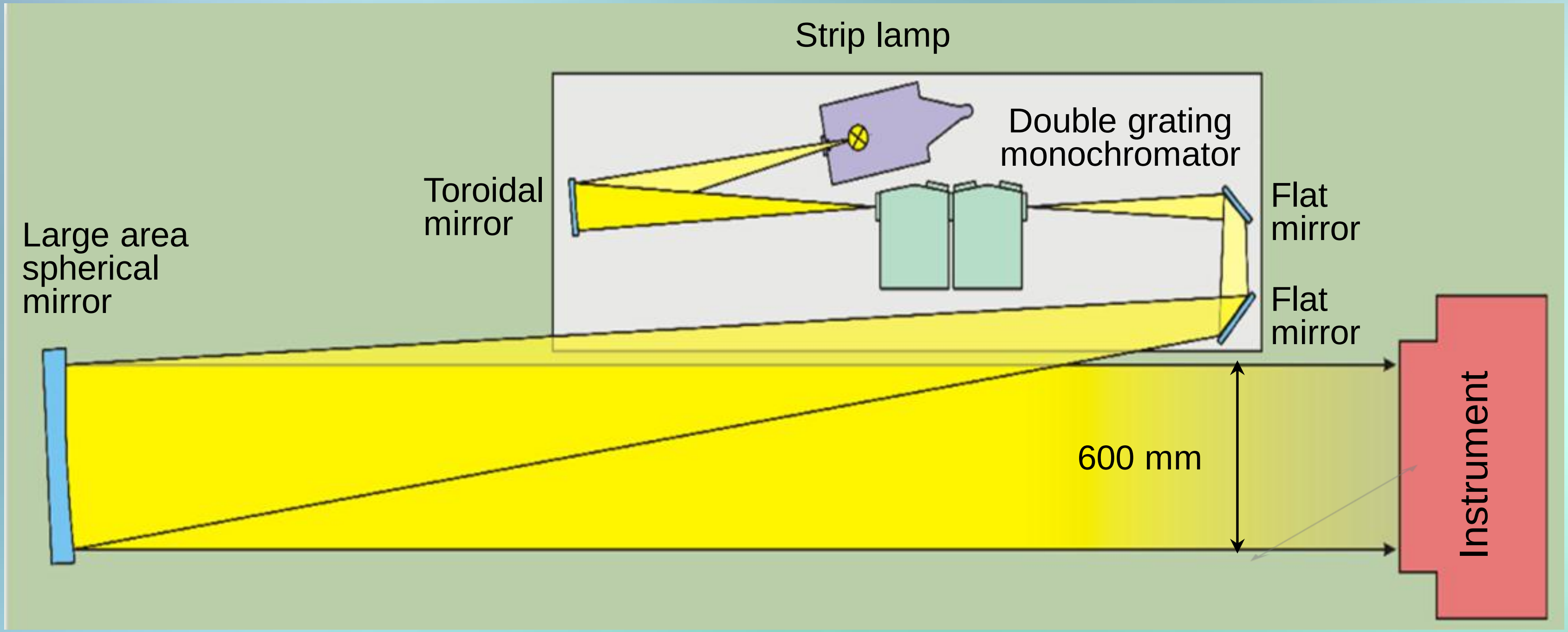
Space Research Institute (IKI RAN, Russia) space-borne radiometer calibration





Radiance of upper part of aperture area exceeds about 2 % the radiance of lower part. This result is in accordance with result of our previous measurements by radiation thermometer.

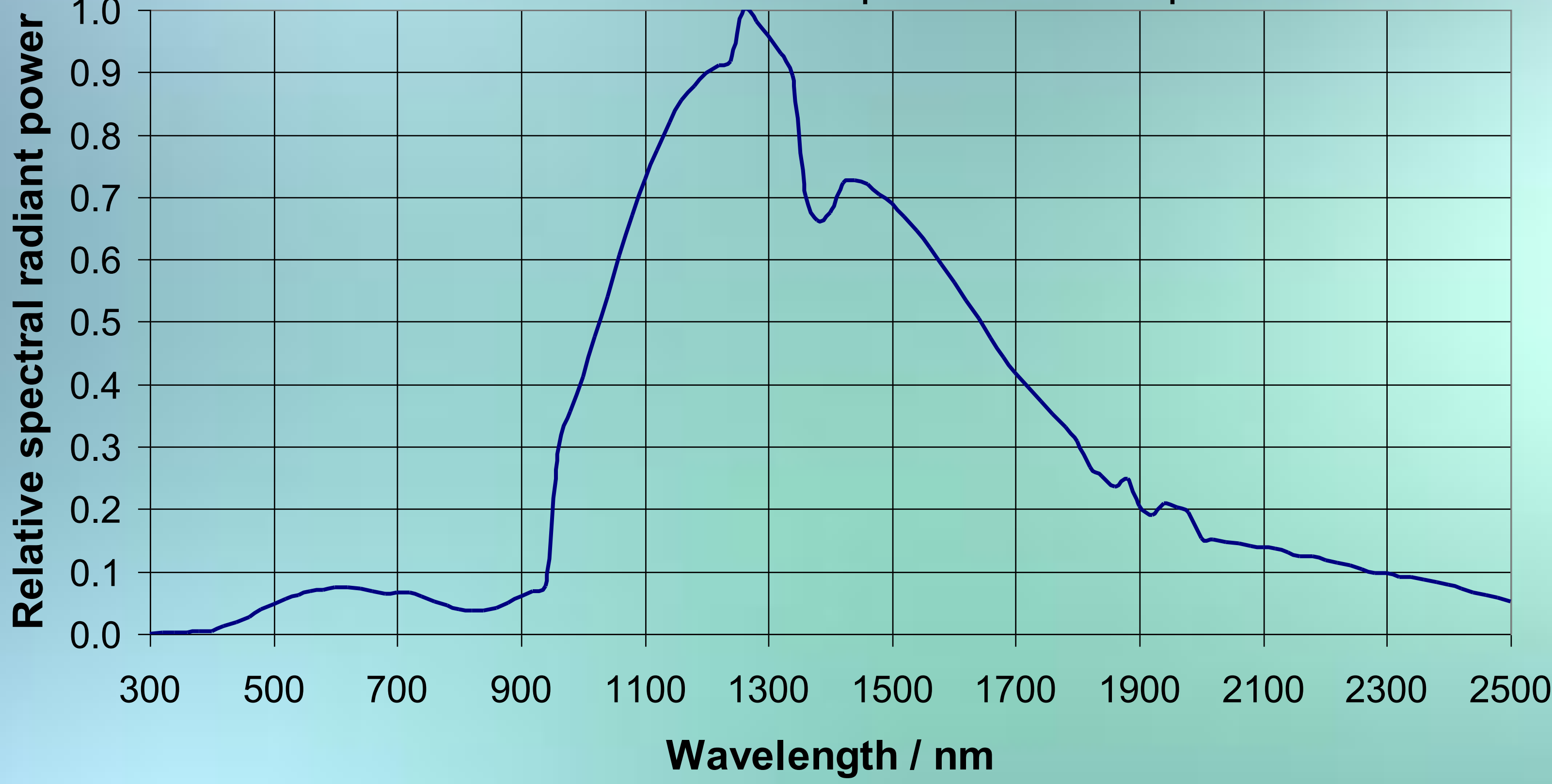
Monochromatic Source



Uncertainty budget for relative distribution of spectral radiant power within spectral range 0.3÷3.0 μm		
Uncertainty components	Type	Relative standard uncertainty (%)
Standard deviation of measurements	A	0.03 ÷ 1.3
Detectors sensitivity	B	0.17 ÷ 1.15
Precision and non-linearity of measuring system	B	0.003
Wavelength accuracy	B	0.003 ÷ 0.07
Spectral reflection coefficients of mirrors	B	0.28
Combined standard uncertainty		***0.33 ÷ 1.76***

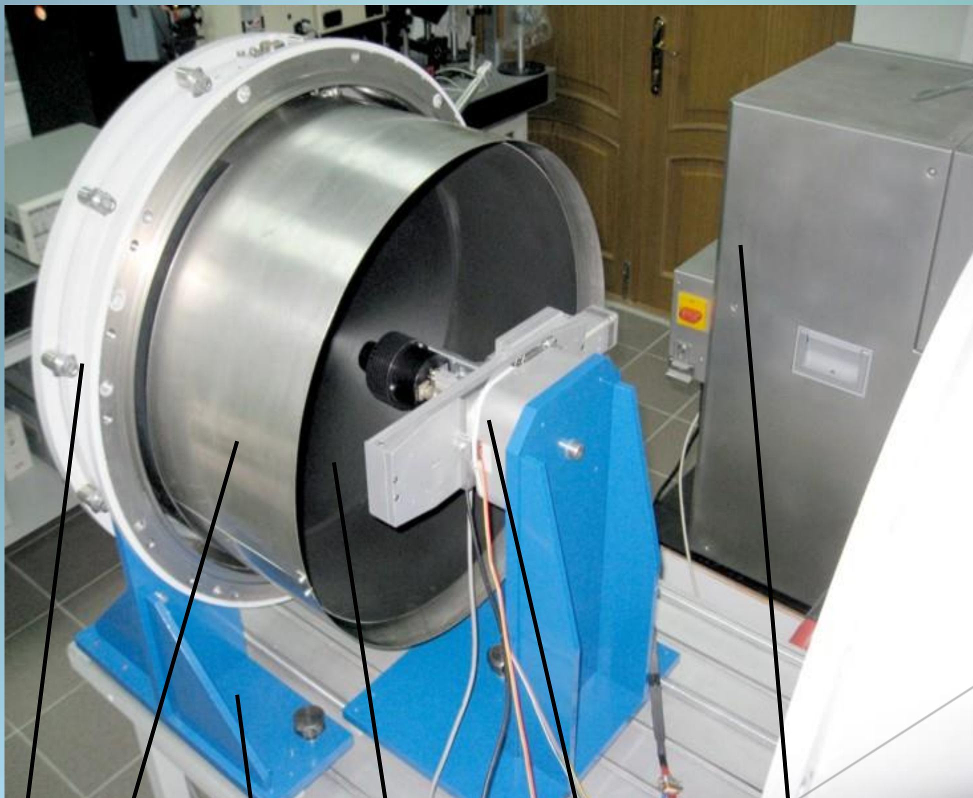
Monochromatic Source

Relative distribution of spectral radiant power



Wavelength, μm	300	500	900	1300	1500	2500
u_A(MS),%	1.59	0.04	0.02	0.08	0.14	0.07
u_B(MS),%	0.37	0.33	0.99	1.65	1.75	1.76
u_c(MS),%	1.71	0.33	0.39	1.76	1.76	1.76

Large area low temperature blackbody (LABB)

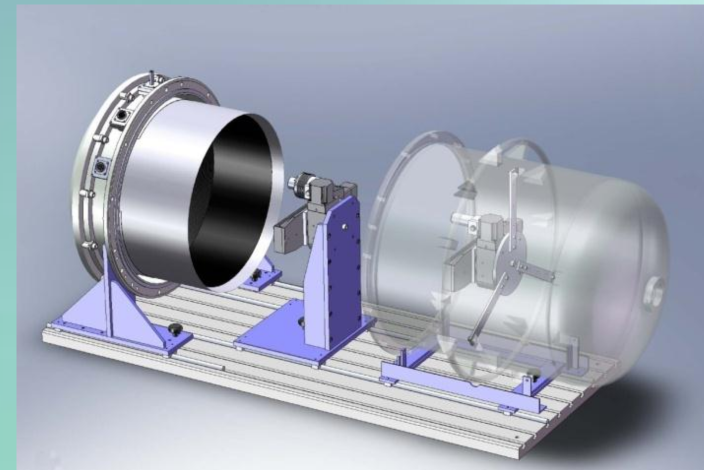


1 – LABB body
2 – radiation screen
3 – bracket
4 – radiator with heat exchanger
5 – 2 axes scanner with IR radiometer
6 – liquid thermostat (HUBER UNISTAT 750)

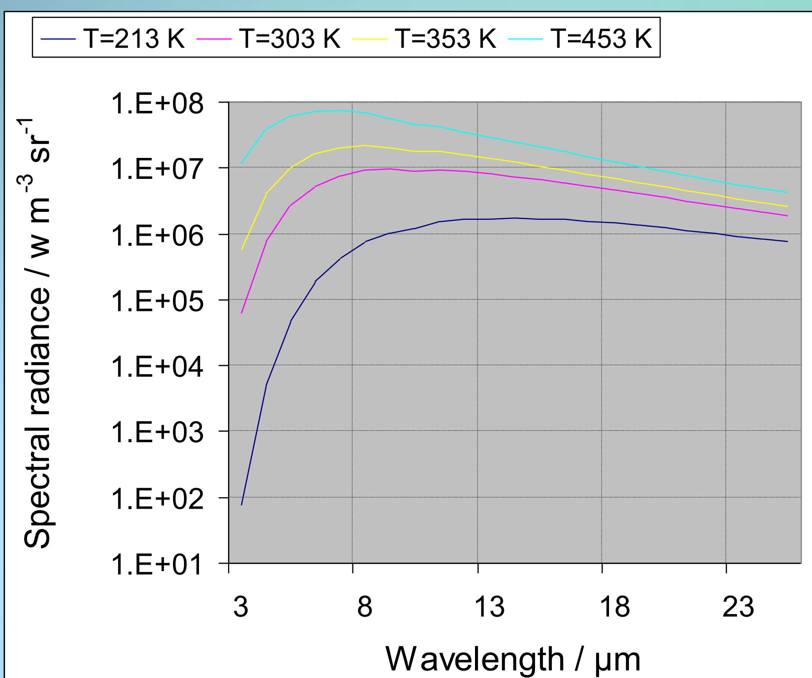
The LABB radiator is an aluminum alloy disk with triangular shape grooves. Diameter of the radiator is 500 mm and thickness is 10 mm. The radiator and the screen are coated by the Duplicolor-Barbecue Spray black matte paint. The temperature of the LABB is maintained by a liquid thermostat and heat exchanger and measured by a set of platinum resistance thermometers.

Large-area low temperature blackbody

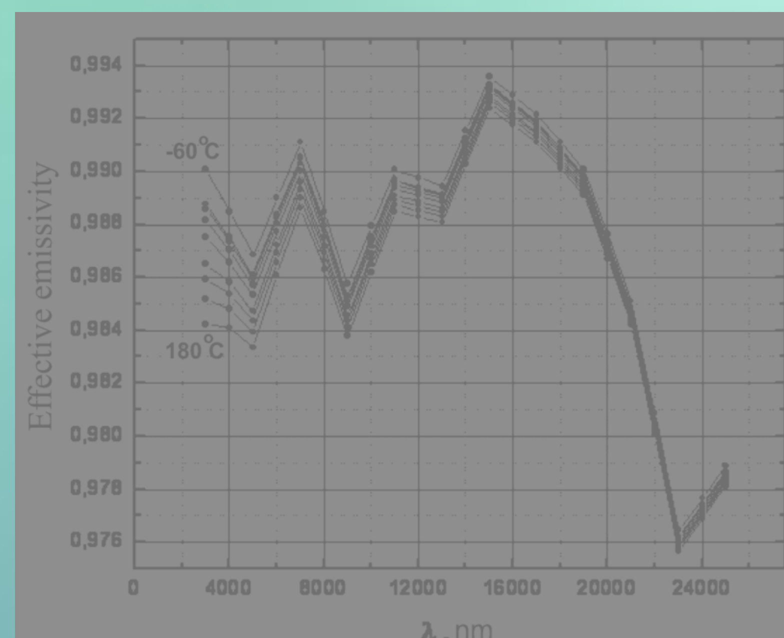
Range of working temperatures	- 60°C ÷ 180°C
Stability of working temperature (maintained by a liquid thermostat)	± 0.02°C
Diameter of radiator	500 mm
Thickness of radiator	10 mm



Spectral radiance

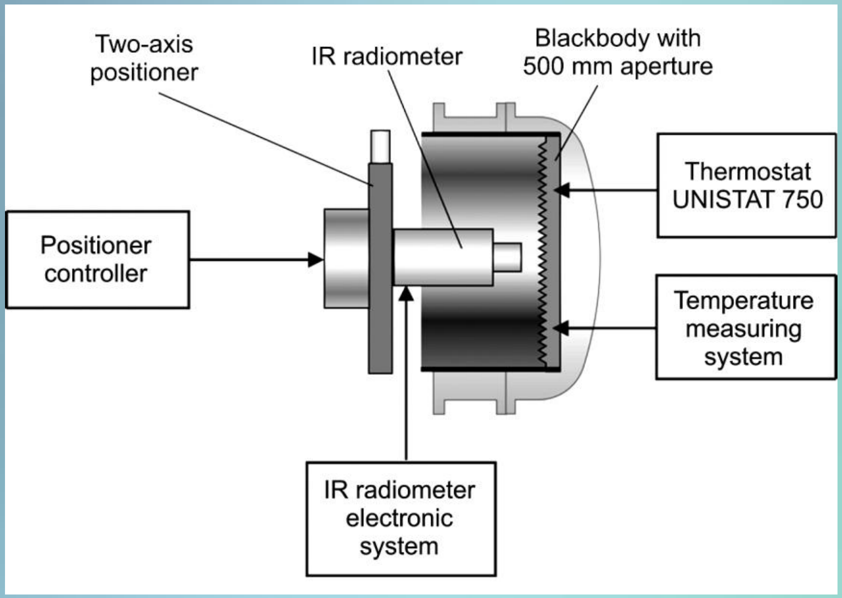


Effective emissivity



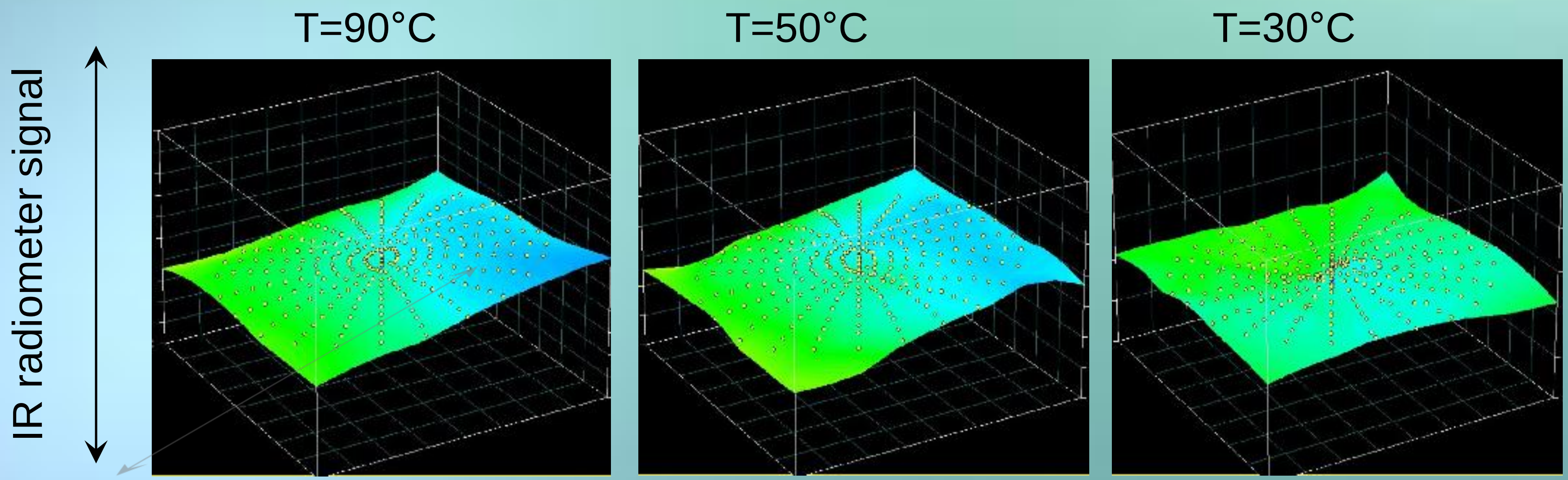
Large-area low temperature blackbody

Research of spatial uniformity by IR radiometer with band from 2 µm to 5µm



Relative deviation (%) from the weighted average of IR radiometer signal for T=30°C

Angle / Radius	0°	60°	120°	180°	240°	300°	330°
0 mm	0.04	-	-	-	-	-	-
20 mm	0.33	0.26	0.42	0.39	0.07	-0.67	-0.86
60 mm	0.26	0.20	0.67	0.56	-0.04	-0.84	-0.92
80 mm	***0.69***	0.24	0.57	0.24	0.09	-0.90	-0.86
120 mm	0.29	0.50	0.68	0.12	0.16	-0.91	-0.95
140 mm	0.42	0.45	0.59	0.29	0.05	-1.14	-0.87
180 mm	0.18	0.34	0.54	0.06	-0.46	***-1.31***	-0.86
200 mm	0.16	0.17	0.52	-0.27	-0.33	-1.17	-1.20



Thank you