

# **Transfer standard pyrometers for radiance temperature measurements below the freezing temperature of silver at NIST**

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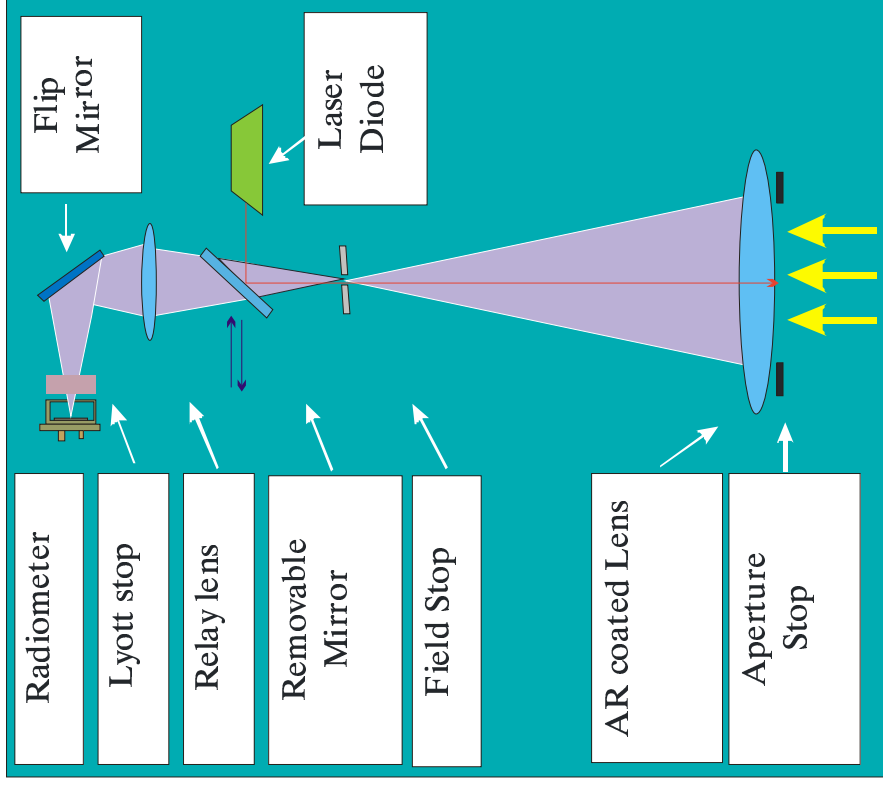
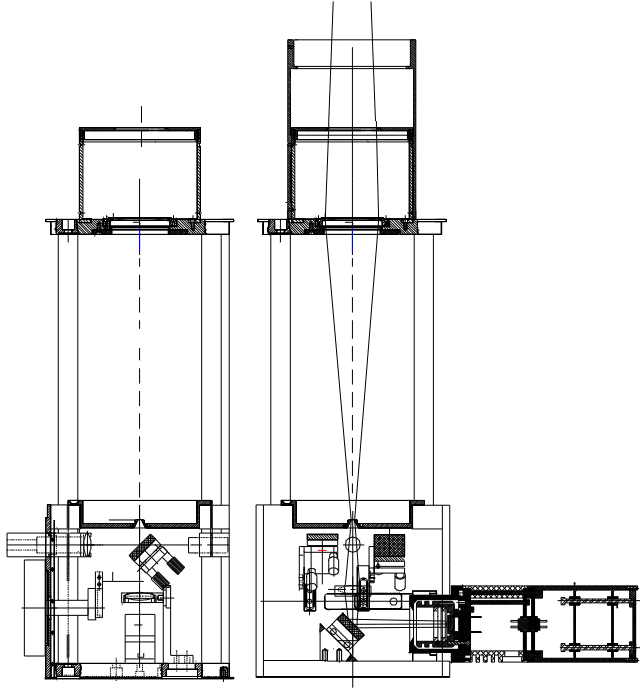
# Introduction

- The radiance temperature can be assigned to a source by measurement of its radiance relative to a known source, for example a fixed point blackbody.
- High-accuracy transfer standard radiometers have to be used for the transfer the radiance temperature scale from the reference sources to customer blackbodies.
- The radiometers can also be used for the temperature interpolation between the reference fixed point sources

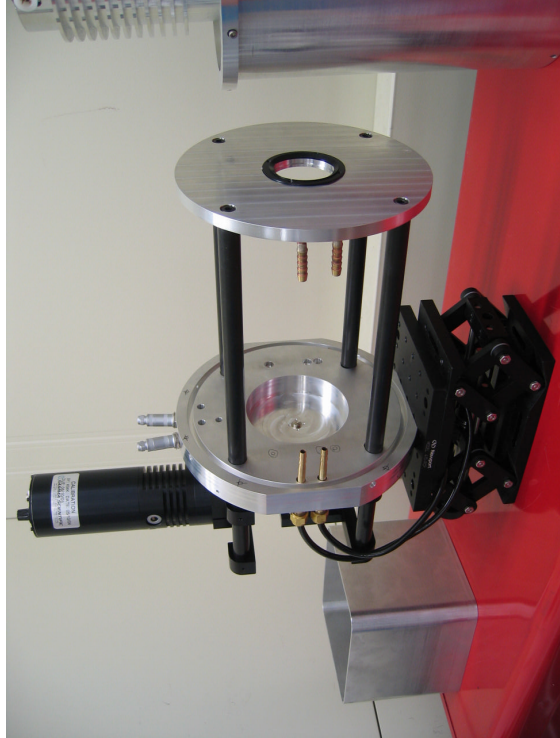
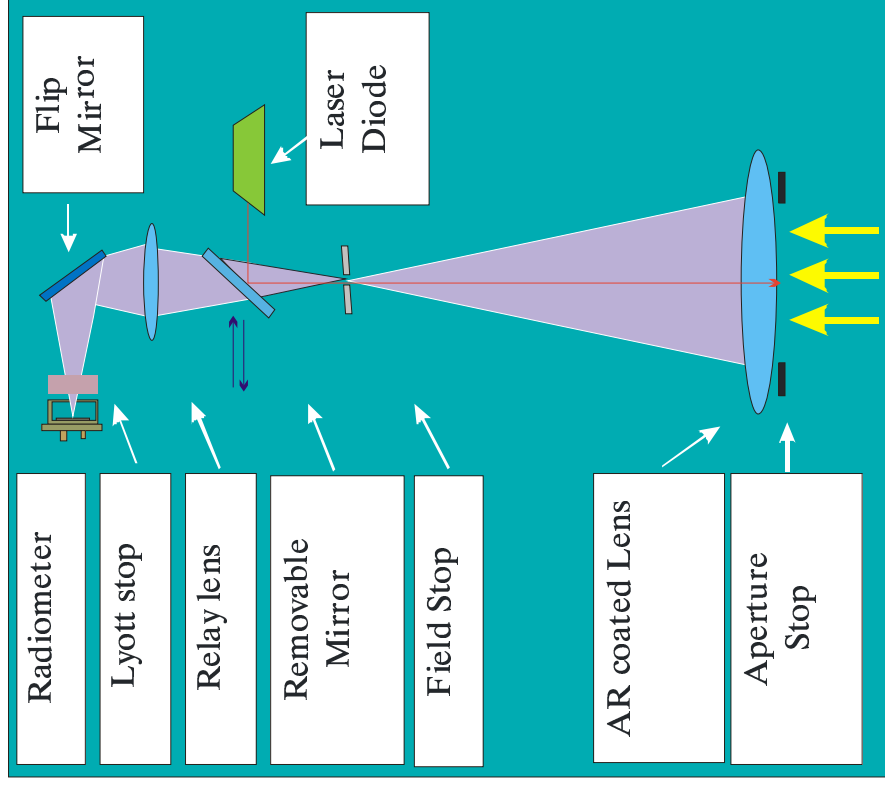
# Transfer standards

- New pyrometers RT900 and RT1550 have been designed for use as transfer standards in the range between the freezing temperatures of Sn (231.928 °C) and Ag (961.78 °C).
- Two different measurement wavelengths, 900 nm and 1550 nm, are used to optimally cover the full temperature range.

# RT900



# RT1550



# RT1550 features

- G8605-25 Hamamatsu InGaAs photodiode operating at  $-28\text{ }^{\circ}\text{C}$
- AR coated GRIN lens
- Water-cooled lens mounts
- Polished Ni-plated Invar field stop
- Non-hygroscopic refractory oxide filter
- Light weight carbon fiber frame with low coefficient of thermal expansion
- Built-in laser diode for alignment

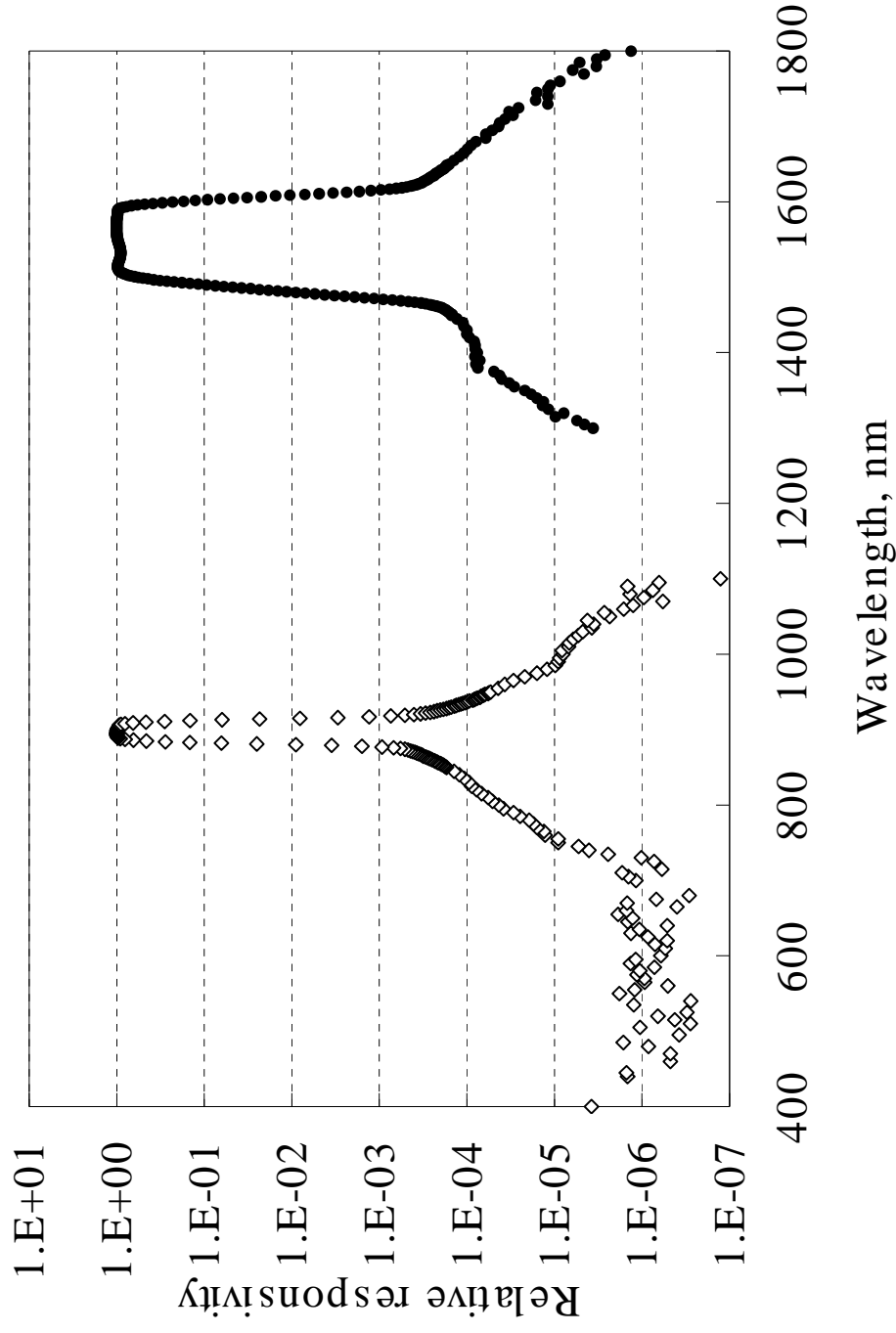
# RT900 and RT1550 specifications

- Temperature ranges start at 200 °C (RT1550) and 500 °C (RT900)
- Nominal spot size 3mm
- F-number f/11
- focal length 500 mm
- Amplifiers from Gamma Scientific with amplification ranging from  $10^3$  to  $10^{10}$  V/A

# Characterization

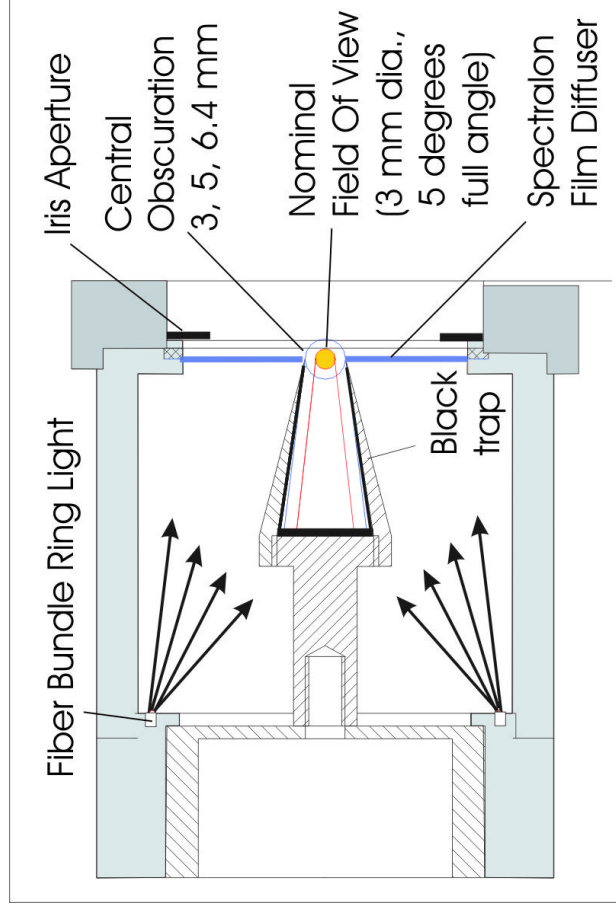
- Relative spectral responsivity
- Out-of-field scatter (SSE) with two independent methods
- Gain corrections between different ranges both optically and with reference current source
- Short-term and long-term stability
- Calibration at Sn, Zn, Al, Ag, and Au fixed points

# Spectral responsivity



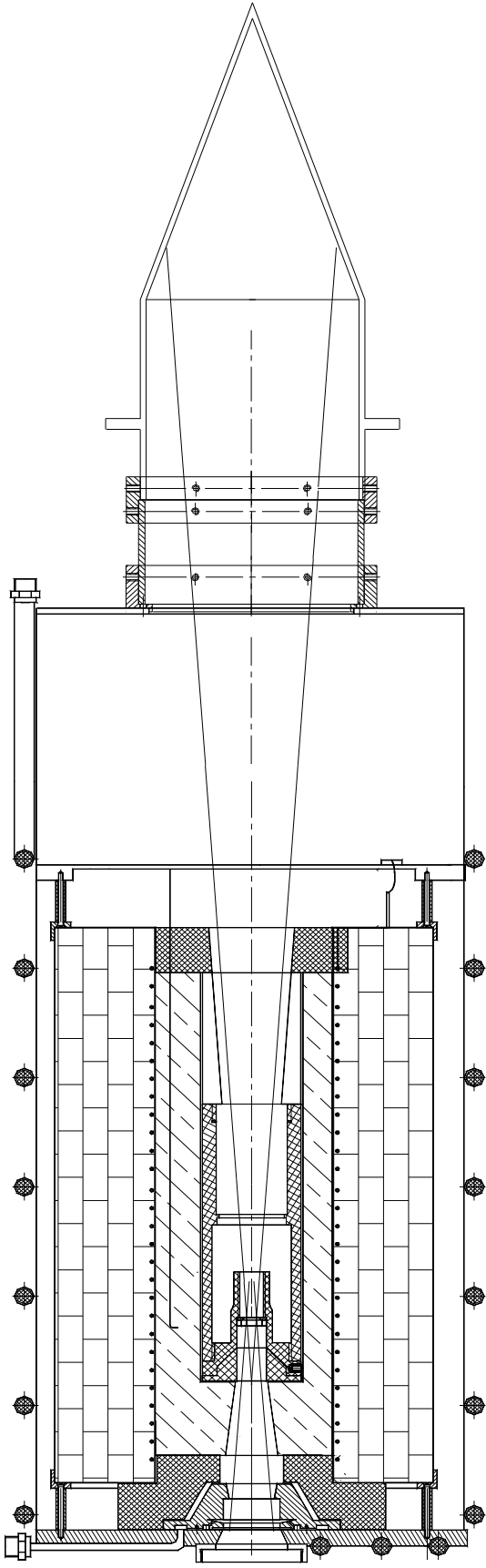
# SSE: Method 1

- Out of field scattered light measured with a white light source featuring a variable aperture

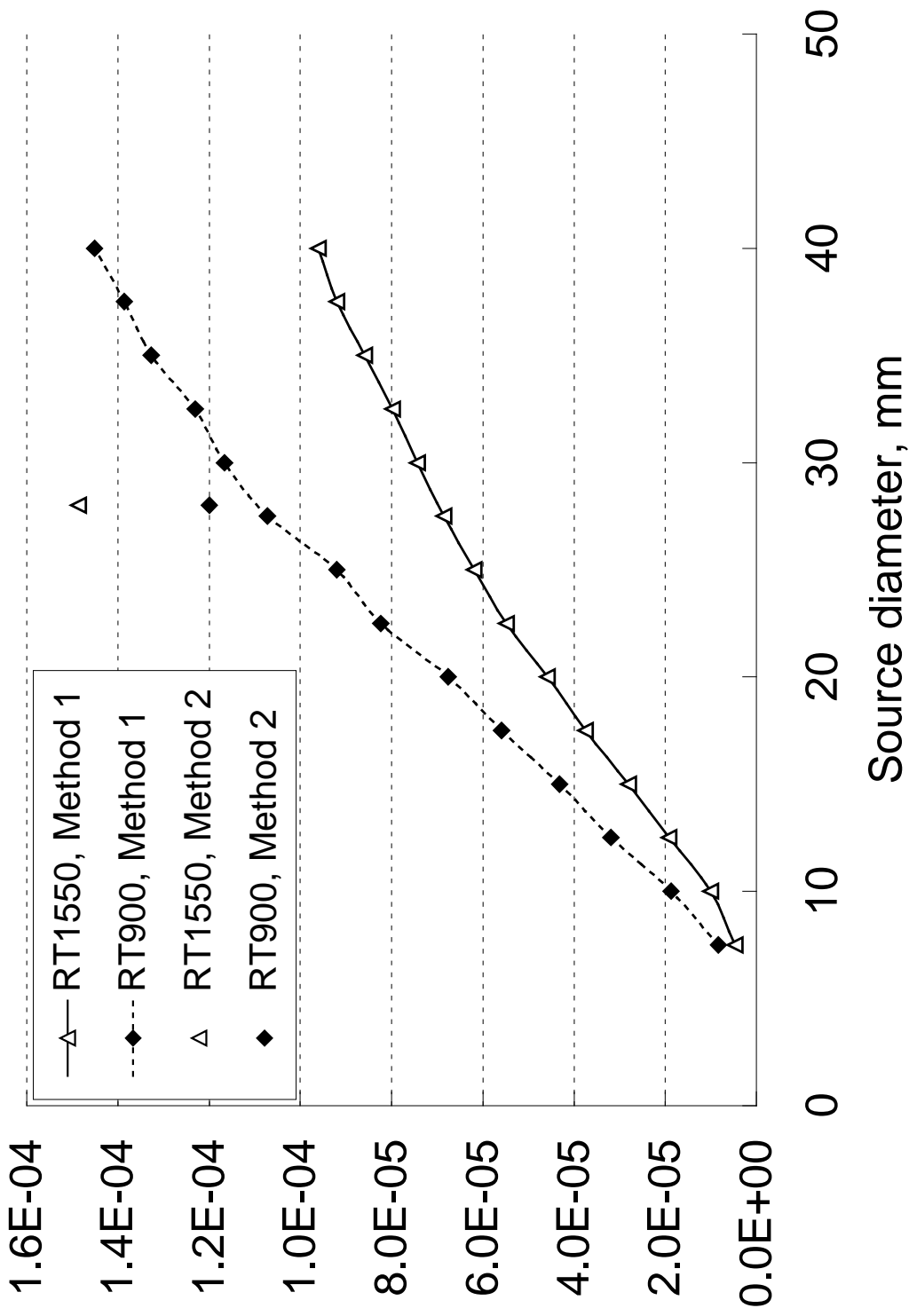


# SSE: Method 2

- The same furnace, which is used for the calibration of pyrometers at fixed point temperatures
- Fixed point crucible is replaced with an empty crucible with rear half of the cavity removed
- A light trap is attached to the furnace

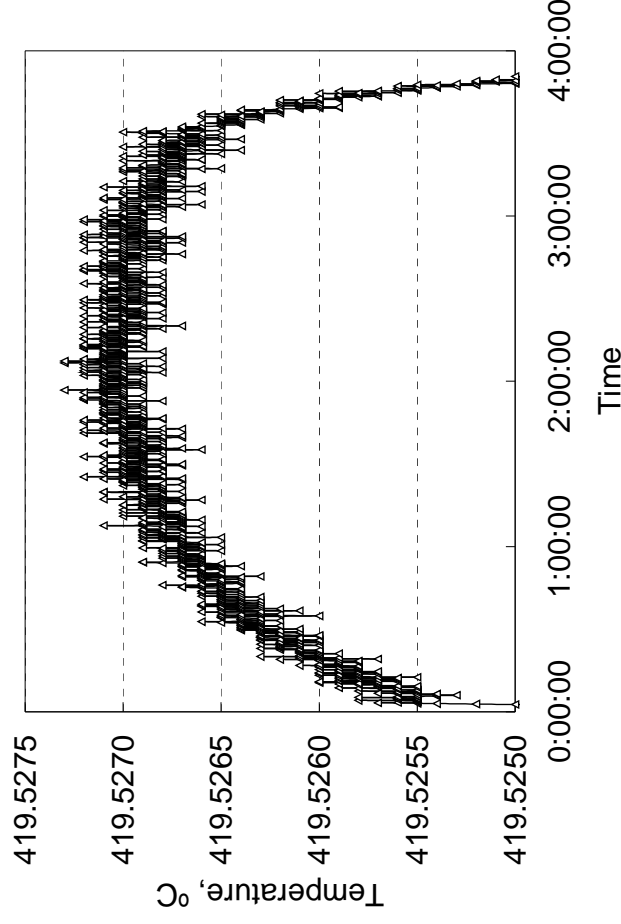


# SSE results



# Stability

- Example of the short term stability of RT1550: measurement of the freezing plateau of Zn
- Long term stability better than 0.1 K over 1 year



# Calibration with fixed points

- RT900: Planck's radiation law
- RT1550: Sakuma-Hattori interpolation function

Fixed point	ITS-90 freezing temperature, °C	Deviation from ITS-90, mK	
		RT900	RT1550
Sn	231.928	n/a	3
Zn	419.527	n/a	23
Al	660.323	-18	-13
Ag	961.780	tie point	44
Au	1064.18	25	n/a

# RT1550 uncertainty

Component	Uncertainty, mK							
	300 C	400 C	500 C	600 C	700 C	800 C	900 C	
Reproducibility	12	11	13	16	18	25	21	
Calibration of reference pyrometer at nearest fixed points	13	17	17	28	28	28	50	
Interpolation of temperature	20	21	25	22	26	28	34	
Combined standard uncertainty	27	29	33	39	42	47	64	
Expanded uncertainty ( $k=2$ )	53	58	66	78	84	94	128	

# Future work

- Comparison of SSE correction with different furnace designs
- Study of long term stability of the pyrometers
- Absolute calibration of the spectral radiance responsivity of RT900 and RT1550