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Research Article

Limitations of Pyrometer Technology in the Ultraviolet and Visible Spectral Bands According to Planck's Law on the Real Body

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Abstract

This article investigates the limitations of pyrometric technology in the visible and ultraviolet spectral bands. These studies rely on a theoretical analysis of thermal radiation, Planck's fundamental laws, and multispectral processing methods based on nonlinear models. Accurate high-temperature measurement is a major challenge in many scientific and industrial fields, including thermal processes, metallurgy, energy, and fundamental research. Uncertainty in emissivity is the main source of error in conventional pyrometric measurements. To reduce the influence of emissivity and improve measurement reliability, several approaches have been developed, including monochromatic, bichromatic, and multispectral pyrometry based on Planck's law. The chromatic luminance characteristics in the visible and ultraviolet bands, obtained from a temperature range across both spectral domains, highlight the high potential of pyrometry for measuring high temperatures in complex environments. These characteristics will be applied with different wavelengths in each visible and ultraviolet spectral band. Comparative studies of the results will be able to highlight the limitations for each band. Compared to traditional approaches, this pyrometry technology offers a small advantage for detecting very high temperatures despite variations in emissivity and environmental uncertainties. The luminance for these two spectral bands exhibits a very low flux almost at temperatures below 1900K.

Keywords

Wavelength, Pyrometer, Visible Spectrum, Ultraviolet Spectrum, Temperature, Luminance, Emissivity

1. Introduction

Pyrometry is based on the fundamental principle that any body with a temperature above absolute zero emits electromagnetic radiation whose intensity and spectral distribution depend on its temperature. However, the relationship between the measured radiation and the actual temperature is strongly influenced by the radiative properties of materials, particularly emissivity [1-3]. Applying the spectral length allows for the characterization of chromatic radiance according to Planck's law [4, 5].

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2. Methodology and Law of Radiation

2.1. Physical Model

Multispectral pyrometry modeling is based on the fundamental laws of thermal radiation. Planck's law describes the spectral radiance of a black body at temperature T [6-8].

$$L_0(\lambda,T) = \frac{2hc^2\lambda^{-5}}{e^{\left(\frac{hc}{k\lambda T}\right)}-1} \tag{1}$$

where h =6,6255 x 10^{-34}Js: constant of Planck,

k =1,38 x 10^{-23} JK^{-1}: constant of Boltzmann,

c =2,996 x 10^8 ms^{-1}: Speed of electromagnetic waves in a vacuum.

For a real material, the measured luminance is weighted by the spectral emissivity $\varepsilon(\lambda, T)$.

$$L(\lambda,T) = \varepsilon(\lambda,T).L_0(\lambda,T) \tag{2}$$

Kirchhoff's fundamental relationship linking emissivity and absorptivity is written, for an opaque body [9].

$$\varepsilon(\lambda) = 1 - \rho(\lambda) \tag{3}$$

where ρ(λ) is the spectral reflectivity.

In multispectral pyrometry, the temperature is estimated from the measured fluxes [10, 11].

For materials with non-linear emissivity, such as steels, that is to say, emissivity does not depend on wavelength. In that case, the emissivity can be modelled as a second-degree polynomial.

$$\varepsilon_\lambda = a\lambda^2 + b\lambda + c \tag{4}$$

The parameters a, b, and c are to be estimated during the measurement [12-14].

2.2. Different Regions of the Ultraviolet and Visible Spectrum

The ultraviolet range covers wavelengths from 0.2μm to 0.4μm and that of visible is between 0.4μm and 0.8μm.

2.3. Theoretical Foundations of Thermal Radiation

The methodology is based primarily on the study of the physical principles of thermal radiation. The electromagnetic radiation emitted by a heated body extends from the ultraviolet to the infrared, with a spectral distribution governed by Planck's law. The black body serves as the reference model, representing an ideal emitter that absorbs and emits perfectly across the entire spectrum [15, 16].

For a real material, the spectral radiance is weighted by an emissivity coefficient, ranging from 0 to 1. This emissivity can be defined in different forms: monochromatic or total, directional or hemispherical [17]. In pyrometry, directional monochromatic emissivity plays a central role, as it directly relates the measured radiance to the actual surface temperature [18].

3. Variation of Chromatic Luminance According to Temperature and Wavelength

The characteristic results of chromatic luminance are illustrated by representative curves as a function of temperature at a given wavelength. Equation (2) describes how the measured luminance is weighted by the spectral emissivity ε(λ,T) in polynomial form.

3.1. Chromatic Luminance in the Ultraviolet Spectrum

The ultraviolet spectrum lies between the 0.2 μm and 0.4 μm bands. Characteristic luminance curves, according to Planck's law for real bodies with polynomial emissivity, are plotted from temperatures of 1000 K to 3000 K.

By experimenting with several wavelengths at 0.2 μm, 0.2 μm, 0.275 μm, 0.325 μm, 0.375 μm, and 0.4 μm within the ultraviolet spectral range, we obtain curves characterizing luminance as a function of temperature variation with these wavelengths.

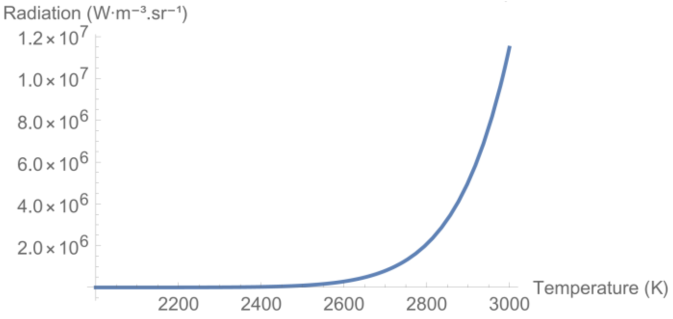

Figure 1. *Radiation in ultraviolet spectrum range at a wavelength of 0.2μm.*

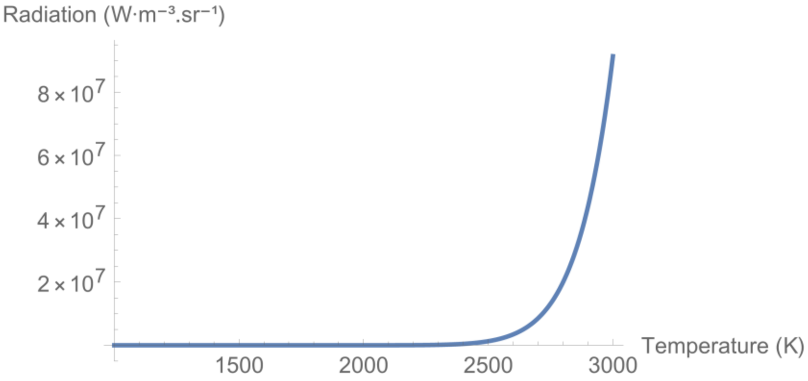

Figure 2. *Radiation in ultraviolet spectrum range at a wavelength of 0.225µm.*

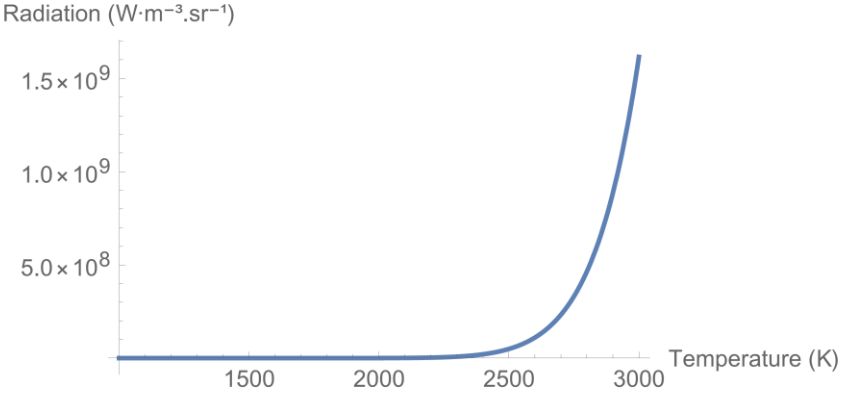

Figure 3. *Radiation in ultraviolet spectrum range at a wavelength of 0.275µm.*

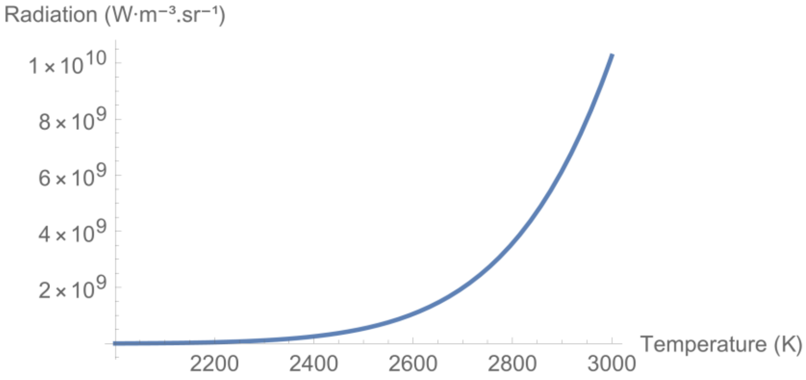

Figure 4. *Radiation in ultraviolet spectrum range at a wavelength of 0.325µm.*

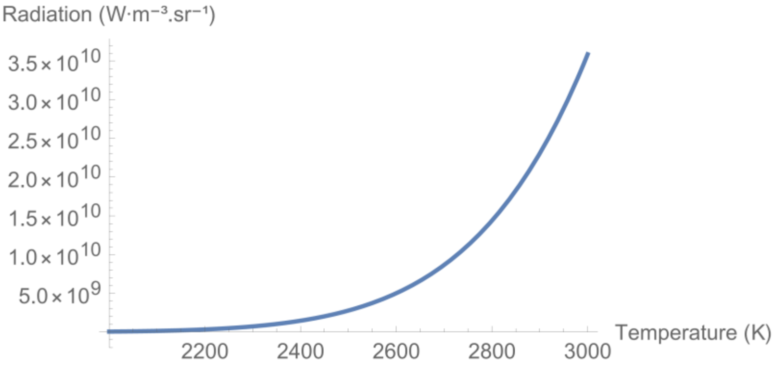

Figure 5. *Radiation in ultraviolet spectrum range at a wavelength of 0.375µm.*

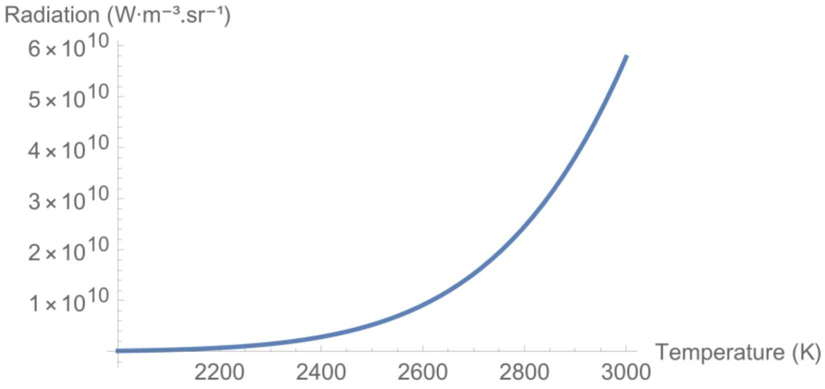

Figure 6. *Radiation in ultraviolet spectrum range at a wavelength of 0.4µm.*

3.2. Chromatic Luminance in the Visible Spectrum

The visible spectrum corresponds to an intermediate region of the electromagnetic spectrum, in which the variation of luminance with temperature remains significant, but less abrupt than in the ultraviolet. The visible spectrum lies between the 0.4 µm and 0.8 µm bands. Characteristic curves of luminance according to Planck's law for real bodies are plotted from temperatures of 500 K to 3000 K.

By experimenting with several wavelengths at 0.4 µm, 0.45 µm, 0.55 µm, 0.65 µm, 0.75 µm, and 0.8 µm within the visible spectral range, we obtain curves characterizing luminance according to the respective temperature variations with these wavelengths.

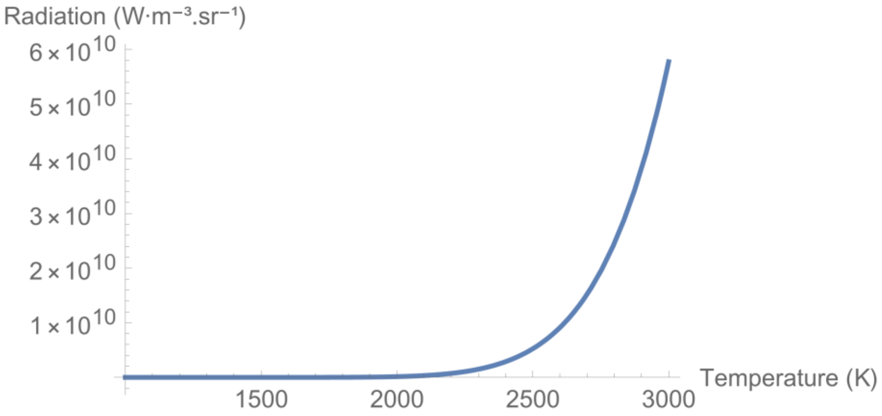

Figure 7. *Radiation in visible spectrum range at a wavelength of 0.4 µm.*

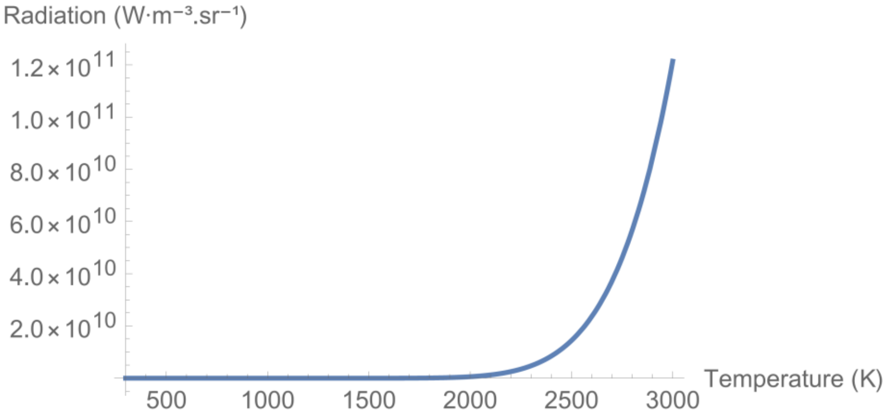

Figure 8. *Radiation in visible spectrum range at a wavelength of 0.45µm.*

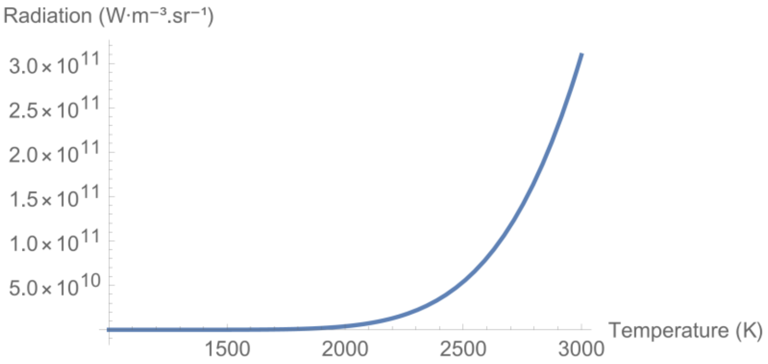

Figure 9. Radiation in visible spectrum range at a wavelength of 0.55µm.

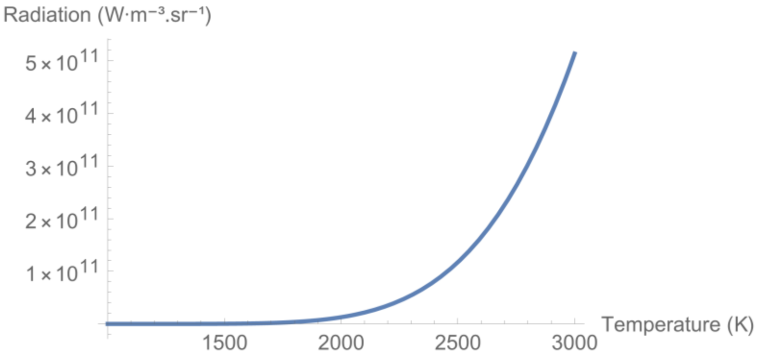

Figure 10. Radiation in visible spectrum range at a wavelength of 0.65µm.

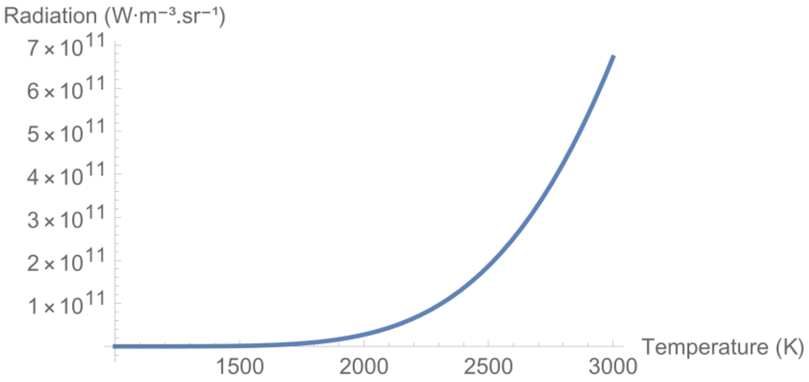

Figure 11. Radiation in visible spectrum range at a wavelength of 0.75µm.

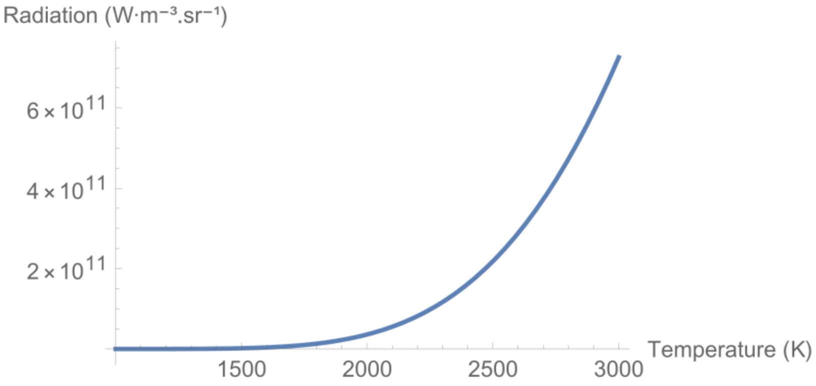

Figure 12. Radiation in visible spectrum range at a wavelength of 0.8µm.

4. Interpretation of Results and Discussion

The results obtained highlight the high potential of pyrometry for measuring high temperatures in complex environments. Compared to traditional approaches, this technology offers greater robustness to variations in emissivity and environmental uncertainties.

4.1. Luminance in the Ultraviolet and Visible Spectral Band

The increased sensitivity in the ultraviolet and visible ranges must be weighed against the practical difficulties related to atmospheric attenuation and stray light sources.

In the ultraviolet range, corresponding to short wavelengths, spectral luminance exhibits a strongly non-linear dependence on temperature, in accordance with Planck's law. The dominant exponential term in this region induces a rapid variation in luminance for small temperature changes. Luminance is only usable above approximately 2300 K, regardless of the wavelengths within the band. Measurement at low temperatures is strongly discouraged due to very low and almost zero luminance levels. From 2800 K onwards, the curves become almost linear, meaning there is a direct affine relationship between luminance and temperature, regardless of the wavelength.

However, measurements in the visible spectrum can be affected by stray light sources (ambient lighting, reflections), necessitating controlled experimental conditions. Measurement is only possible at temperatures above approximately 1900 K. Luminance is very low at temperatures below this value, regardless of wavelength within this spectral band. From 2500 K onwards, the curves become almost linear, meaning there is a direct affine relationship between luminance and temperature, regardless of wavelength.

4.2. Selection of Optimal Wavelengths

According to spectral emission curves of real materials in the ultraviolet and visible ranges, for the ultraviolet range, short wavelengths offer high temperature sensitivity, but they are also more susceptible to environmental disturbances and emissivity variations depending on the sequential selection method. In the visible range, a trade-off is observed between thermal sensitivity and robustness against interference.

In both spectral bands, the use of longer wavelengths offers a slightly wider temperature range. Conversely, shorter wavelengths can only be used for measuring a narrower temperature range.

4.3. Error and Uncertainty Analysis

Error analysis highlights several sources of uncertainty: spectral variations in emissivity, detector noise, influence of the radiative environment, and approximation of mathematical models. The results show that the gray-body assumption, often used in bichromatic pyrometry, is not always valid for real materials at high temperatures.

5. Conclusions

In conclusion, in the visible spectral range, spectral luminance exhibits a wide region of nonlinearity at temperatures below 1900 K. This nonlinearity indicates the difficulty in detecting fluxes. Similarly, in the ultraviolet range, luminance obtained at temperatures below 2600 K also exhibits strong nonlinearity.

In these nonlinear regions of the ultraviolet and visible spectra, the design of such a pyrometer becomes very complex and requires a compensation system due to ambient radiation. Furthermore, measurement at low temperatures is completely impossible due to the very high and uncorrectable error rate.

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Author Contributions

Ratianarivo Paul Ezekel: Conceptualization, Investigation, Methodology, Resources, Writing – original draft, Writing – review & editing

Rastefano Elisee: Project administration, Supervision, Validation

Data Availability Statement

The data is available from the corresponding author upon reasonable request.

Conflicts of Interest

The authors declare no conflicts of interest.

References

[1] L. DEJAEGHERE, Measurement method using multispectral pyrometry and development of a high-temperature device, Ph.D. Thesis, University of South Bretagne, 2016.

[2] P. E. RATIANARIVO, Optimization of wavelength selection for a quadraspectral pyrometer for the austenitization of steels, Ph.D. Thesis, University of Antananarivo, 2018.

[3] Th. Duvaut, Comparison between multiwavelength infrared and visible pyrometry: Application to metals, https://www.sciencedirect.com/science/article/pii/S1350449507001375

[4] P. POUPEAU, Heat Treatments of Metals and Alloys (M1105), Engineering Techniques Edition, Metallic Materials Treatise.

[5] J. P. BARDON, Surface Temperatures, Fundamental Concepts (R2730) Engineering Techniques Edition.

[6] TairanFu, MinghaoDuan, JiaqiTang, ConglingShi, Measurements of the directional spectral emissivity based on a radiation heating source with alternating spectral distributions, https://www.sciencedirect.com/science/article/pii/S001793101500784X

[7] G. R. Gathers, Analysis of multiwavelength pyrometry using nonlinear chi-square fits and Monte Carlo methods, https://link.springer.com/article/10.1007%2FBF00503888

[8] M. Boivineau, G. Pottlacher, Thermophysical properties of metals at very high temperatures obtained by dynamic heating techniques: recent advances, https://www.inderscienceonline.com/doi/pdf/10.1504/IJMPT.2006.009468

[9] Simone MATTEÏ, Thermal radiation from opaque materials https://www.techniques-ingenieur.fr/base-documentaire/energies-th4/transferts-thermiques-42214210/rayonnement-thermique-des-materiaux-opaques-be8210

[10] Tairan Fu, Jiangfan Liu, Minghao Duan, Anzhou Zong, Temperature measurements using multicolor pyrometry in thermal radiation heating environments, https://doi.org/10.1063/1.4870252

[11] Christophe Rodiet, Benjamin Rémy, Alain Degiovanni, Franck Demeurie, – Optimisation of wavelengths selection used for the multi-spectral temperature measurement by ordinary least squares method of surfaces exhibiting non-uniform emissivity, https://www.tandfonline.com/doi/abs/10.1080/17686733.2013.812816

[12] AntónioAraújo, Dual-band pyrometry for emissivity and temperature measurements of gray surfaces at ambient temperature: The effect of pyrometer and background temperature uncertainties, https://www.sciencedirect.com/science/article/pii/S0263224116304687

[13] Philippe Herve, Julie Cedelle, Ionut Negreanu, Infrared technique for simultaneous determination of temperature and emissivity, https://www.sciencedirect.com/science/article/pii/S1350449510000721

[14] Christophe Rodiet, Benjamin Remy, Alain Degiovanni, Optimal wavelengths obtained from laws analogous to the Wien's law for monospectral and bispectral methods, and general methodology for multispectral temperature measurements taking into account global transfer function including non-uniform emissivity of surfaces, https://www.sciencedirect.com/science/article/pii/S1350449516300147

[15] C. RODIET, T. PIERRE, B. REMY et A. DEGIOVANNI, Temperature measurement by multispectral method in the infrared and ultraviolet https://www.researchgate.net/publication/265047799

[16] Jinlong Chen, Yongcai Guo, Dongying Wang, Shaoqian Xue, Min Jiao, Chao Gao, A data processing method for two-Color pyrometers in accurate temperature measurement of high-temperature flow fields, https://www.sciencedirect.com/science/article/pii/S0263224124023169

[17] Zongju Yang, Bo Wang, Jingmin Dai, Zhijian Hu, Development of multi-spectral pyrometer for measuring cathode surface temperature of pulsed vacuum arc discharge, https://www.sciencedirect.com/science/article/pii/S2211379723008070

[18] Christophe Rodiet, Temperature Measurement by Multi-Spectral Methods and Thermal Characterization of Anisotropic Materials by Integral Transformations: Theoretical and Experimental Aspects, Doctoral thesis, Ph.D. Thesis; Mechanics and Energetics; EMMA Doctoral School: Mechanical Energy and Materials; 2014.

Biography

Ratianarivo Paul Ezekel is a professer at Polytechnical High School of Antsirabe, Vakinankaratra University, Electronic Engineering Department. He completed his PhD in Electronic Divices et Systems Engineering from Antananarivo University in 2018, and his Master of Engineering in Automatic Electronic Systems from Polytechnical High School of Antananarivo in 2010. Recognized for his exceptional contributions, Dr. Ratianarivo Paul Ezekel has been known as the chef department of electronic engineering at Polytechnical High School of Antsirabe.

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Research Field

Ratianarivo Paul Ezekel: Electronic system, Instrumentation, Embedded systems, programmable system, spintronic
Rastefano Elisee: Semiconductor, electronic system, signal processing, spintronic