Red Detector Tests

May 5^{ed} -2006

1. Black Body @ 900F, Comparison between red and blue detectors:

Table #1: Detector’s signal with and without filters –BB at 900F

Filter(micron)	**Red[*] [mV]**			**Blue[†] [mV]**
	G = min.	**G = med.**	**G = max.**	**17/32**
Open	106[‡]	1540	2600	8880
10.6	3.2	35	56	B.L.[§]
5.3	5.4	44	70	440
3.6	3.4	37	60	470
1.765	B.L.	15	24	102
1.325	B.L.	16	25	122
Open	106	1560	2600	9120

We define now the ratio:

$$\frac{I_F}{I_O} = \frac{\text{Detector's signal with filter}}{\text{Detector's signal without filter}} \times 100\% \qquad (1)$$

According to SPECTROGON (the filters’ company) the filters have Gaussian spectral response of the following form:

$$T_F(\lambda) = T_{peak} \exp\left(-\frac{(\lambda - \lambda_{peak})^2}{2\left(\frac{HW}{2}\right)^2} \right) \qquad (2)$$

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[*] SNR of 40. Scope noise level is 1mV, and detector noise level is 4mV.

[†] SNR of 30. Scope noise level is 1mV, and detector noise level is 5mV.

[‡] For low gain the signal is too small, therefore, the results accuracy are subject to the SNR of the detector and the scope.

[§] B.L.: below noise level of the scope. N.L.: ~ 1mV.

wherein T_{peak} is the maximum of transmittance, $\lambda_{peak}[\mu m]$ is the wavelength at the maximum of the transmittance and $HW[\mu m]$ is the full width of the pass band measured at half the maximum peak transmittance. In the following table the ratio defined in Eq. 1 is introduced for the results recorded in Table #1.

Table #2: Detector's signals ratio –BB at 900F

Filter(micron)	**Red - %**			**Blue - %**
	G = min.	**G = med.**	**G = max.**	
10.6	3.02	2.25	2.15	-
5.3	5.09	2.84	2.69	4.88
3.6	3.20	2.39	2.307	5.22
1.765	-	0.97	0.92	1.13
1.325	-	1.03	0.96	1.35

2. Black Body @ 1300F, Comparison between red and blue detectors:

Table #3: Detector's signal with and without filters –BB at 1300F

Filter(micron)	**Red [mV]**			**Blue [mV]**
	G = min.	**G = med.**	**G = max.**	**17/32**
Open	260	3400	6400	12000
10.6	4.4	46	88	B.L.
5.3	6.9	80	152	412
3.6	7.8	94.4	180	620
1.765	2.8	26	48	132
1.325	3	30	54	148
Open	260	3360	6480	11900

Table #4: Detector's signals ratio –BB at 1300F

Filter(micron)	**Red - %**			**Blue - %**
	G = min.	**G = med.**	**G = max.**	
10.6	1.69	1.36	1.36	-
5.3	2.65	2.37	2.36	3.45
3.6	3.00	2.79	2.79	5.18
1.765	1.07	0.77	0.75	1.10
1.325	1.15	0.88	0.84	1.23

The spectral response of the red detector is shown in the following curve as measured by the IR Company. A best fit for this curve is given by a 5th order polynomial.

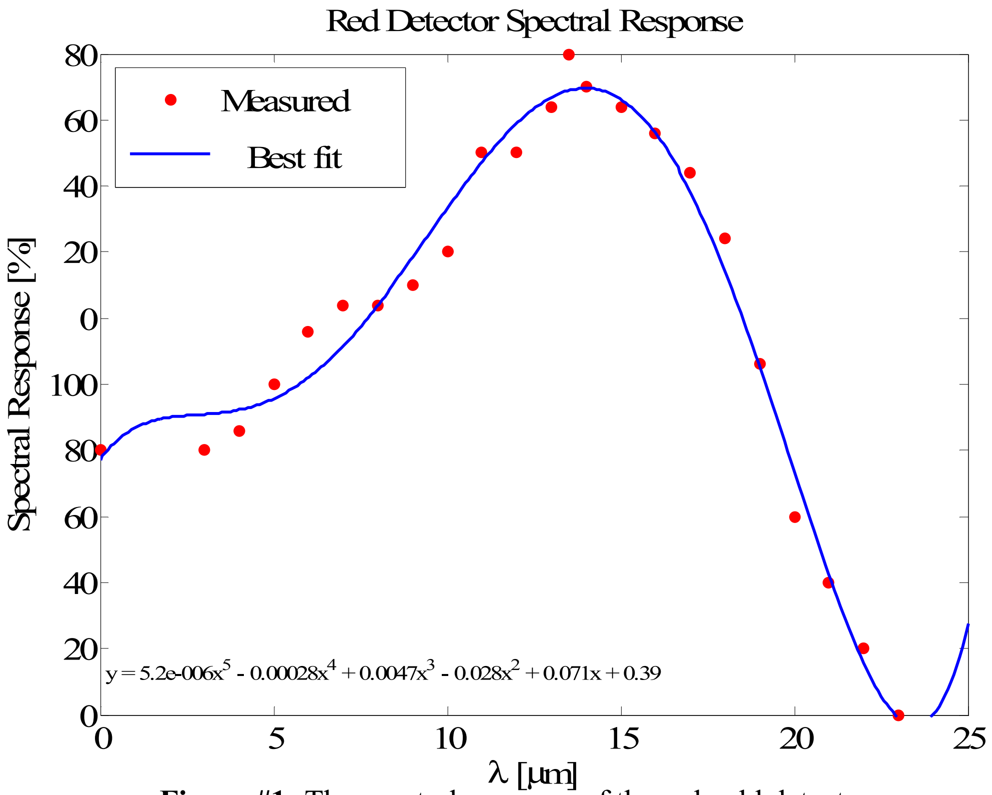

Figure #1: The spectral response of the red cold detector

The intensity distribution of a black body radiation is given by:

$$\mathrm{I}_{\mathrm{BB}}(\lambda) = \frac{2\pi hc^2}{\lambda^5 \left(e^{hc/\lambda kT} - 1\right)}, \tag{3}$$

where *h* is Plank's constant, *c* is the speed of light in vacuum, *k* is Boltzmann's constant, *T* is the absolute temperature of the black body and λ is the wavelength. Curves for the normalized intensity versus the wavelength for the tested temperatures are introduced in the following figure.

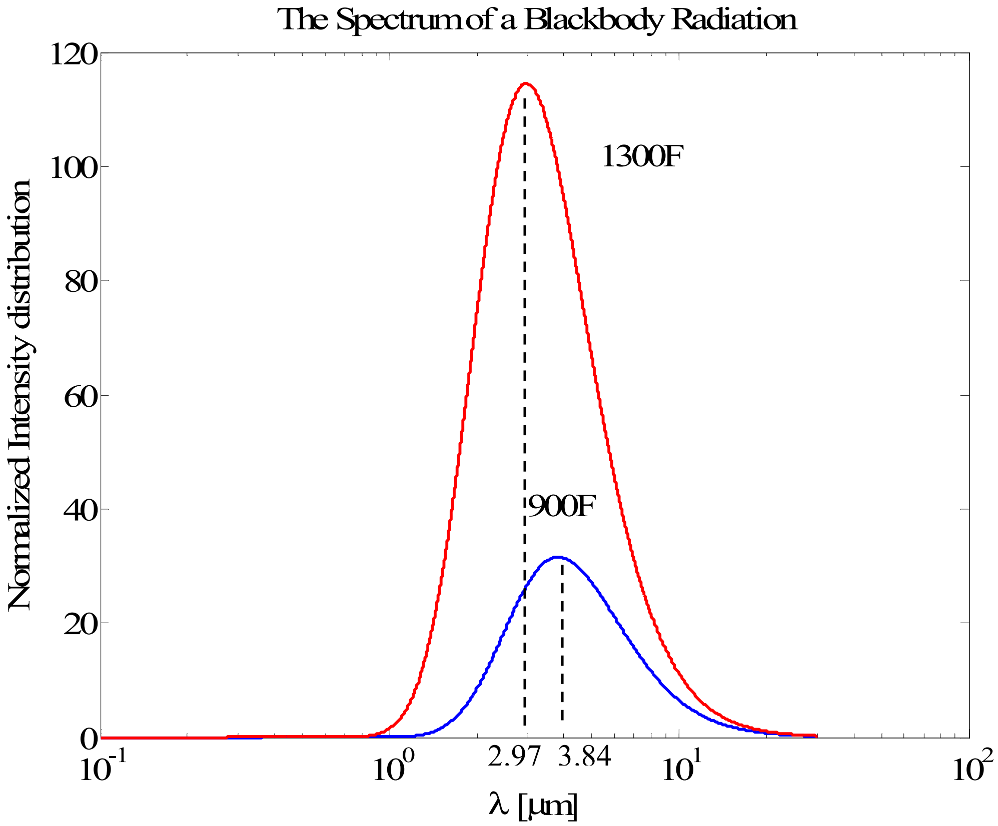

Figure #2: The spectrum of a blackbody radiation

In order to have an analytical evaluation of the detector performance for the different set of filters we should consider the filters spectral responses. The main problem with these filters is that the company doesn't provide us with the exact peak transmittance of the filter. For the following set of filters (were used in the test) the company provides us with the following numbers:

Table #5: Filters' main characteristics

Filter #	λ_{peak} [μm]	HW [μm]	$\mathrm{T}_{\mathrm{peak}} > [\%]$
1	1.325	0.03	70
2	1.765	0.01	70
3	3.600	0.17	70
4	5.300	0.20	70
5	10.600	0.37	70

As a first step we assume for all the filters a transmittance of 0.7 and based on the measurements we will try to get better estimate to its real transmittance.

Denoting the spectral response of the detector by $\mathrm{T}_{\mathrm{D}}(\lambda)$ the signal measured by the detector due to the blackbody radiation and the presence of a filter is given by

$$\mathrm{I}_{\mathrm{F}}=\int_{0}^{\infty} d\lambda \mathrm{I}_{\mathrm{BB}}(\lambda)\mathrm{T}_{\mathrm{F}}(\lambda)\mathrm{T}_{\mathrm{D}}(\lambda)\mathrm{G}(\lambda), \tag{4}$$

where $\mathrm{G}(\lambda)$ is the gain of the detector. We assume a frequency independent gain and linear operation of the detector.

In a similar way the signal measured in the absence of the filter is given by

$$\mathrm{I}_{\mathrm{O}}=\int_{0}^{\infty} d\lambda \mathrm{I}_{\mathrm{BB}}(\lambda)\mathrm{T}_{\mathrm{D}}(\lambda)\mathrm{G}(\lambda) \tag{5}$$

Assuming frequency independent gain the ratio defined in Eq. 1 can be calculated and is given by:

$$\frac{\mathrm{I}_{\mathrm{F}}}{\mathrm{I}_{\mathrm{O}}}=\frac{\int_{0}^{\infty} d\lambda \mathrm{I}_{\mathrm{BB}}(\lambda)\mathrm{T}_{\mathrm{F}}(\lambda)\mathrm{T}_{\mathrm{D}}(\lambda)}{\int_{0}^{\infty} d\lambda \mathrm{I}_{\mathrm{BB}}(\lambda)\mathrm{T}_{\mathrm{D}}(\lambda)}\times 100\% \tag{6}$$

In the following curves we plot the ratio defined in Eq. 1 as measured during the tests (Tables #2 and #4) compared to the calculated value. Based on these curves the real transmittance of the different filters is determined.

First we introduce the spectral response of the blackbody, filters and detector on the same plot (the blackbody spectrum is normalized to its peak).

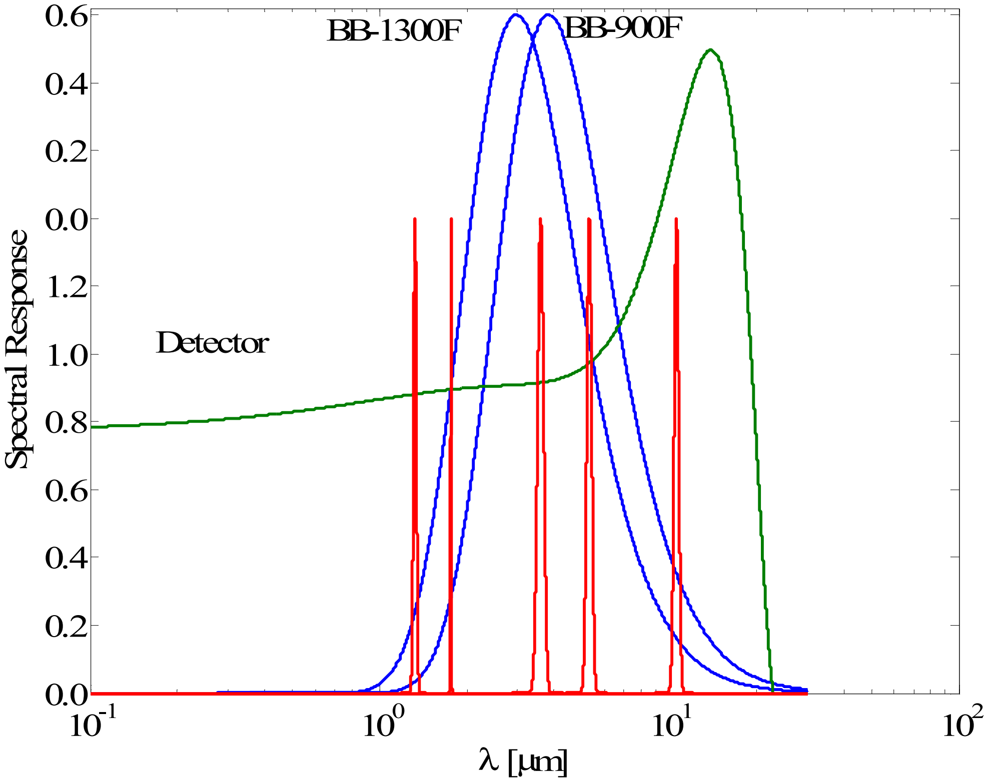

Figure #3: Spectral responses for blackbody, filters and red detector

The detector's signal was recorder for three different gains: minimum gain, medium gain and maximum gain. The readings for minimum gain are not that accurate when the signal is weak due to noise from the scope and the detector. Therefore, in our evaluation of the filters' transmittance we count only on the ratio recorded at medium and maximum gain. The curves shown in Figures 4 and 5 indicate that the ratios for these gains almost overlap.

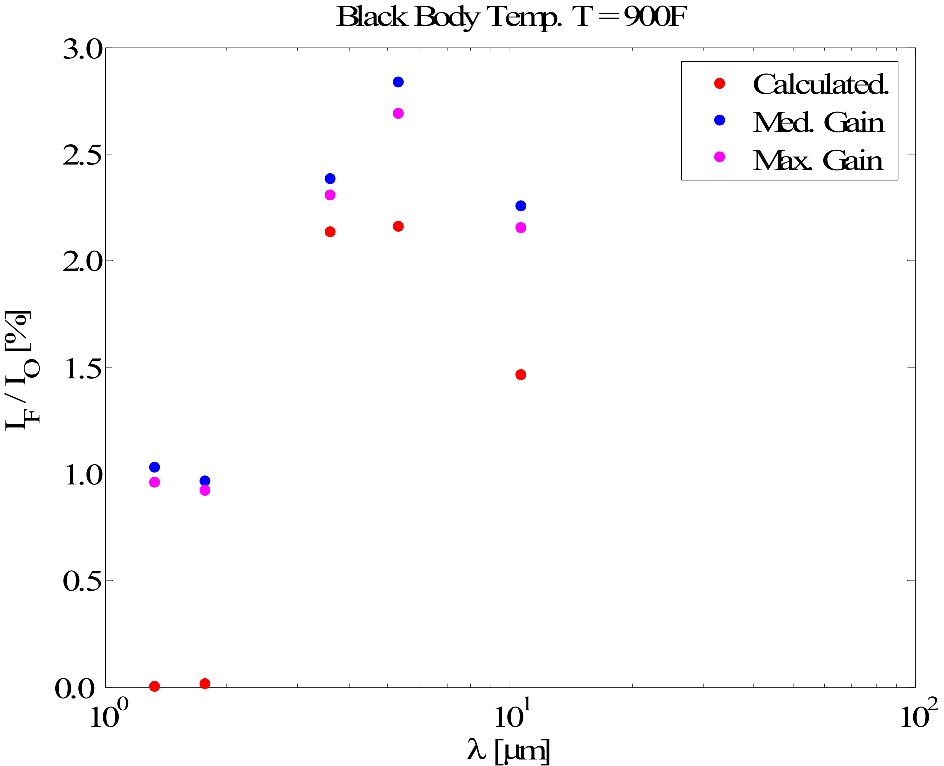

Figure #4: Signals ratio at 900F

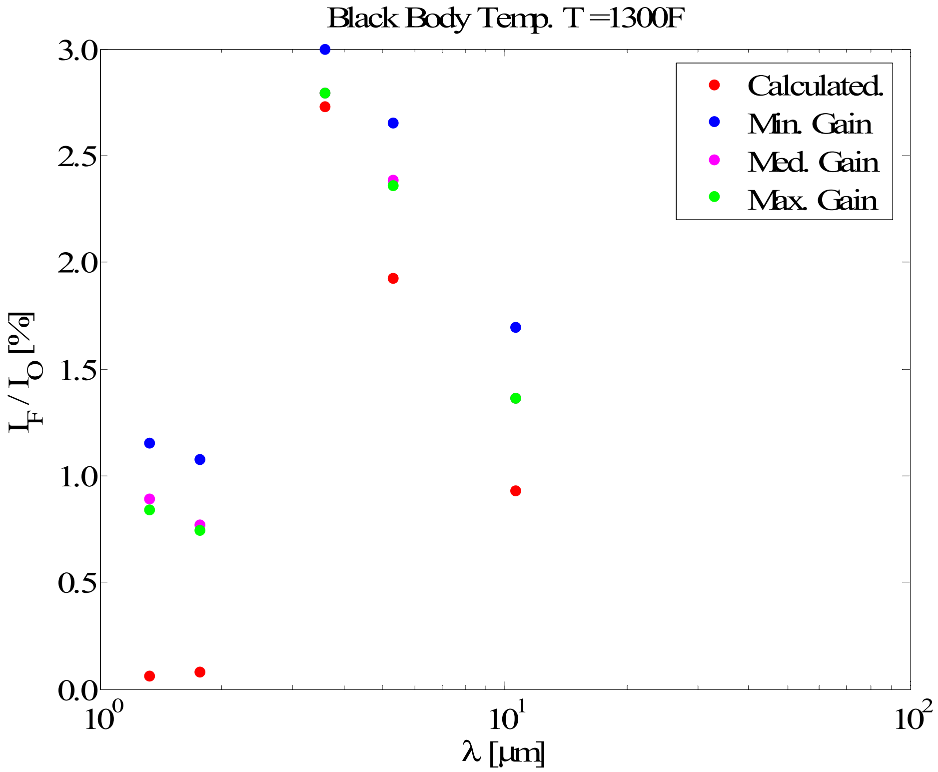

Figure #5: Signals ratio at 1300F

Based on the curves presented in figures 4 and 5 the transmittance of each filter is estimated to be:

Table #6: Filters' estimated transmittance

Filter #	λ_{peak} [μm]	T_{peak} ~ [%]
1	1.325	-[**]
2	1.765	-[††]
3	3.600	70
4	5.300	88
5	10.600	98

[**] We weren't able to determine the transmittance. It seems that the signal is too weak and the numbers we measured are due to noise rather than real signal. As a matter of fact blackbody radiation is useless at these temperature for wavelengths shorter than 2micron (see figure 3).

[††] See comment above.

3. Black Body @ 1300F, Beam Splitter Tests

	Open -90		**Open -45**		**10.6 -90**		**10.6 – 45**		**3.6 – 90**		**3.6 -45**	
	T	**R**	**T**	**R**	**T**	**R**	**T**	**R**	**T**	**R**	**T**	**R**
B.S. #1[‡‡]	28	32	25	24	19	17	16	10	32	19	19	17
B.S. #2[§§]	32	33	30	11	27	36	27	10	38	41	32	11

[‡‡] The splitter with the bigger diameter.

[§§] The splitter with the smaller diameter.