Technical Note

Calibration of Infrared Thermometers [1] [2]

In this technical note the general procedure and important relationships for the calibration of infrared thermometers are explained. For a detailed description of the different calibration methods and a detailed uncertainty consideration we recommend the standard VDI/ VDE 3511 part 4.3 Calibration of radiation thermometers.

Infrared thermometers are calibrated with the help of reference radiation sources, so called black bodies.
These radiation sources can produce different radiation temperatures with a high stability which are used to determine the calibration constants of the infrared thermometers.
For the calibration process it is of essential importance to know the exact value of the radiation temperature. It can be measured either by using a contact thermometer (in combination with the determination of the emissivity) or by using a transfer standard infrared thermometer.

The emissivity of an ideal radiation source would be 1,00 for all wavelengths and emission angles.
From all real existing sources cavity radiation sources are achieving the best results (emissivity values up to 0,999). The emissivity of a plate radiation source is strongly dependent on the surface properties and is typically at 0,96.
For the here described calibration method the knowledge of the exact emissivity value of the used radiation source is not necessary.

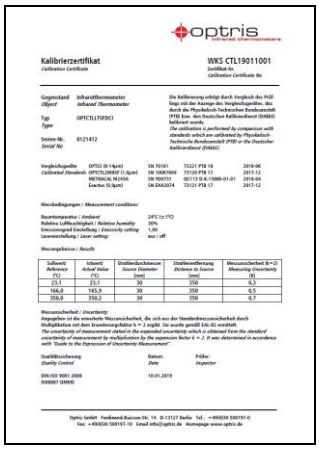
For the initial factory calibration Optris is defining the calibration temperatures in a way that all constants can be determined with the best possible accuracy. For a re-calibration by the user or a local calibration laboratory the calibration temperatures should be selected close to the temperatures of the specific application or, if not known, according to the rule:

- low end of range +10% of the infrared thermometer or room temperature
- middle of the temperature range
- high end of range -10%

Transfer standard

Optris is using a traceable transfer standard radiation thermometer (in the following text mentioned as CTlaser-PTB) to measure the radiation temperature of the reference source. As the CTlaser-PTB needs to be traceable to the ITS-90, the PTB (Physikalisch-Technische Bundesanstalt – the German national metrology institute) is calibrating this instrument in regular periods.

Reference IR thermometer CTlaser-DCI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Kalibrierzertifikat

WKS CTL19011001

Certificate of calibration for CTlaser-DCI

The CTlaser-DCI is a reference IR thermometer which is based on the IR thermometer series optris CTlaser. The units are produced with pre-selected components supporting a high stability of measurement. In combination with a dedicated calibration at several points the CTlaser-DCI achieves a higher accuracy than units out of the series production and is therefore qualified to be used as dedicated calibration instrument (DCI).

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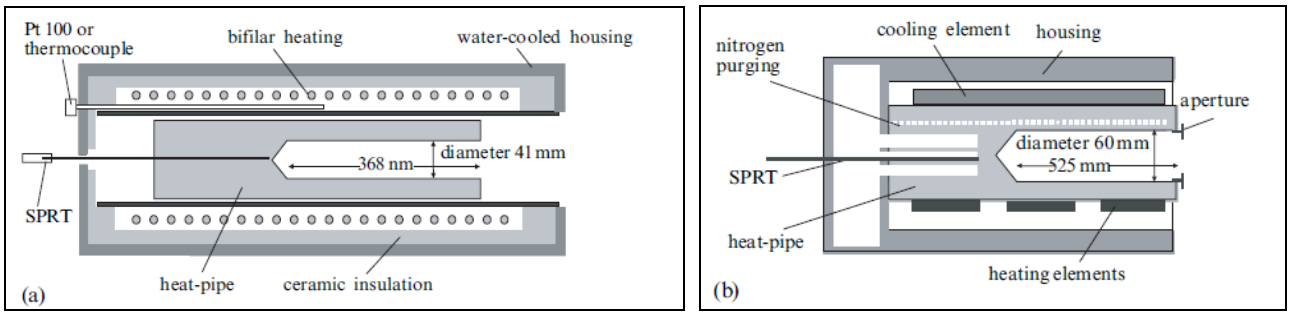
ITS-90

The 1990 International Temperature Scale (ITS-90) prescribes a system of measurement devices and methods that ensure a uniform temperature measurement worldwide. The ITS-90 is a very good approximation of the thermodynamic temperature. It is based on 17 well reproducible fixed points like melting points of highly pure metals.
The calibration process makes the measurement with an infrared thermometer traceable to ITS-90. To achieve this, the infrared thermometers are compared within a closed chain of comparative measurements with a known uncertainty with the national temperature standards from the PTB.

Fixed point	Temperature/ K	Temperature/ °C
Triple point of Mercury [Hg]	234,3156	-38,8344
Triple point of Water [H_2O]	273,16	0,01
Melting point of Gallium [Ga]	302,9146	29,7646
Melting point of Indium [In]	429,7485	156,5985
Melting point of Tin [Sn]	505,078	231,928
Melting point of Zinc [Zn]	692,677	419,527
Melting point of Aluminium [Al]	933,473	660,323
Melting point of Silver [Ag]	1234,93	961,78

Fixed points of the ITS-90 (Selection) [Source: www.its-90.com/ 12.01.2012]

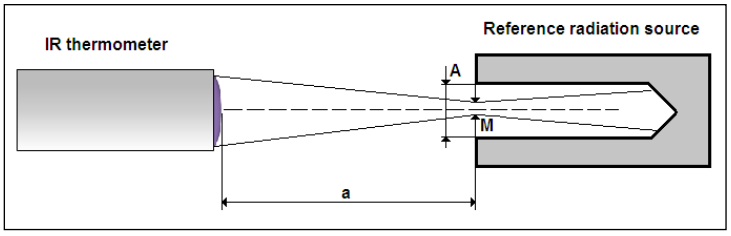
For the calibration of the transfer standard radiation thermometers the PTB is using high-precision heat pipes. Due to different temperature stabilization procedures in combination with a high thermal mass of the cavities these heat pipes are reaching a high temperature stability of ±10 mK.



Schematic layout of heat pipes used at the PTB: sodium and caesium heat pipes (a) / water and ammonia heat pipes (b) [3]

Calibration Geometry

The optics of an IR thermometer is described by the distance to spot ratio (D:S). Depending on the quality of the optics a certain amount of radiation is also received from outside the specified measurement spot. The signal change in correlation with a resize of the radiation source is described by the Size-of-source effect (SSE).
The radiation maximum which the IR thermometer is receiving equals the radiation of a hemispheric radiation source. Therefore the value which is specified in datasheets and technical documentation as measurement spot is in general a certain defined percentage of this radiation maximum – values of 90% or 95% are common. Consequently all manufacturers of IR thermometers are using accurately defined geometries for the calibration of their units; means depending on the aperture of the radiation source **(A)** a distance **(a)** between the IR thermometer and the reference source is defined.



A	**Diameter of the effective area of the reference radiation source**
M	**Measurement spot of the IR thermometer at distance a**
a	**Measurement distance**

Calibration geometry

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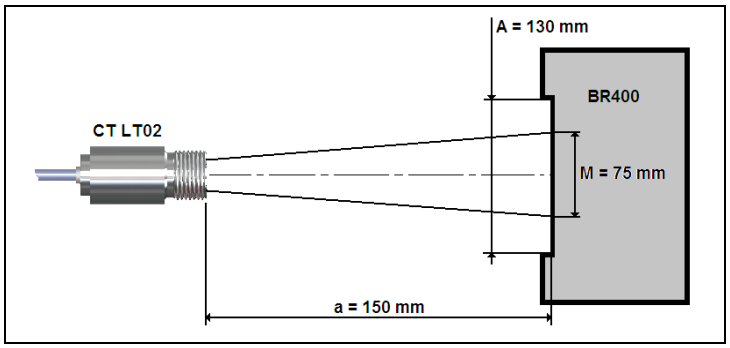
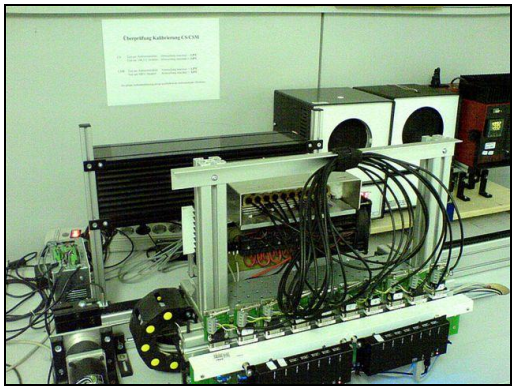
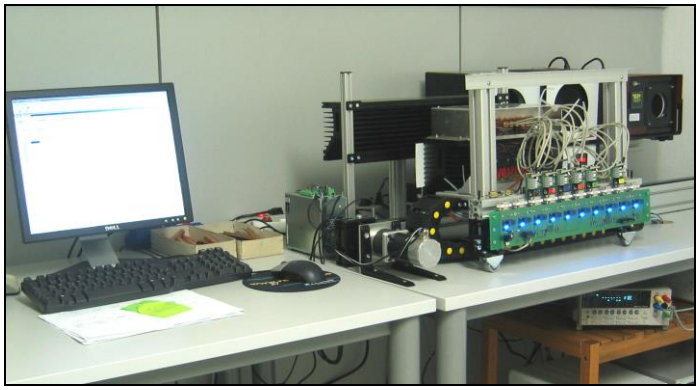


Example: Calibration geometry of the optris CT LT02 on a BR400 source

Product	model	Source up to 400°C Ø: 130 mm	Source up to 550°C Ø: 65 mm	Source up to 1200°C Ø: 30 mm	Source up to 500°C Ø: 51 mm
		Calibration distances			
optris CT	LT02	150 mm	90 mm		
	LT15	210 mm	150 mm		
	LT20	210 mm	150 mm		
optris CTlaser LT	LTCF1		110 mm		
	LTCF2		150 mm		
	LTCF3		200 mm		
	LTCF4		350 mm		
	LTSF		350 mm		
optris CTlaser 1M, 2M, 3M		150 mm	90 mm	60 mm	
optris CT 1M, 2M, 3M		150 mm	90 mm	60 mm	
optris CS		210 mm	150 mm		
optris CSmicro		210 mm	150 mm		
optris LS	SF mode	800 mm	350 mm		250 mm
	CF mode		110 mm		
optris PI	80°	240 mm			**100 mm**
	48°/ 64°	650 mm	325 mm	150 mm	**250 mm**
	23°/ 31°	780 mm	390 mm	180 mm	**300 mm**
	6°/ 9°	2300 mm	1200 mm	540 mm	**900 mm**

Calibration geometries for Optris IR thermometers (selection – the complete list can be ordered)





Automated calibration stations at Optris GmbH

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Calibration

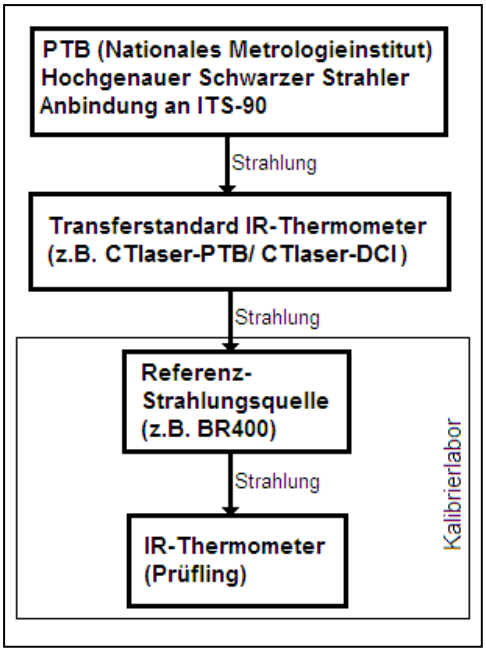
The basic requirements for a calibration laboratory are:

- Laboratory room with stable temperature and humidity
- Measurement equipment for air temperature and humidity
- Reference radiation source
- Traceable transfer standard radiation thermometer (e.g. CTlaser-PTB) or a dedicated calibration instrument (e.g. CTlaser-DCI)
- Adjustable holder for the infrared thermometer

For creating calibration certificates beside the laboratory temperature and humidity also the measurement distance and source diameter (calibration geometry) should be documented.

Calibration procedure:

1. Checking the optics of the CTlaser-PTB/ CTlaser-DCI and of the test unit – cleaning, if necessary
2. Switch on both units; consider warm-up time
3. Set the emissivity value to 1,00 on both units, if possible
4. Set the reference radiation source to a temperature which is significantly different to the internal temperature of the CTlaser-PTB/ CTlaser-DCI; wait for stabilization of the radiation source
5. Bring the CTlaser-PTB/ CTlaser-DCI into measurement position [1)] and determine the radiation temperature of the reference source
6. Bring the test unit into measurement position [1)] and note the reading [2)]
7. Set up the next radiation temperature; wait for stabilization of the source; repeat point 5 and 6



[1)] Determination of the measurement position:

- Put the unit at distance **a** centered to the aperture of the radiation source (for this purpose an adjustable aperture which is placed in front of the source can be helpful)
- Set the aperture to 0,9 x measurement spot size
- Adjust the unit to the center of the aperture via maximum search
- After this please open the aperture to 100% of the calibration geometry or remove it

[2)] On portable IR thermometers reading stands for the shown temperature on the display. For online IR thermometers the signal at the analog output has to be measured. The function T_{Rad} = f (signal) must be known.

Literature

[1] VDI/ VDE Standard: Temperature measurement in industry – Specification for radiation thermometers, 2001, VDI/ VDE 3511, Part 4.1

[2] VDI/ VDE Standard: Temperature measurement in industry, Radiation thermometry – Calibration of radiation thermometers, 2004, VDI/ VDE 3511, Part 4.3

[3] Jörg Hollandt, Rüdiger Friedrich, Berndt Gutschwager, Dieter R Taubert, Jürgen Hartmann – High-accuracy radiation thermometry at the National Metrology Institute of Germany, the PTB;
Published in: High Temperatures - High Pressures, 2003/2004, volume 35/36, pages 379 - 415

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