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# Differential sensor in front photopyroelectric technique: I. Theory

**R Ivanov[1], G Gutierrez-Juarez[2], J L Pichardo-Molina[3], I Moreno[1], A Cruz-Orea[4] and E Marín[5]**

[1] Facultad de Física, Universidad Autónoma de Zacatecas, Calz. Solidaridad Esquina Paseo de la Bufa s/n, C.P. 98060, Zacatecas, Zac., México
[2] Instituto de Física, Universidad de Guanajuato, Loma del Bosque 103, Lomas del Campestre, C.P. 37150, León, Gto., México
[3] Centro de Investigaciones en Óptica, Loma del Bosque 115, Lomas del Campestre, C.P. 37150, León, Gto., México
[4] Departamento de Física, CINVESTAV-IPN, Av. IPN 2508, San Pedro Zacatenco, C.P. 07360, México D.F., México
[5] Centro de Investigación en Ciencia Aplicada y Tecnología Avanzada, Instituto Politécnico Nacional, Legaría 694, Colonia Irrigación, C.P. 11500, México D. F., México

E-mail: rumen@planck.reduaz.mx

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**Abstract**

In this paper the theory of the differential front photopyroelectric technique is developed. The thermal effusivity measurements of a sample through photopyroelectric direct (no-differential) experiments do not have sufficient resolution and accuracy to detect small changes in the thermal effusivity. To assess minor variations in this thermal magnitude, differential methods should be used. These methods compare properties of a reference sample and another unknown sample, which are placed separately in both halves of the differential cell. It is shown that in order to achieve better metrological properties of the differential measurement and electromagnetic interference immunity, the signals of both halves must be subtracted directly at the output of the two parallel connected pyroelectric sensors. The thickness of the samples should have the maximum possible value, at least 10 times higher than the thermal diffusion length for minimum frequency. The results of numerical simulations for the amplitude, phase, real and imaginary parts with water as a reference sample and the other sample with a thermal effusivity very close to that of water (contaminated water) are presented. These results show that measurements should be made in the nearly ideal voltage mode, which ensures a better signal-to-noise ratio than the ideal current mode.

## 1. Introduction

Photoacoustic (PA) and photothermal techniques (PT) have been used for many years in non-destructive evaluation of different materials. Among the PT, the photopyroelectric (PPE) technique has proved to be a very useful tool for measuring the thermal properties of liquid samples, primarily the thermal effusivity ($e$) and diffusivity ($\alpha$) [1, 2]. The PPE technique has two experimental configurations; the first one is the back photopyroelectric (BPPE) configuration [3–5], in which the sample is illuminated directly. The second is the front photopyroelectric (FPPE) configuration [6–9] in which the PPE detector is illuminated.

From the metrological point of view, each technique can be used in a direct or differential mode. In the direct mode, the physical parameter is measured in an absolute way. In the differential mode, two samples are used, one corresponding to the reference material with well-known parameters, and the other is a sample for which its parameters have been slightly modified. The idea of this mode is to obtain the difference between the parameters. Knowing this difference and the corresponding parameter value of a reference material, we can find the parameter value of the unknown sample with high accuracy. Both types of measurements are very useful; however, when the objective is to measure small variations

 