Realization of the NIST Detector-Based Spectral Irradiance Scale

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NIST Radiance Temperature and Spectral Radiance and Spectral Irradiance Scales

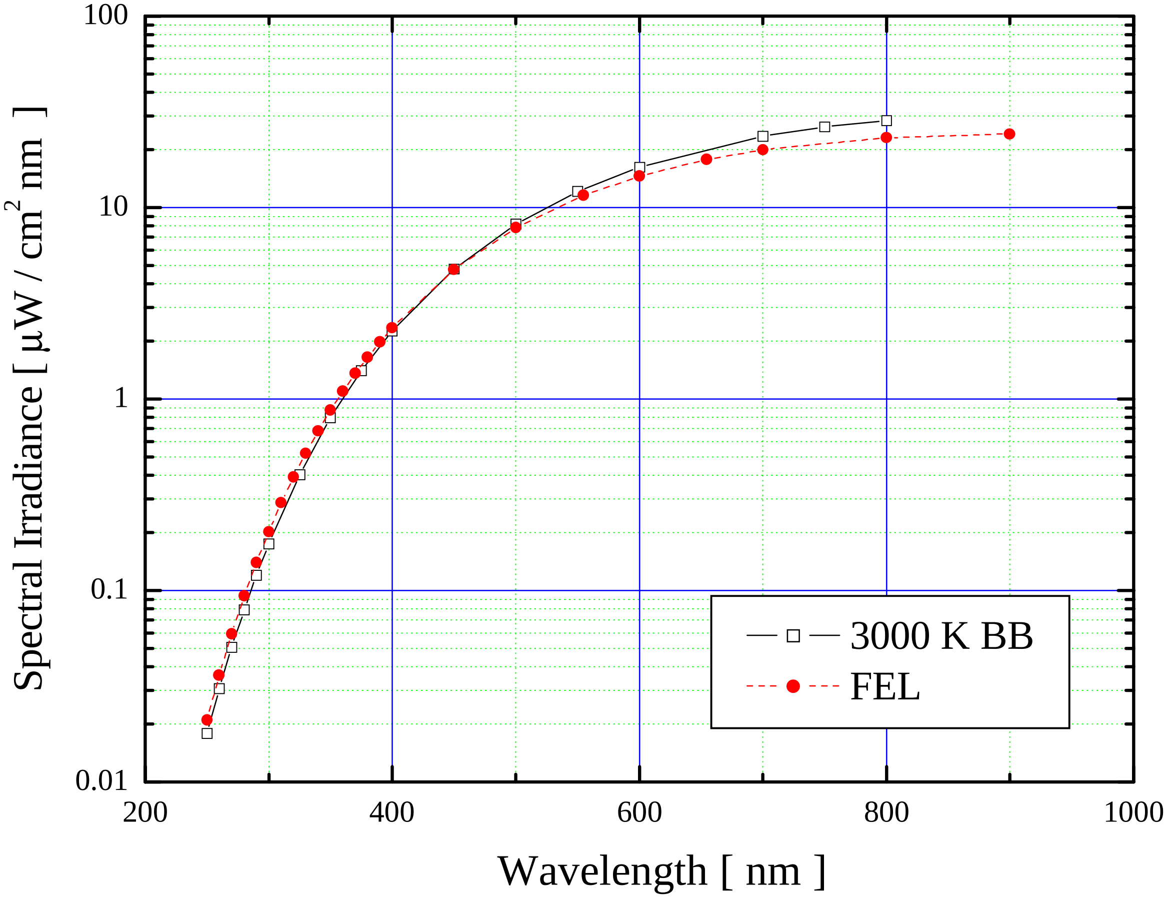
- Gold Point Black Body 1337.33 K

- Lamp 1 at 1337.33 K → Radiance Temperature Assignment of blackbody using pyrometer
- Lamp 2 at 1530 K
- Variable Temperature Black Body 1610.7 K to 2654.2 K → • Radiance Lamps calibrated (1 to 2 per year) target area 0.6 mm by 0.8 mm

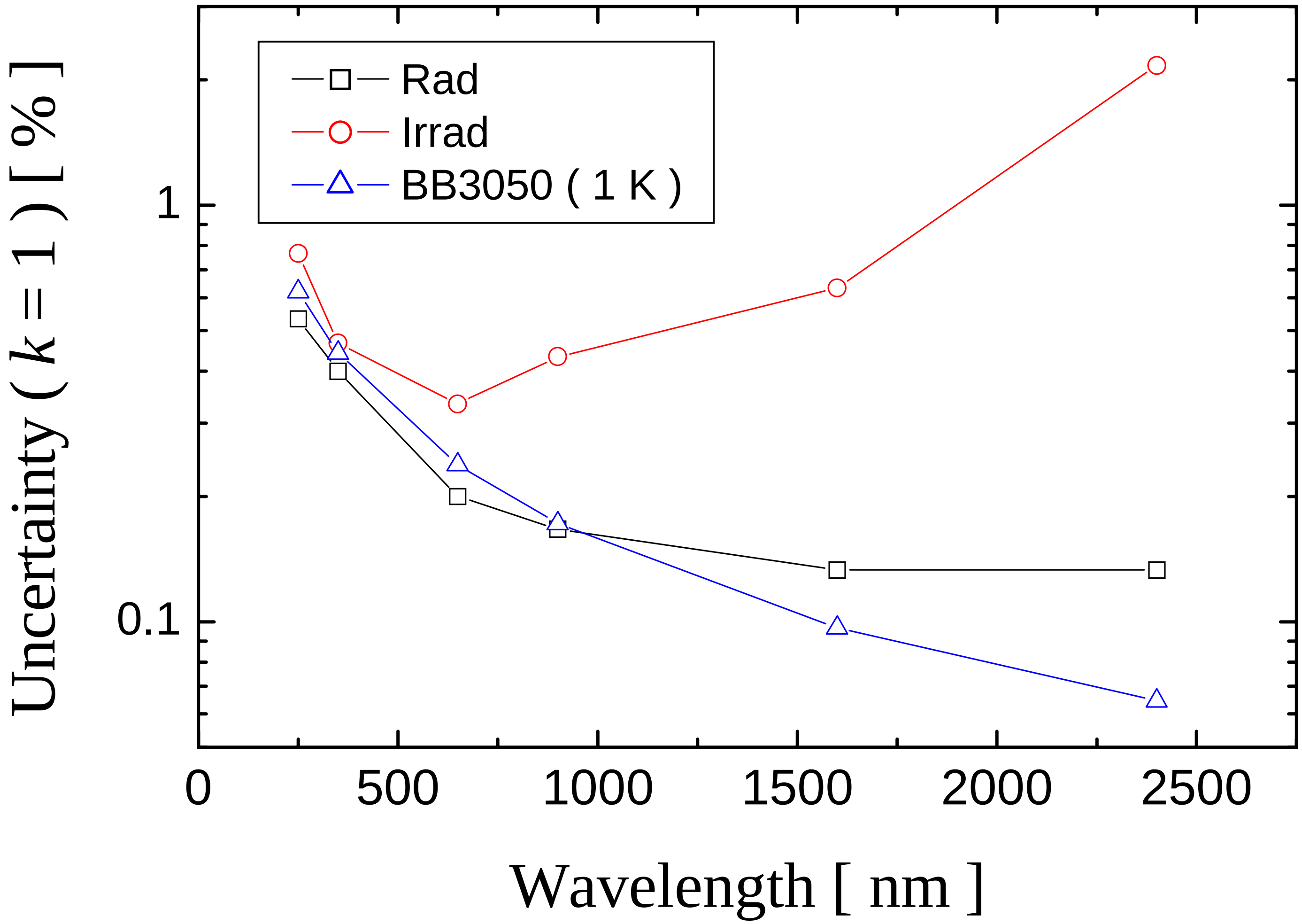
- Integrating Sphere Source
- 4 Working Standard Lamps → • 1000 W FEL irradiance Lamps (50 - 60 per year) Calibrated

Solution

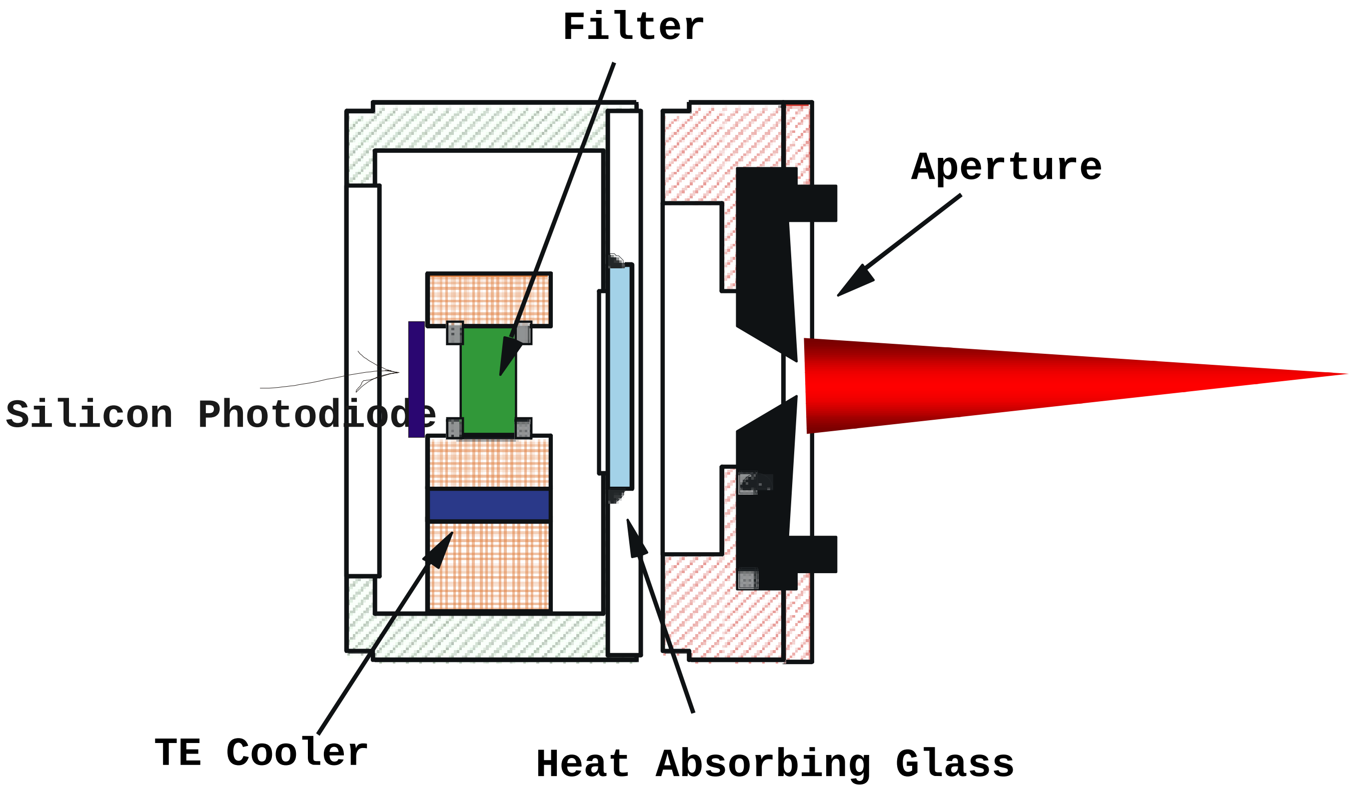
– Use a high temperature black body (3000 K) to directly calibrate FEL lamps (50 cm away from 1 cm^2 aperture)



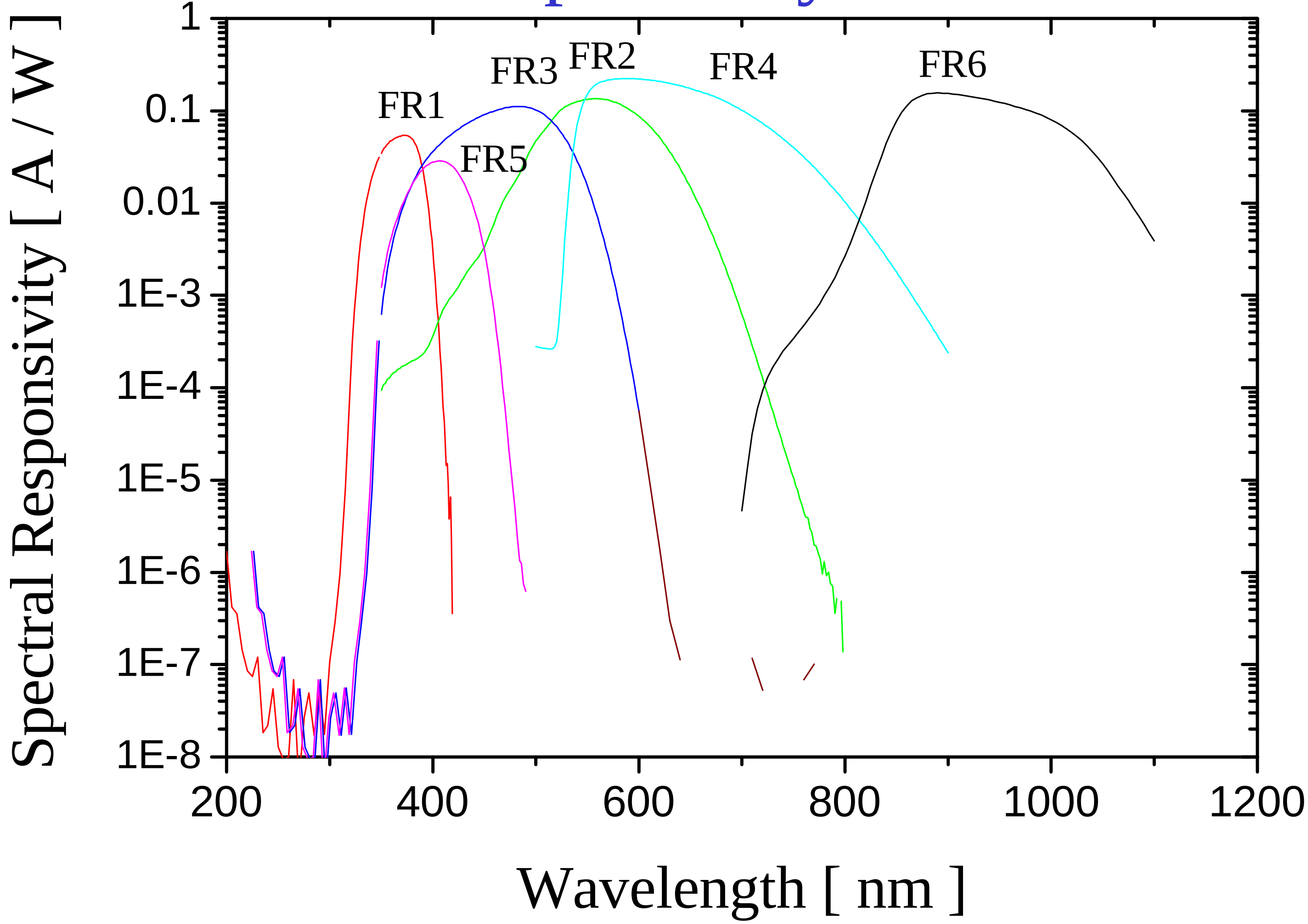
Reduction in uncertainty



Design of the filter radiometers



Filter Radiometer Absolute Spectral Power Responsivity



Measurement Equation 1
(determination of thermodynamic temperatures)

For filter radiometers (FR) the signal
S_i

$$S_i = \frac{G A_{BB} A_i (1+\delta_i)}{D_i^2} \varepsilon \int \rho_i(\lambda) L(\lambda, T_i) d\lambda$$

where

ε emissivity
ρ absolute spectral responsivity (A / W)
d distance between the fr aperture and the HTBB aperture

$D_i^2 = d^2 + r_i^2 + r_{BB}^2$

$\delta_I = r_i^2 \, r_{BB}^2 / D_i^4$

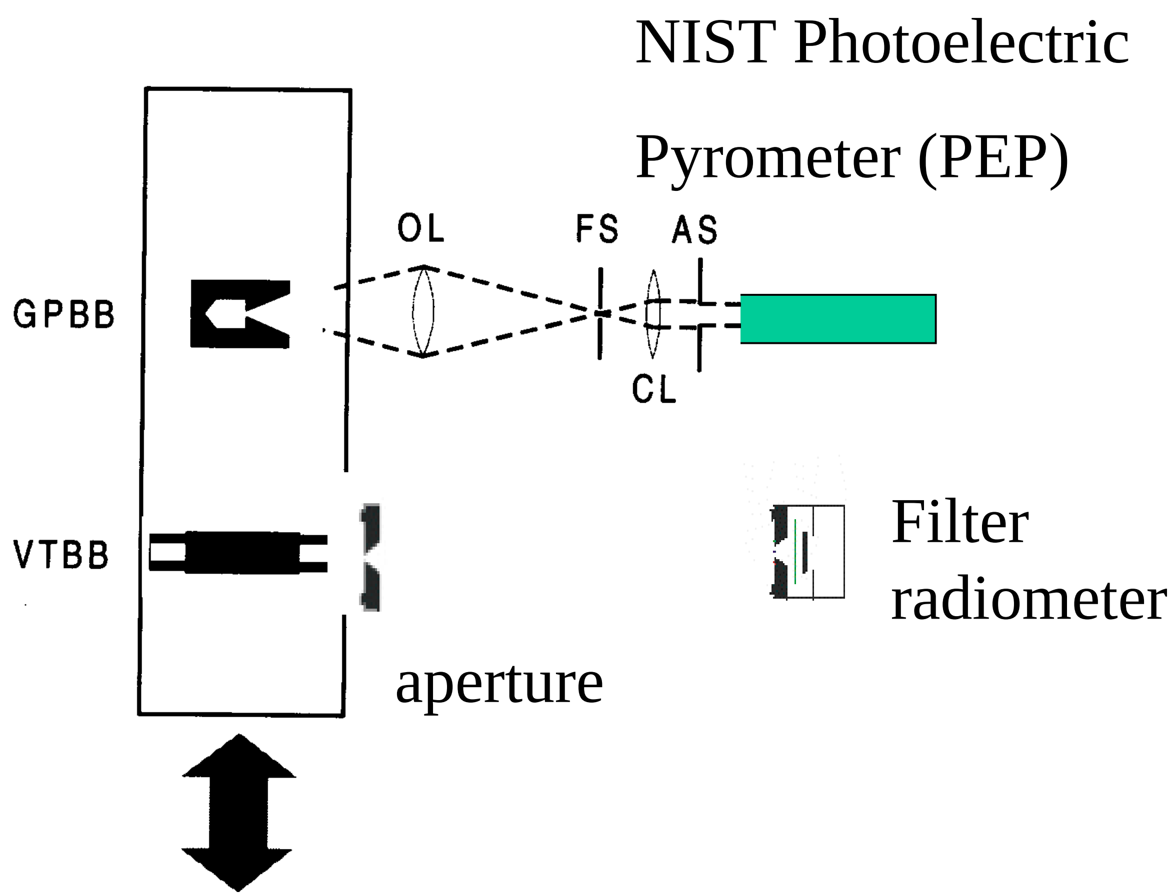
G preamp gain
L Planck radiation law

How accurate are the filter radiometers?

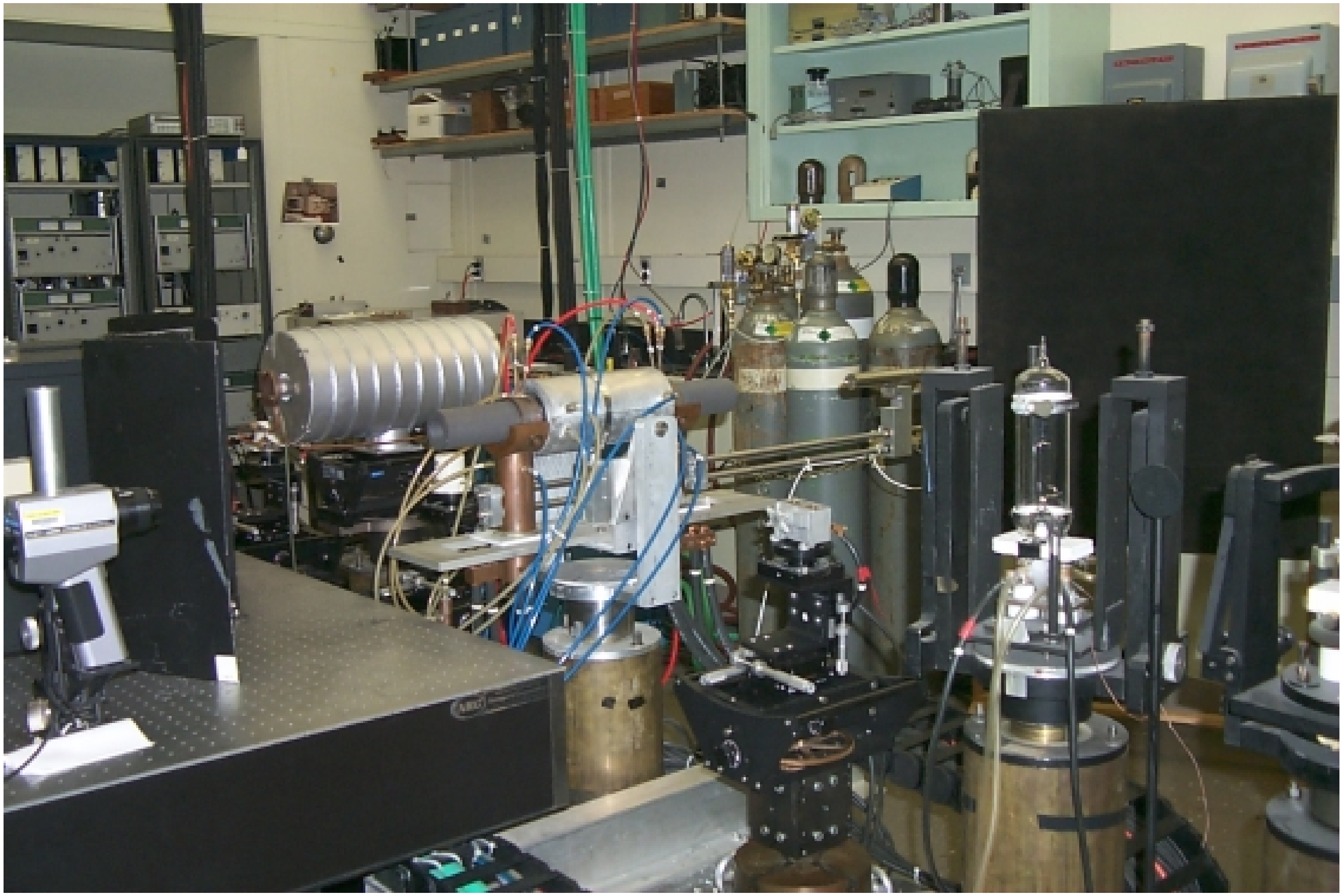
- Source: Variable Temperature Blackbody (VTBB) temperature stabilized using an optical feedback system (emissivity = 0.9985 $\pm$ 0.0005) .

- Two different determinations of radiance temperature
  - Source-based comparison to a gold fixed-point blackbody (ITS-90).
  - Detector-based using filter radiometers calibrated for absolute spectral power response (based on High Accuracy Cryogenic Radiometer)

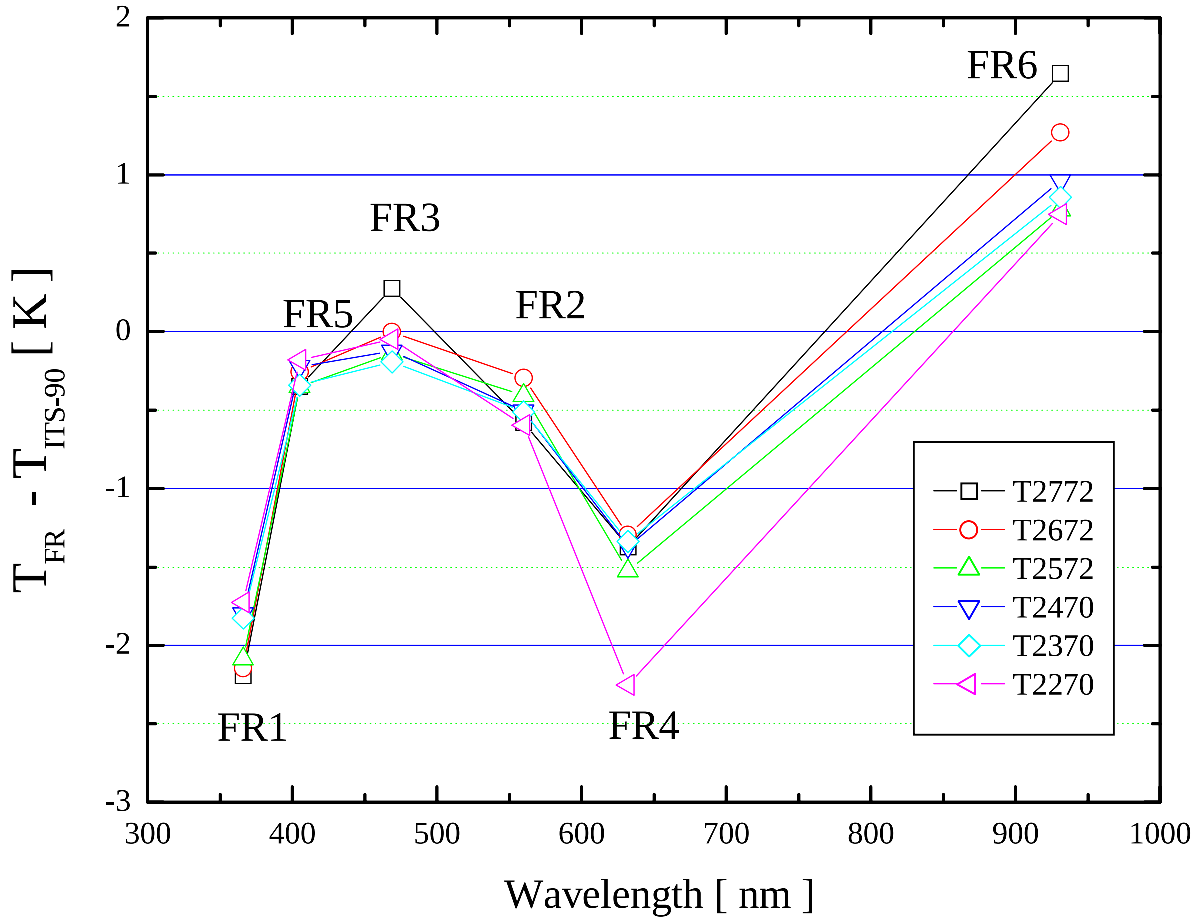
The NIST Radiance Temperature Calibration Laboratory



The NIST Pyrometry Lab.



What is the accuracy of filter radiometers?
Measurements done on BB calibrated with gold-point lamp



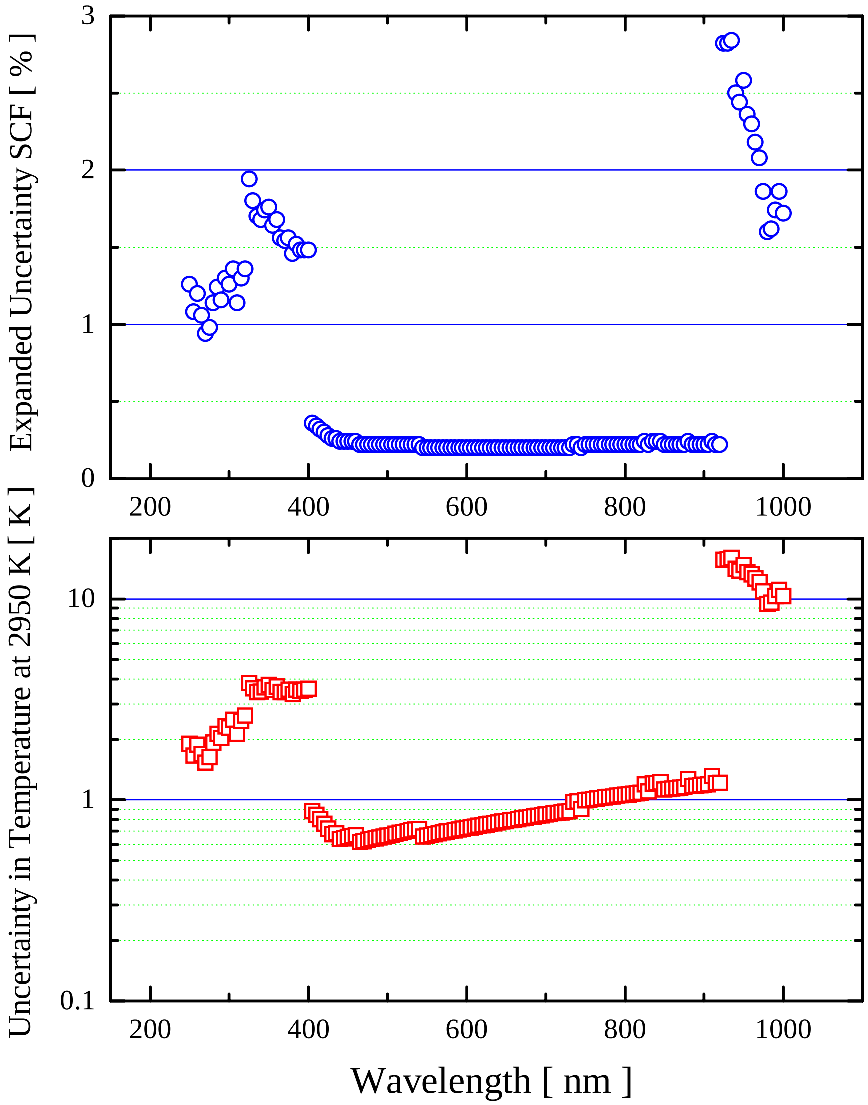
What are the uncertainties in the detector-based scale?

- Using the derivative of the Wien approximation

$$\frac{\Delta L}{L} = \frac{c_2}{\lambda} \frac{\Delta T}{T^2}$$

Spectral optical power is directly proportional to spectral radiance for a fixed geometric configuration.

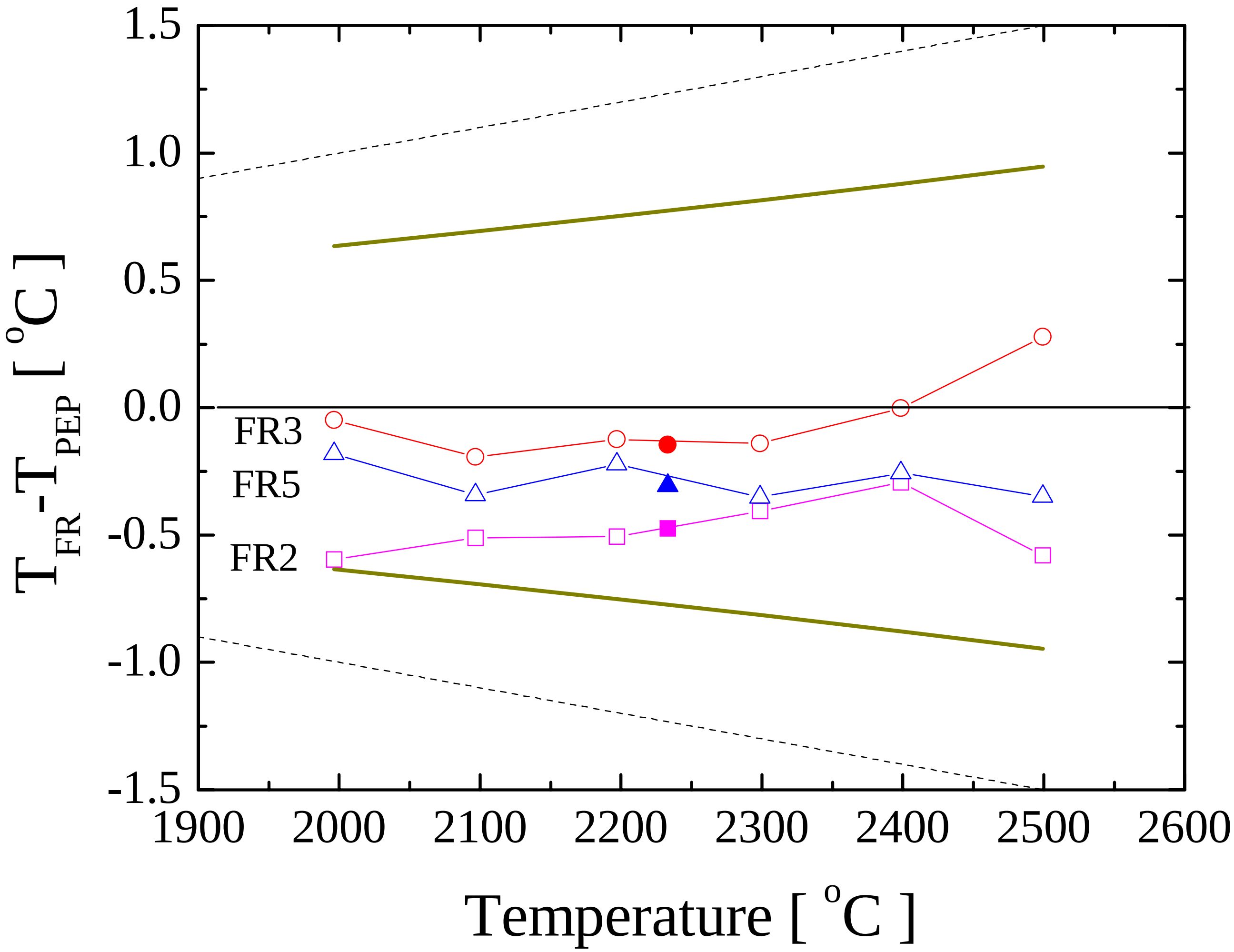
The Relationship between Spectral Power Responsivity and Radiance Temperatures



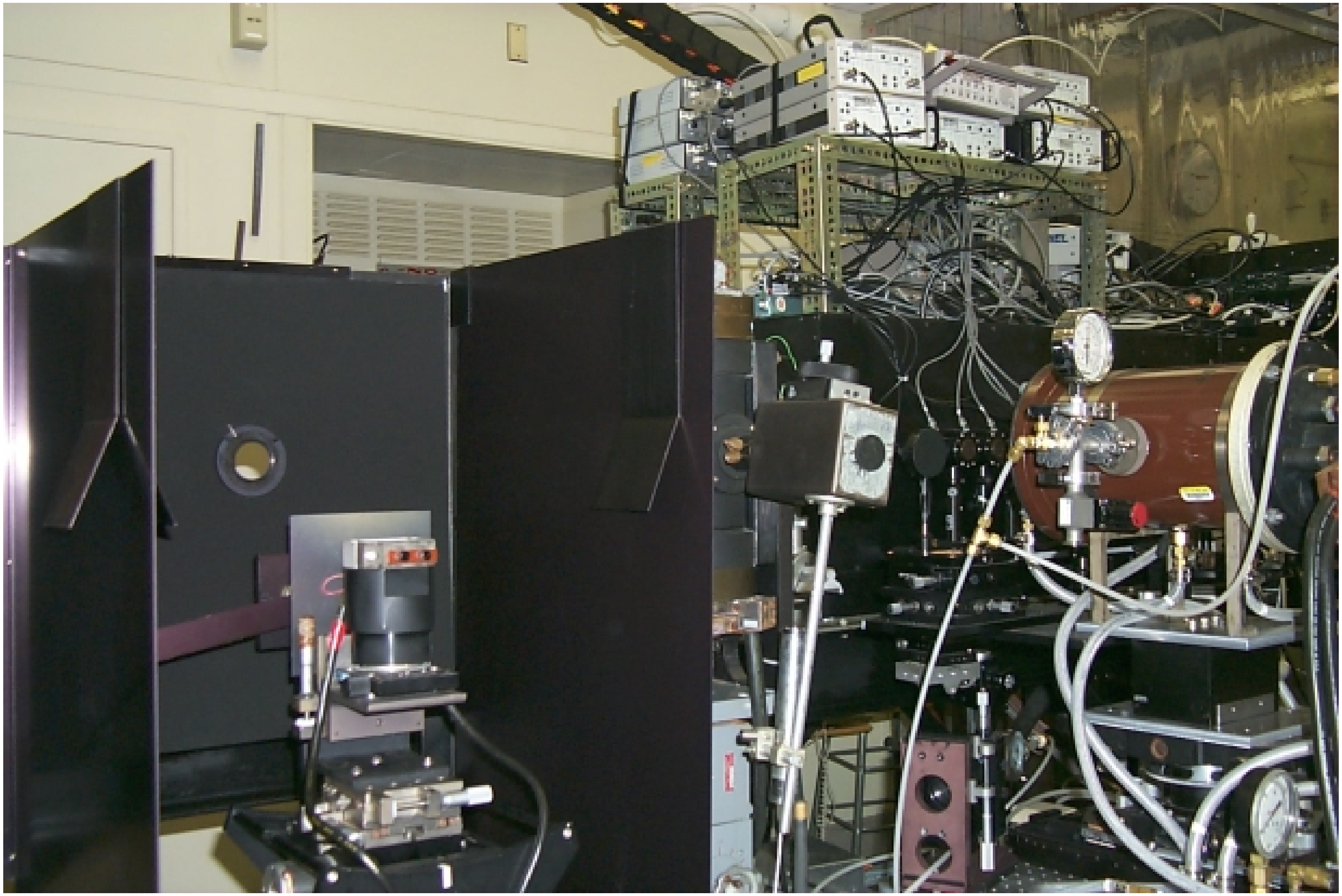
SCF_Temperature.OPJ

$$\frac{\Delta L}{L} = \frac{c_2}{\lambda} \frac{\Delta T}{T^2}$$

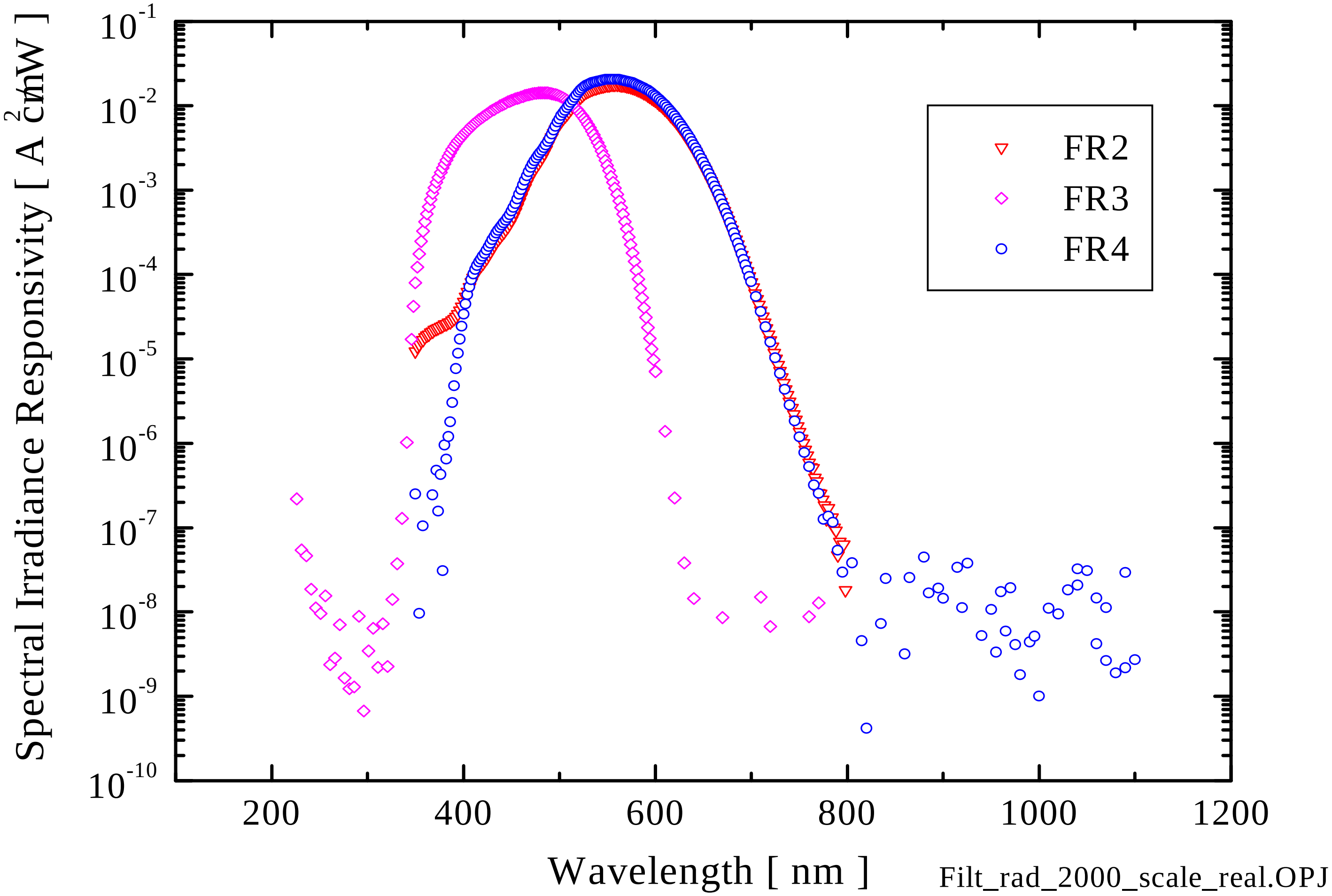
What is the agreement with the current NIST radiance temperature scale?



Measurements in FASCAL



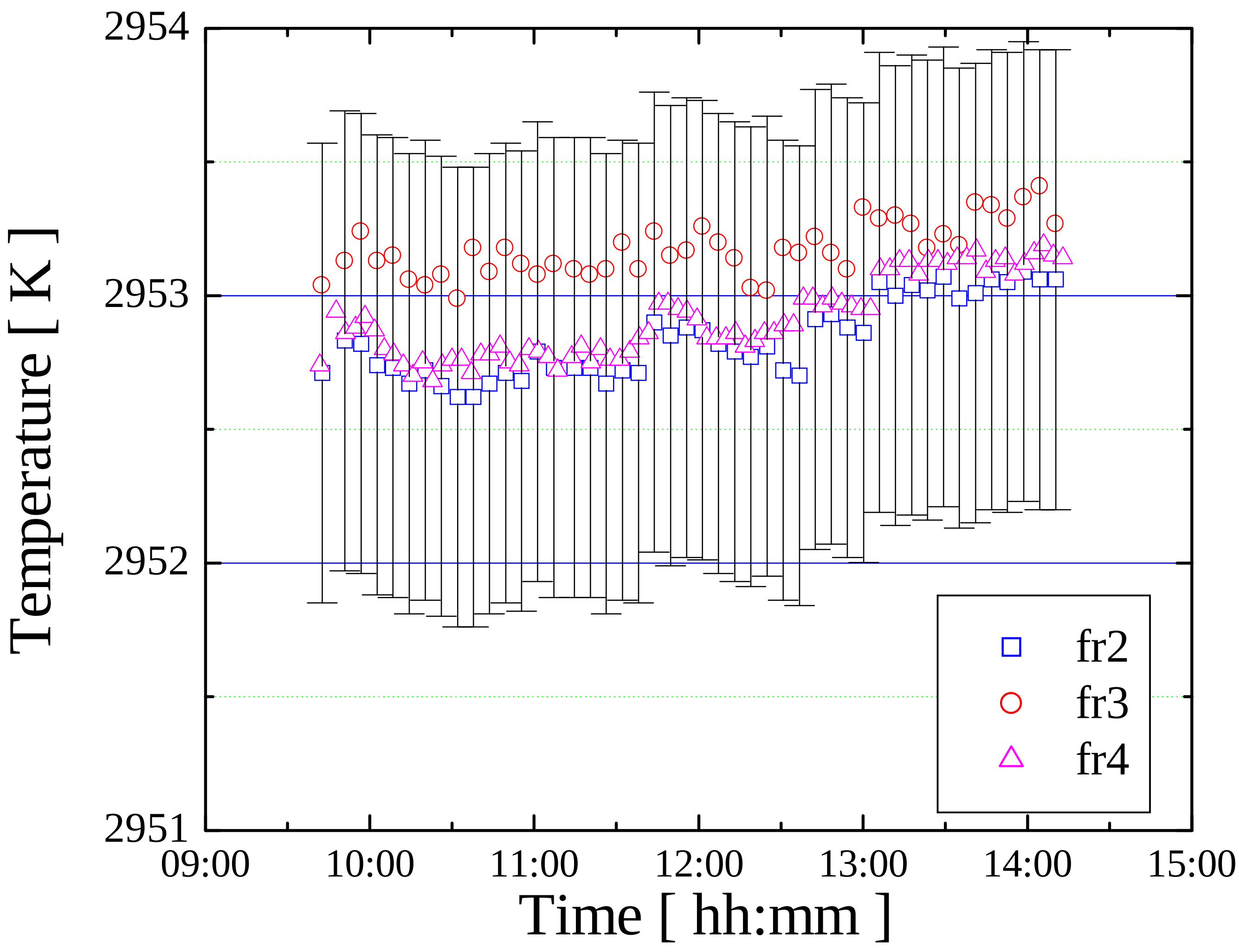
Spectral Irradiance Responsivity of Filter Radiometers



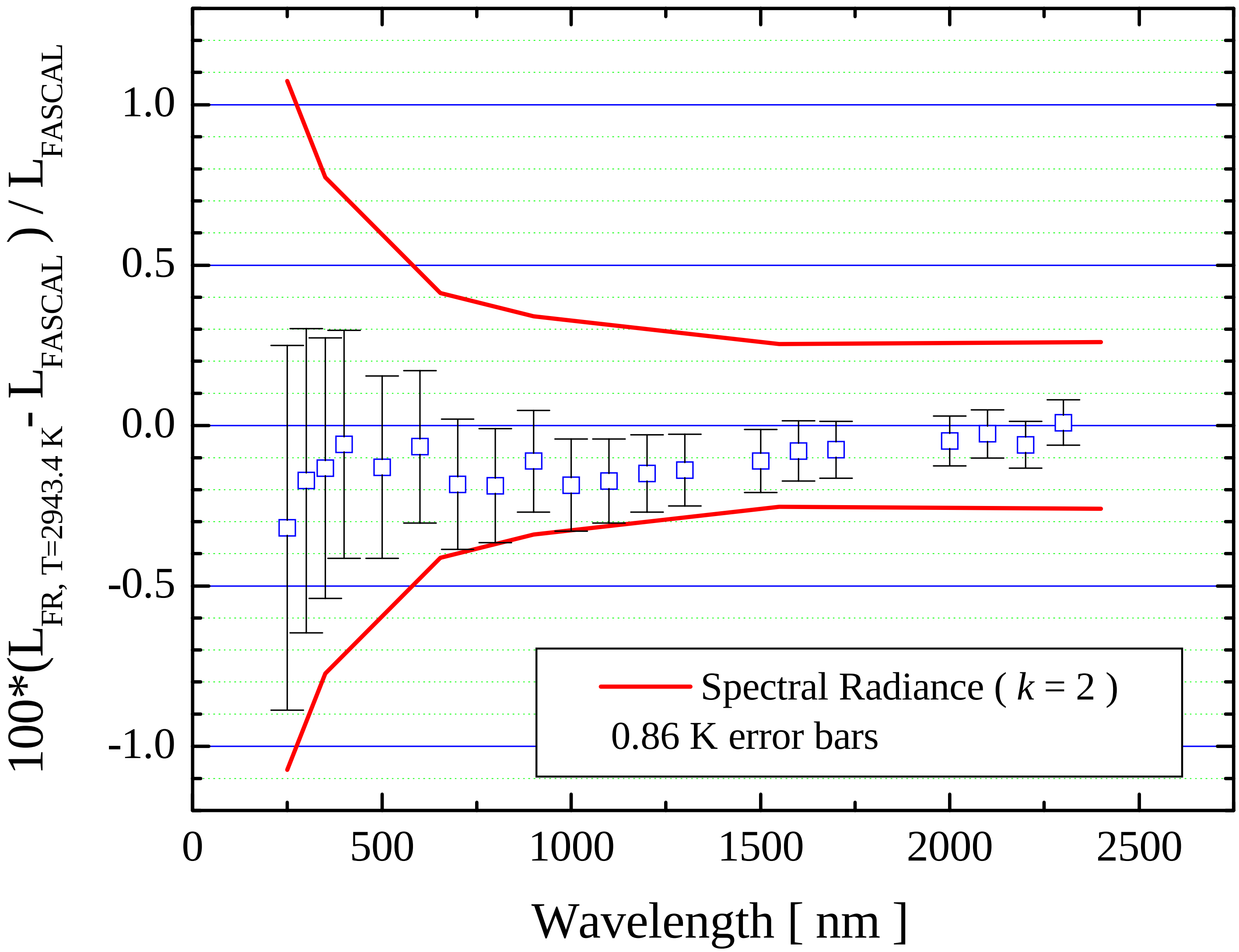
Uncertainties in the Spectral Irradiance Responsivity

Source of uncertainty [550 nm]	Expanded uncertainty [%]
Amplifier gain	0.006
Area of detector aperture	0.02
Area of HTBB aperture	0.02
Spectral power responsivity, FR	0.22
Measurement precision, HTBB/FR	0.006
Solid angle factor, HTBB/FR	0.026
Combined expanded uncertainty [k = 2]	**0.26**

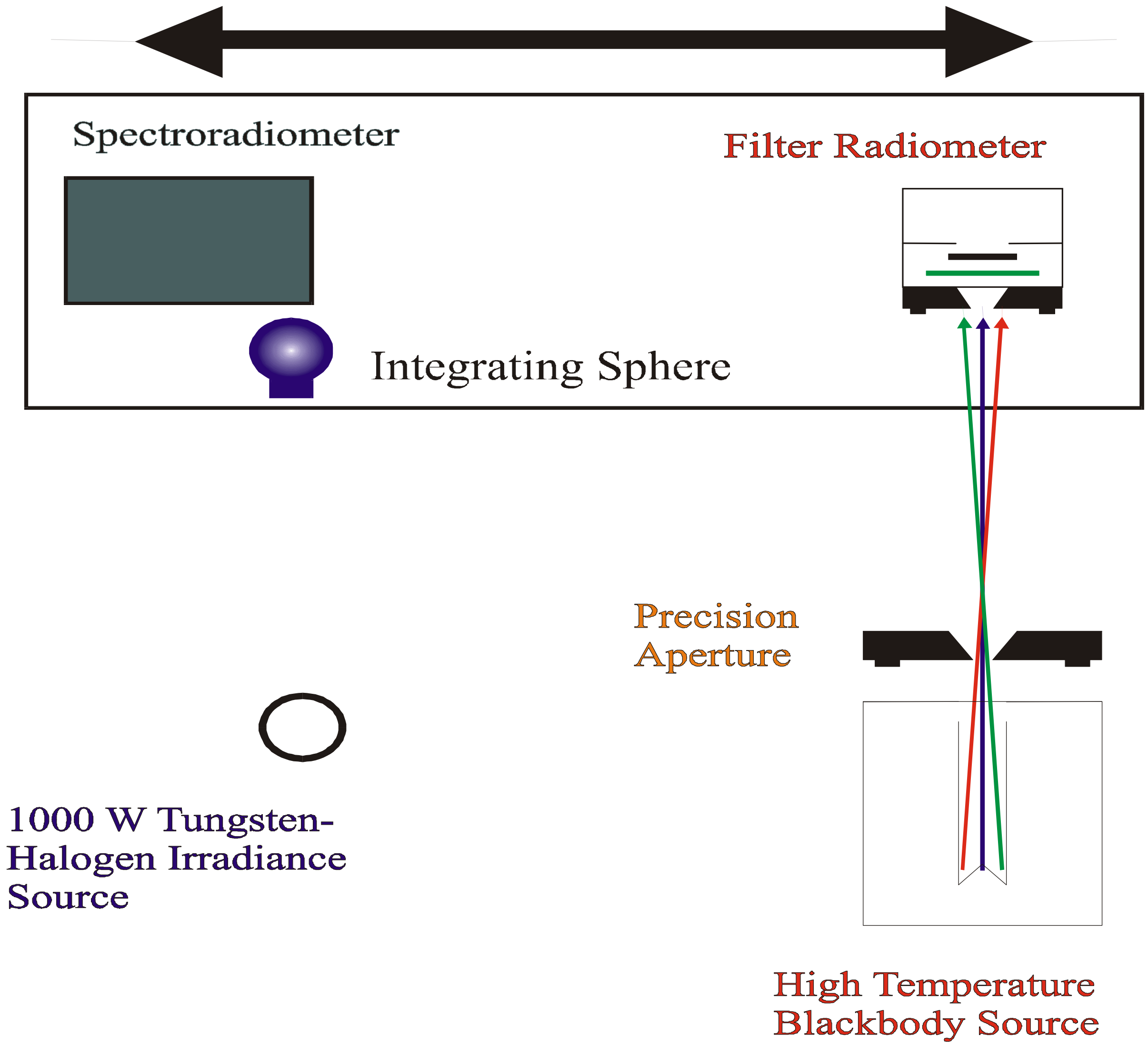
Temporal Stability of the HTBB



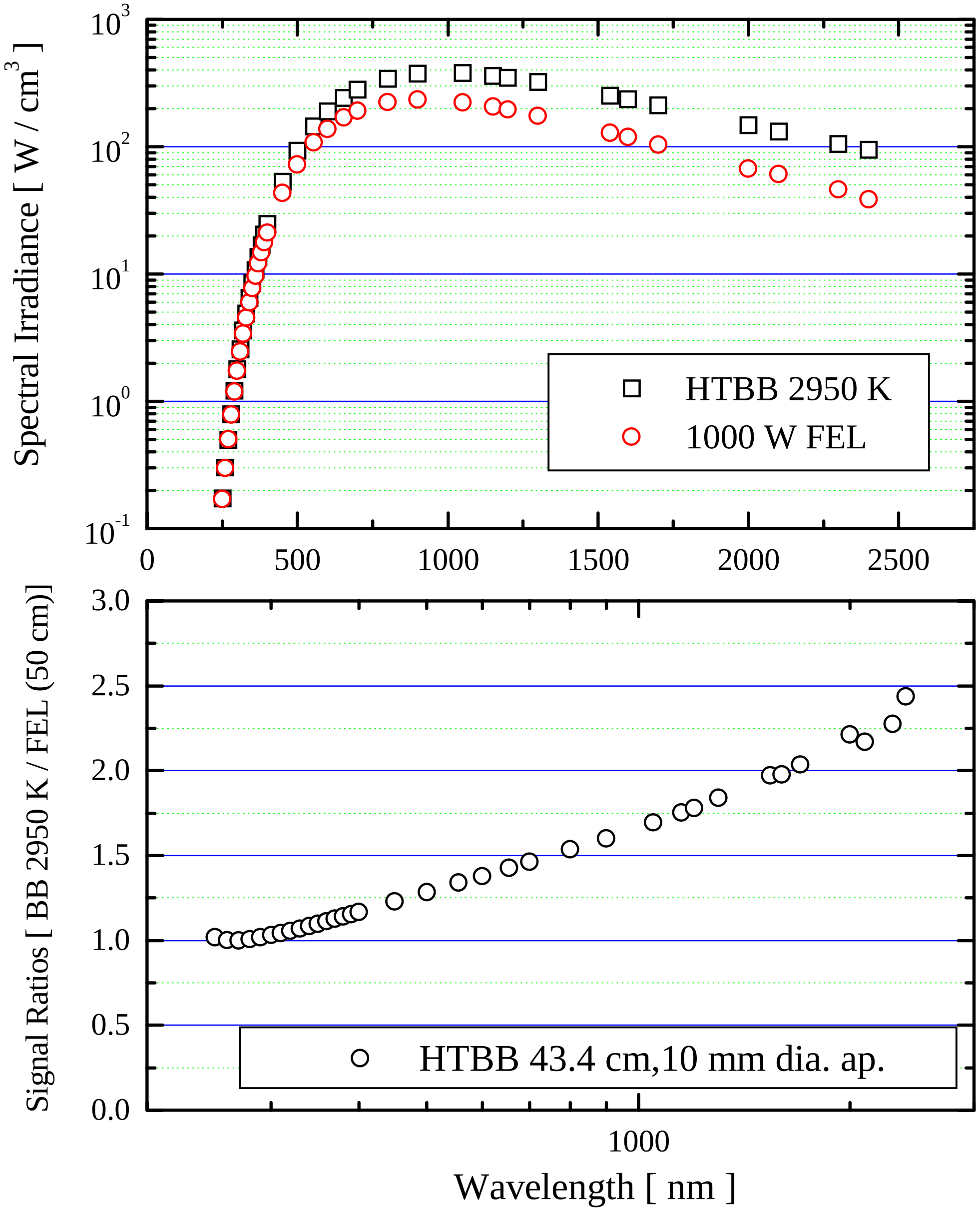
Comparison of the VTBB (FASCAL) and the HTBB



Spectral Irradiance Measurement



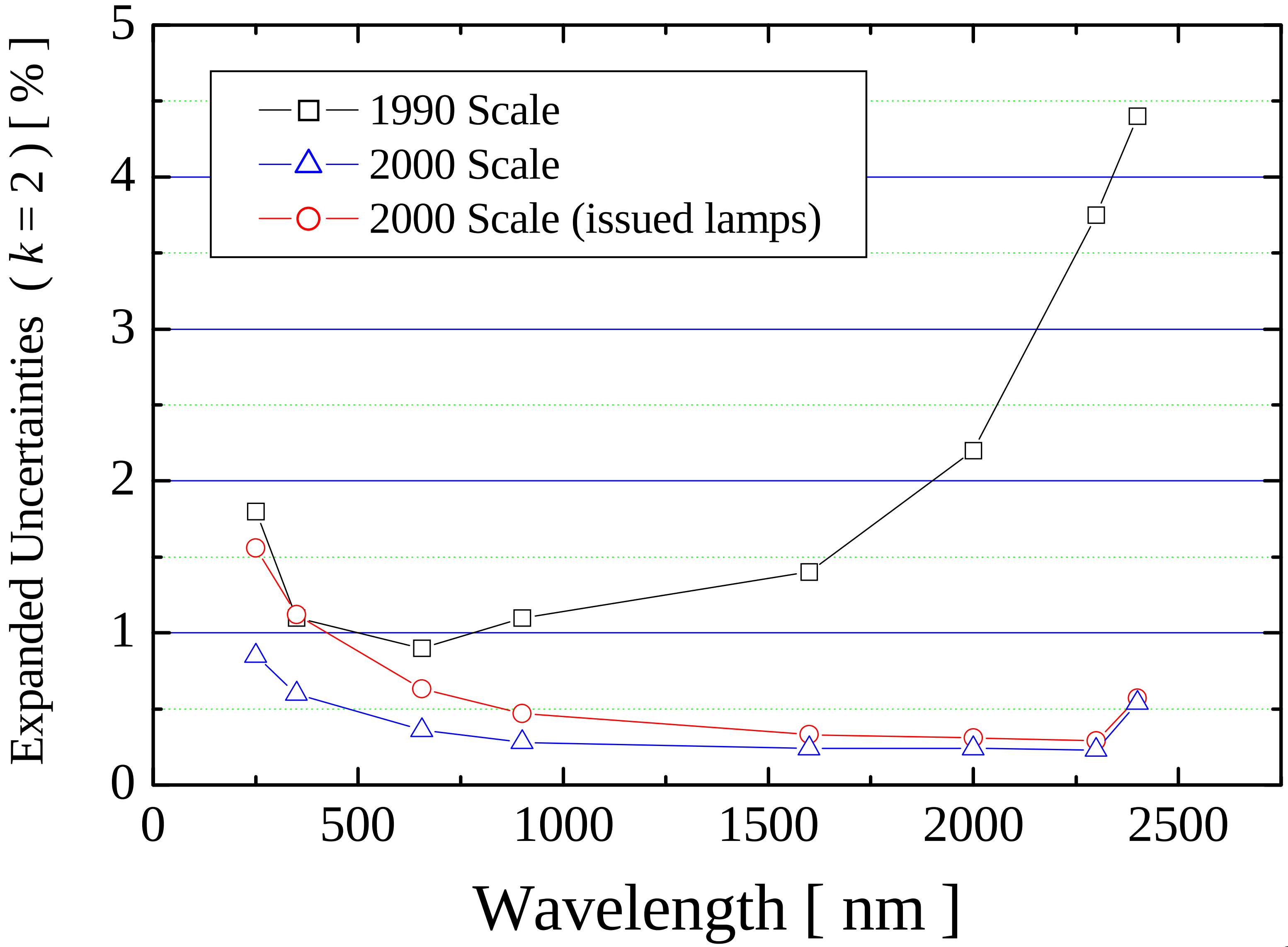
Comparison of the Spectral Irradiances of HTBB and the FEL Lamp



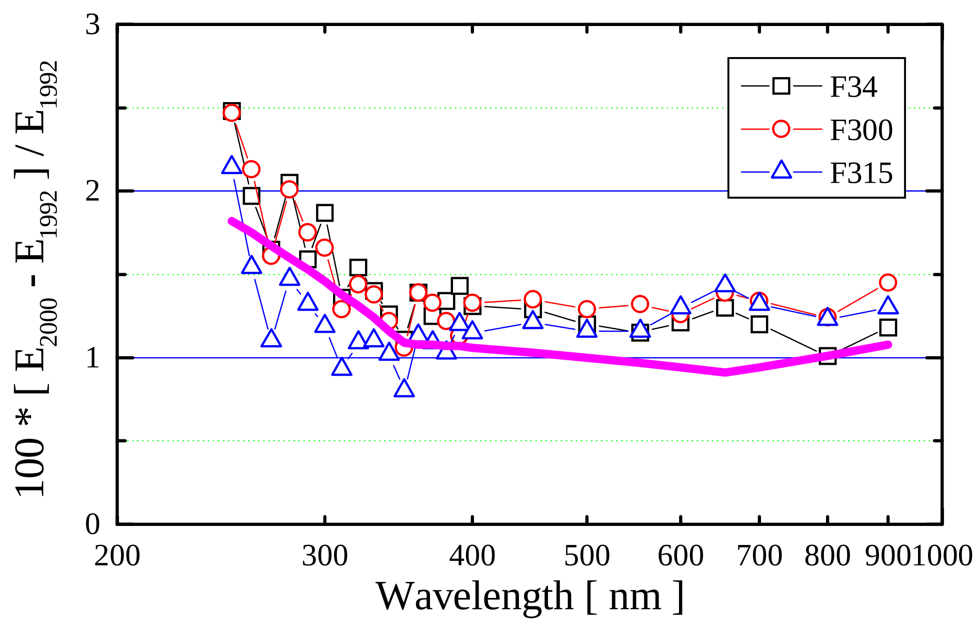
Uncertainties (k=2)of the Detector-based Spectral Irradiance Scale

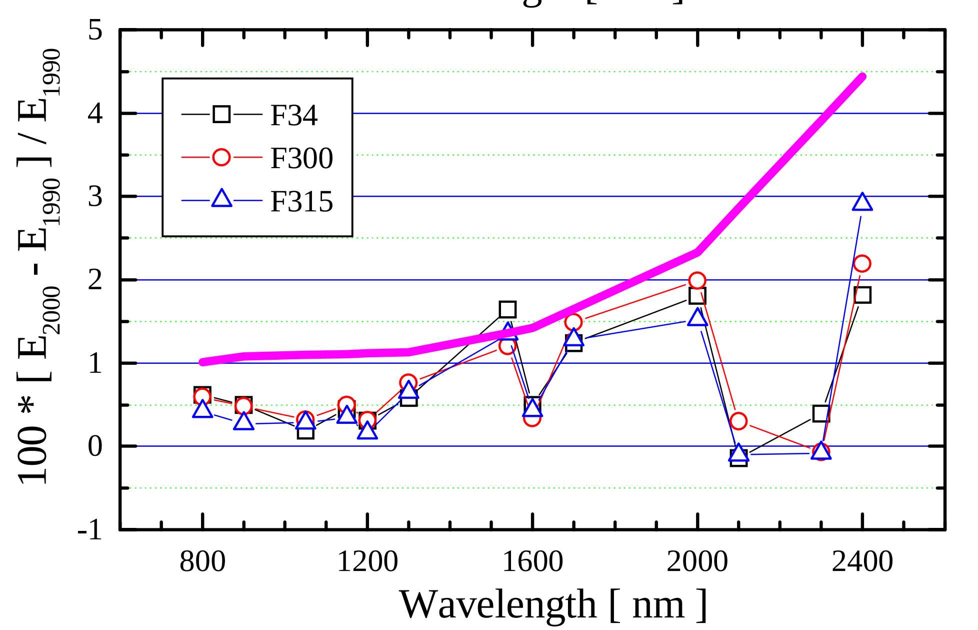
	Wavelength [nm]							
	250	350	655	900	1600	2000	2300	2400
1) HTBB Temperature Uncertainty [0.86 K at 2950 I	0.57	0.41	0.22	0.16	0.09	0.08	0.07	0.07
2) HTBB spectral emissivity	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
3) HTBB spatial uniformity	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
4) HTBB temporal stability [0.1 K / hour]	0.07	0.05	0.03	0.02	0.01	0.01	0.01	0.01
5) Geometric Factors in Irradiance Transfer	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
6) Spectroradiometer Responsivity Stability	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.5
7) Wavelength accuracy [0.1 nm]	0.58	0.38	0.18	0.005	0.011	0.013	0.011	0.011
8) Lamp / Spectroradiometer transfer	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
9) Lamp Current Stability	0.08	0.06	0.03	0.02	0.02	0.01	0.01	0.01
Total (k = 2)	0.85	0.60	0.36	0.28	0.24	0.24	0.23	0.54
10) Uncertainty of the primary working standards								
11) lamp-to-lamp transfer	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
12) Long-term stability of working standards	1.31	0.94	0.50	0.36	0.20	0.16	0.14	0.14
Total (k = 2)	1.56	1.12	0.63	0.47	0.33	0.31	0.29	0.57
13) Uncertainty of the issued standards								

Spectral Irradiance Scale Uncertainties



Measurements of the Check Standard Lamps

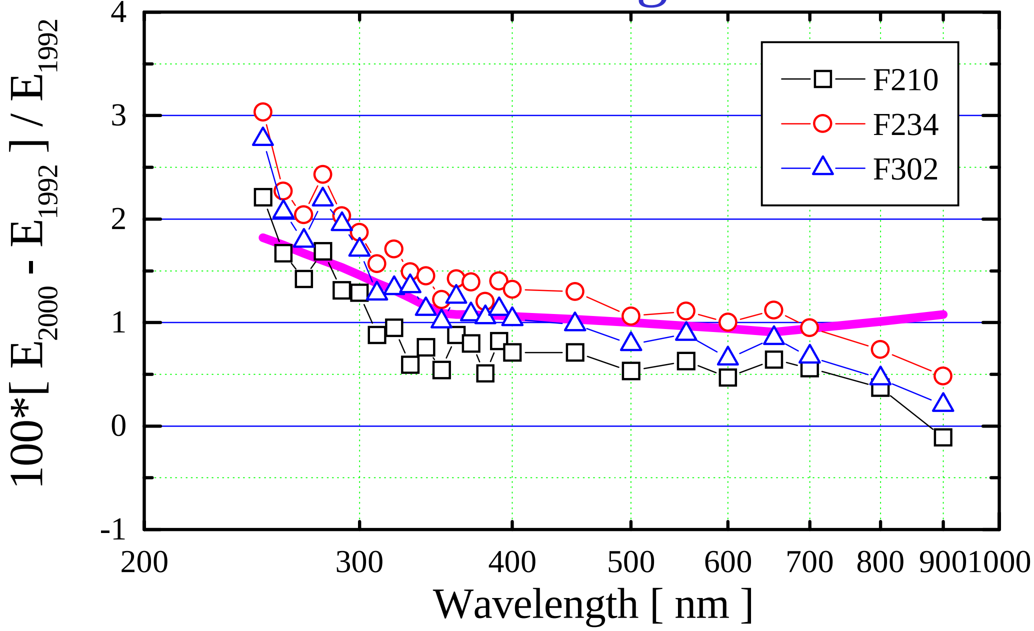


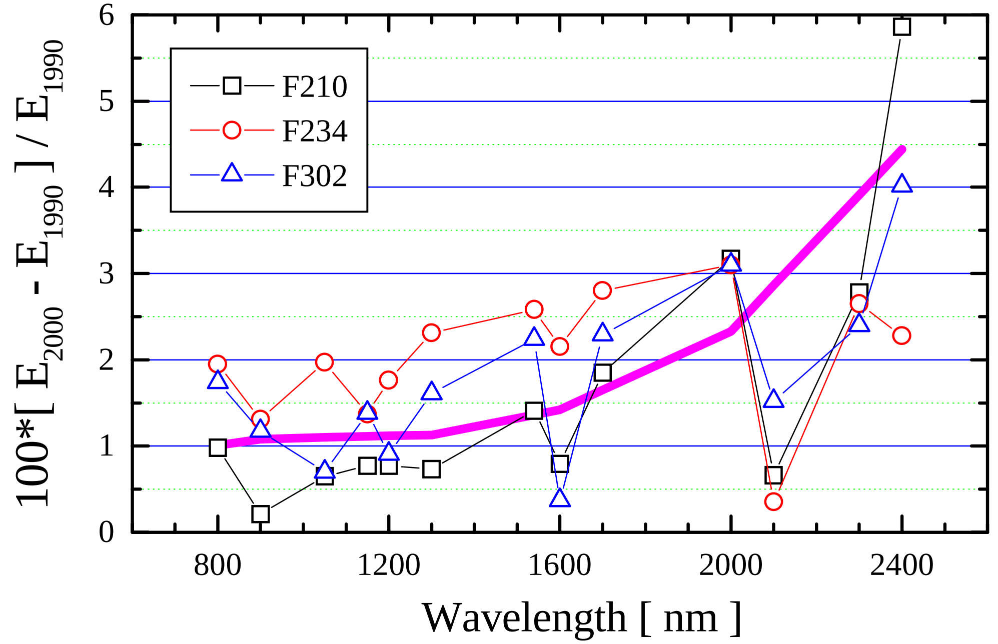


- All spectral irradiance differences are within the combined uncertainties of the respective scales.

E_scale_check_stands_2000_1992_1990.OPJ

Measurement of the Working Standard Lamps

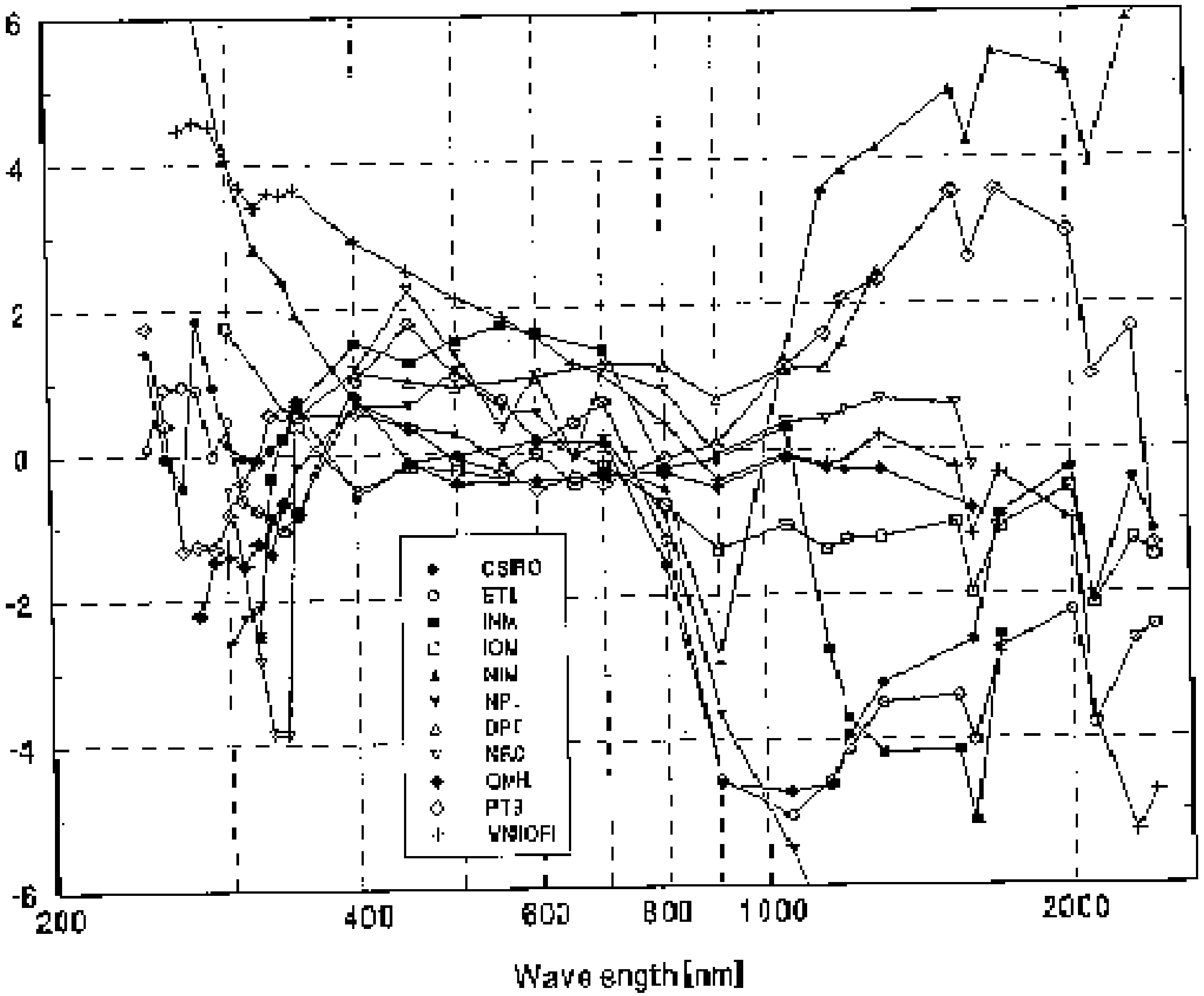




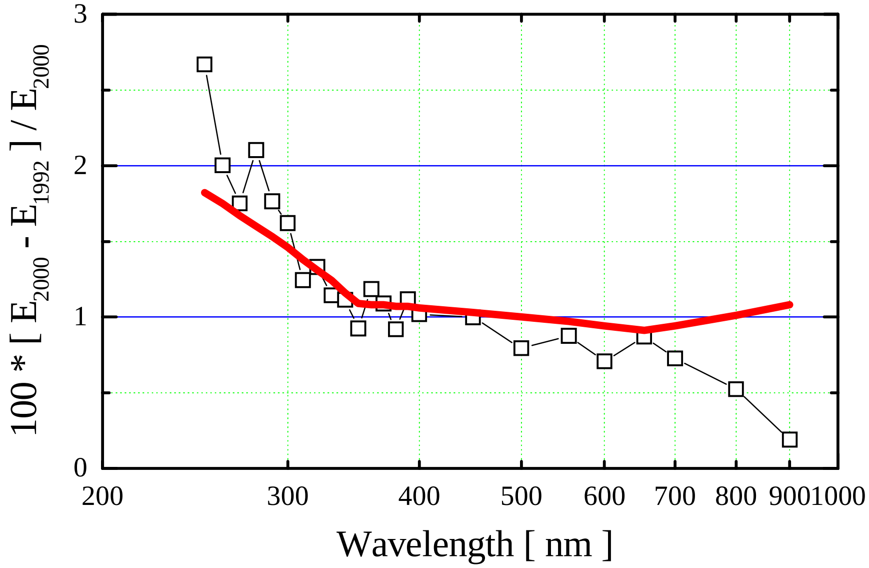
Spectral Irradiance Scale Uncertainties.OPJ

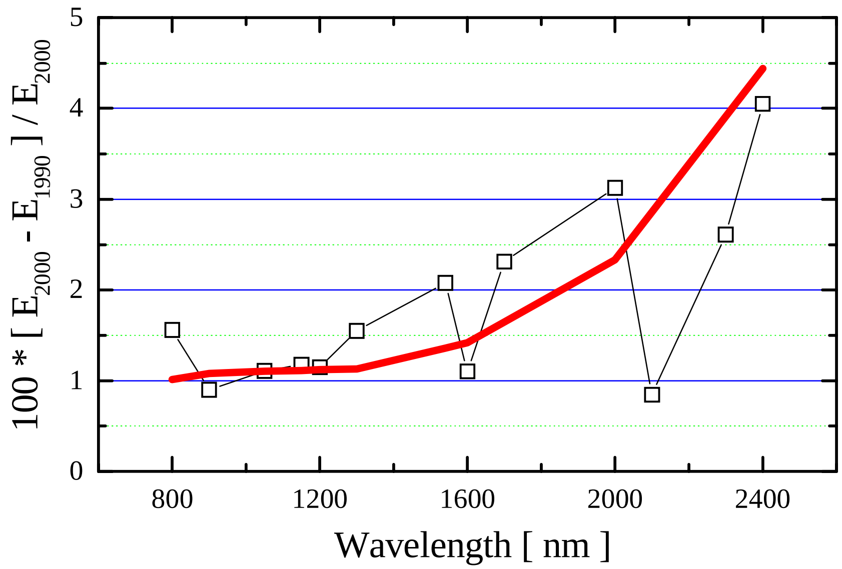
1990 CCPR Spectral Irradiance Comparison

Difference from NIST [%]



Differences between the spectral irradiances of the averaged working standard lamps and the spectral irradiances using the detector-based scale





Some values outside k = 2, but all values within k = 3.

Results and Conclusions

- Detector-based verifications:
  - Radiance temperature scale
  - Spectral radiance scale
- Realization of the detector-based spectral irradiance scale.
- Spectral irradiance standards issued from NIST beginning from calendar year 2001 are based on the detector-based scale.
- Spectral irradiance scale realizations performed on an yearly schedule.
- CCPR K1-a Key Comparison of spectral irradiance from (250 nm to 2500 nm).

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