

Problem

Infra-red temperature measurement is a convenient way for non-contact temperature acquisition, especially on the occasion of NBI components heating data realtime recording. For the application of such method, we did some verification to make the future placement more reliably.

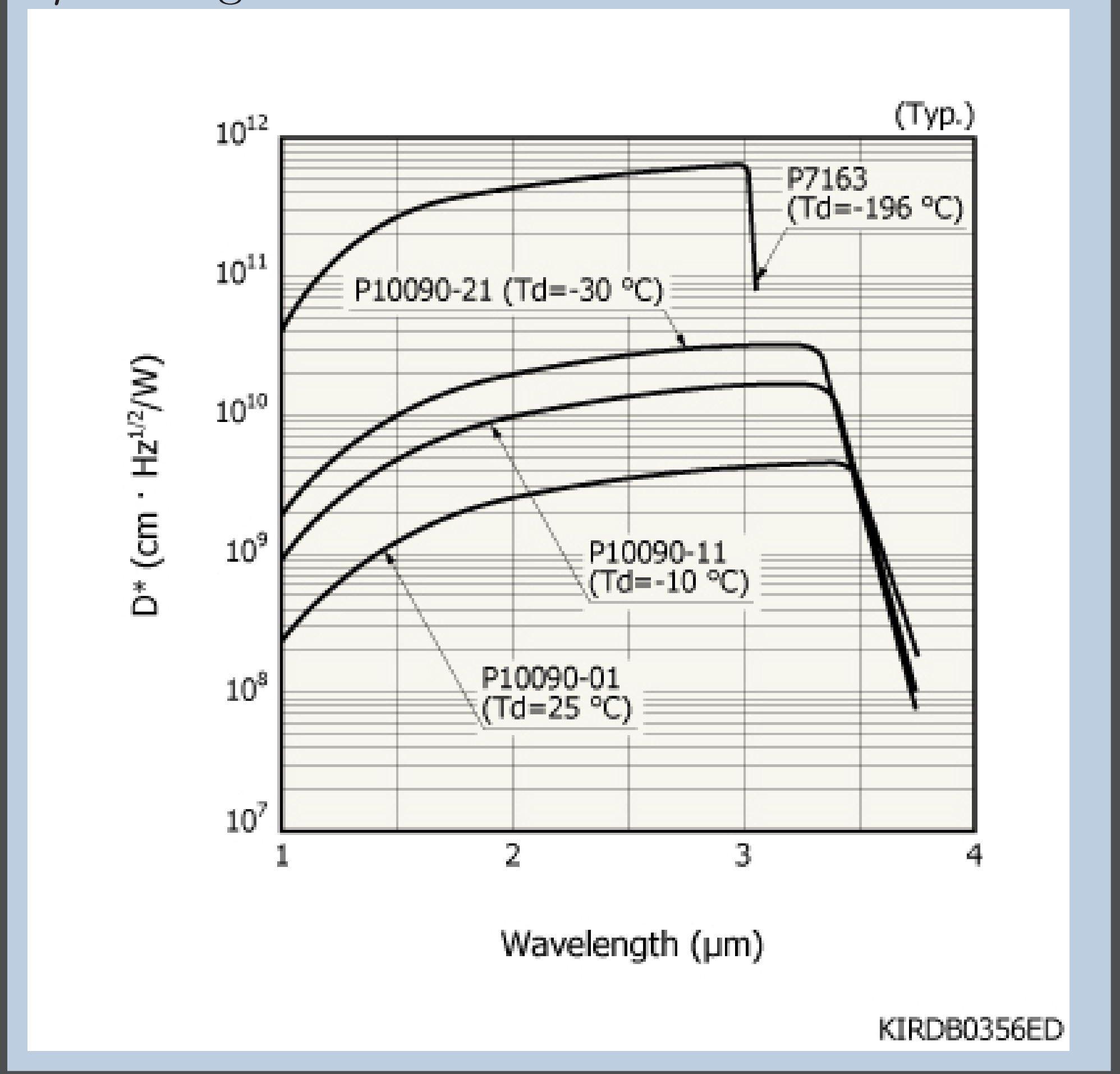
Basic Concepts

Radiation temperature measurement is acquired widely to be based on the famous Planck's law of blackbody radiation, which indicate that any object with a temperature higher than absolute zero is constantly radiating infrared rays outward. According to the law, the radiation emission at a given temperature is constant in object and varies among materials which ruled by its emission rate.

- ## Models
- Just as other emission model, the received energy of a given radiation source is dominated by its spatial placement and the emission rule of the give source. So, my work here is to verify:
- the radiation rule of the blackbody
 - the spatially variation rule of the received emission.

Setup

We use a blackbody as the temperature source, with a range of 0 - 600°C. And HAMAMATSU's P10090-21 as the infra-red detector, suitable for 3μm range.



Conclusion

Those two rules are the bases for a more accurate infra-red measurement way of NBI process monitoring. As for infra-red measurement, results changes with different arrangement which should be verified beforehand.

Verification of the Radiation Rule

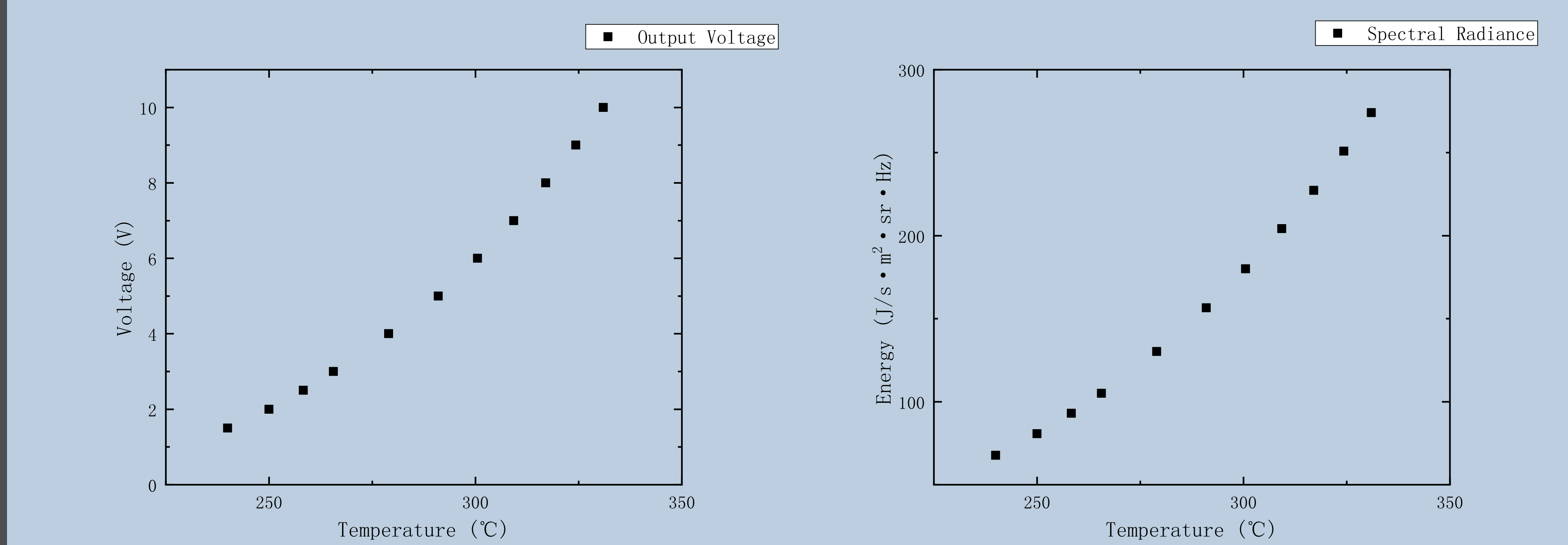
For a typical monochromatic radiation temperature measurement, the measured voltage of the transferred emission follows this equation:

$$V_{num} = \rho M \cdot \frac{\Delta A_B}{\pi l_B^2} \times D_{decay} \times S_{sensor} \times T_{trans} \times A_{amp}$$

Among them, ρ represent the emission rate of the source, ΔA_B is light collection area and l_B shows its distance, D_{decay} give a sum to the optical attenuation, T_{trans} gives us the conversion factor from radiation to electric signal, A_{amp} is the amplifier magnification, M is the blackbody spectral radiance, which follows Planck blackbody radiation formula:

$$M = \int_{\lambda_1}^{\lambda_2} \cdot \frac{2\pi hc^2}{\lambda^5} \cdot \frac{d\lambda}{e^{hc/k_B \lambda T} - 1}$$

Among them, h is Planck's constant equals 6.626e-34 J · s, c is the speed of light equals 2.997925e8 m / s, T is the temperature of the source, λ is spectral wavelength, and k_B is Boltzmann's constant equals 1.38054e-23 J / K. To verify the emission rule, we keep the spatial placement fixed and change the temperature of the source to collect the data. Under such situation, the output voltage V_{num} is proportional to Planck blackbody spectral radiance M . But considering the zero drift, the presented $M - V_{num}$ relationship is a linear function theoretically. So we did the verification:



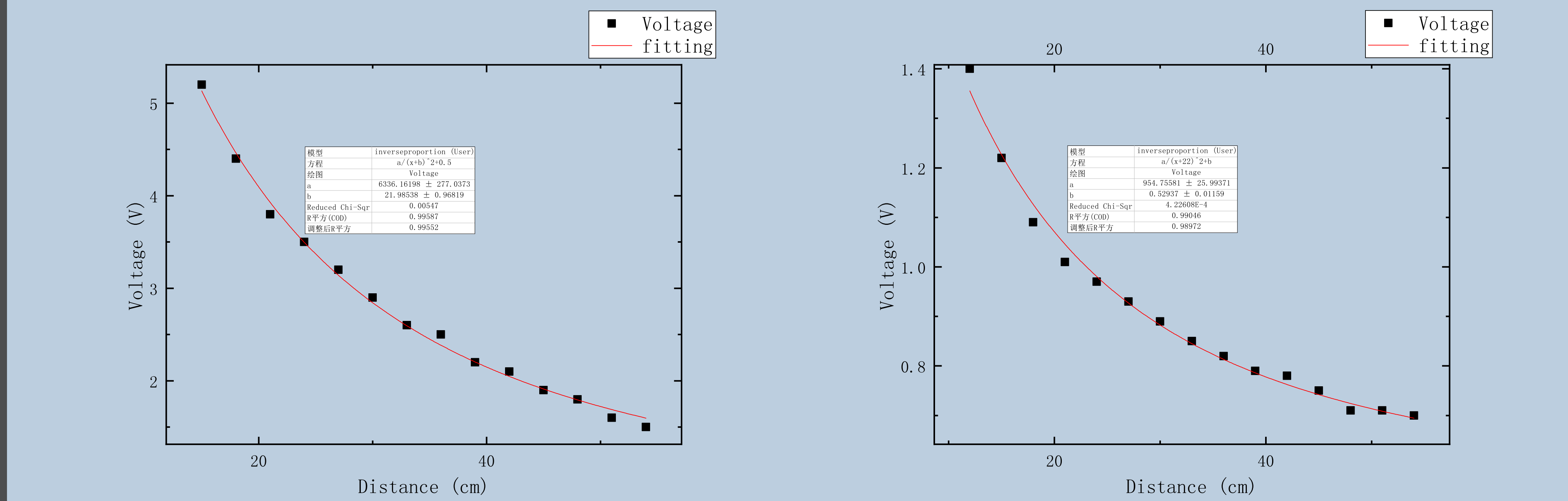
Using the above $M - V_{num}$ data, we did a linear fit and get a COD of 0.99969, So $M - V_{num}$ have a typical linear relationship.

Verification of the Spatial Variation Rule

To verify the spatially variation rule, we keep the source temperature and the spatial phase fixed and change the observing distance to record the vary of the output voltage V_{num} . The distance should be inversely proportional to the output voltage V_{num} . And due to the zero drift b_0 and the initial distance of the blackbody source l_0 , the actual relationship follows equation:

$$V_{num} = \frac{k}{(l_B + l_0)^2} + b_0$$

We used two different temperature sets, each has a zero drift of 0.5V, since l_0 is a constant number we use one data set to fitting the k, l_0 data with $b_0 = 0.5V$, another one using the l_0 data and fitting the k, b_0 to see whether b_0 fitted to 0.5V.



The result shows that $b_0 = 0.53V$, so the fitting result meets the expected data and the spatial relationship is verified.