Radiometric temperature measurements using In(Ga)As(Sb) backside illuminated photodiodes

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There is curtain amount of processes, like micro-structuration of thin metal film deposited onto plastic substrate or cutting the body tissue with fiber-optic "laser knife", which needs fast and reliable radiometric « point » temperature measurements of substances with unknown/changing emissivity in the 50-1000°C range. Most of existing mid-IR pyrometers is not able to perform adequately the above job due to low radiation intensity and/or lack of additional measuring channels.

Our report describes performance of the dual band pyrometers with sensor head composed of two photodiodes (PDs) placed along single optical axis whereas first PD being the "short wave" one with respect to the second PD. This design includes for example two heterostructure PDs with InAs and InAsSb active layers joined together by a chalcogenide glue and sensitive in the 3.3- 4.6 µm spectral range. P-InAsSbP/n-InAs/n+-InAs and p-InAsSbP/n-InAsSb/n-InAs PD chips with ~150 µm thick InAs substrates can be mounted under a single Si lens so that they operate in a backside illumination (BSI) mode with the result that both photodiodes exhibit narrow spectral response and additionally they receive radiation from single spot of an object. The narrow spectral response makes possible the use of the "monochromatic" approximation for the pyrometer transfer function with the accuracy better than 1%. Addition of a fiber input to the abovementioned dual band PD simplifiers the calibration procedure and utilization of the pyrometer as amount of radiation reaching active areas becomes independent on the fiber end/object distance. Experimental confirmation of the statement was achieved in experiments with 0.4-0.6 mm core diameter sapphire or As_2S_3 (CIR) fibers coupled with 3.4 µm/4.2 µm and 3.4 µm/4.6 µm dual band PD.

Analysis of the existing PD amplifiers suggests that high accuracy measurements needs temperature stabilization, say at 20°C, e.g. using TEC [1]. This stabilization makes possible « point » temperature measurements with a record resolution of 10 µs (detection bandwidth ≥100 kHz) and accuracy of 1% in the 50-1000 °C range.

The technology to be described in the report include but not limited to on-line temperature control of the surgical laser knife (with the single BSI InGaAsSb PD [2] and quartz fiber) or small (Ø=0.4 mm) body spots (with the 3.4 µm/4.2 µm dual band PD and CIR fiber) in the presence of the high-power near infrared (0.8-0.9 µm) medical laser diffuse radiation.

References

[1] S. E. Aleksandrov, G. A. Gavrilov, and G. Yu. Sotnikova, "Effect of Low Frequency Noise on the Threshold Sensitivity of Middle IR Photodetectors in a Broad Frequency Range", Technical Physics Letters, 2014, Vol. 40, No. 8, pp. 704–707

[2] S.A. Karandashev, B.A. Matveev, M.A. Remennyi et al "Properties of GaInAsSb/GaSb (λ=1.8–2.3 µm) Immersion Lens Photodiodes at 20–140°C" Semiconductors, 2007, Vol. 41, No. 11, pp. 1369–1374. 2007

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Figures

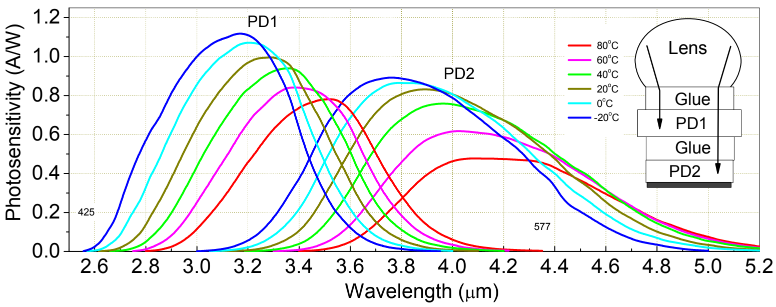

Fig. 1. Photoresponse spectra of the dual band photodiode with InAs (PD1) and InAsSb (PD2) active layers at several photodiode temperatures. In the insert – schematic of the device (RF patent application# 2013109254).

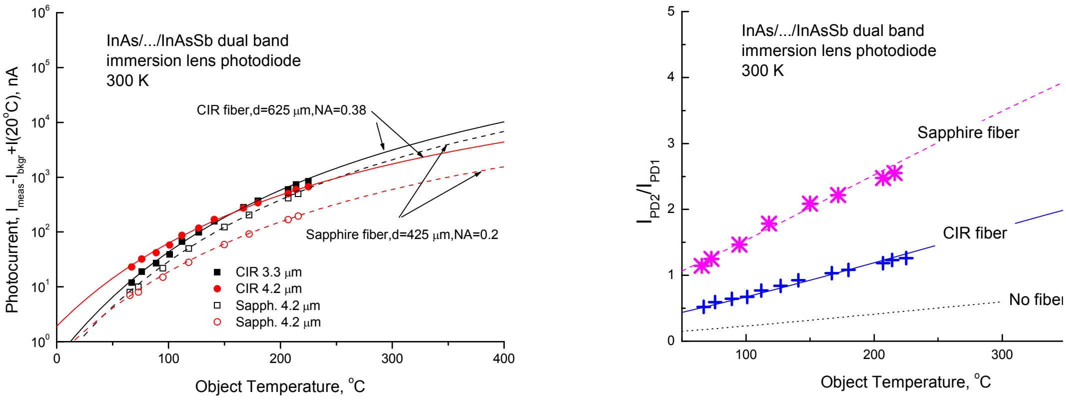

Fig. 2. Photocurrents (left) and photocurrents ratio (right) in dual band photodiode (see PD1 and PD 2 in Fig.1) coupled with sapphire (open symbols, dashed lines) and CIR (filled symbols, solid lines) fibers vs object temperature (points) together with simulated "monochromatic" response (lines).

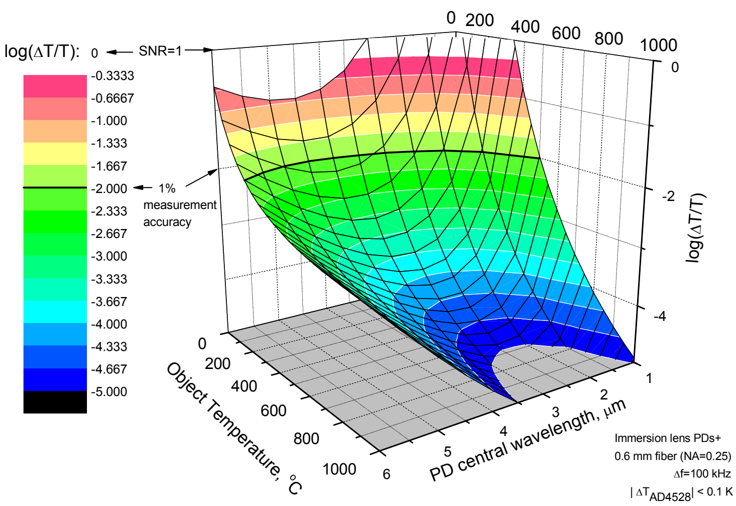

Fig. 3. Logarithm of the temperature measurement error ΔT/T (simulated values) vs PD wavelength coupled a fiber (Ø=0.6 mm, NA = 0.25) and with the AD4528 amplifier (Δf=100 kHz, |ΔT| ≤ 0.1 K) and vs object spot (Ø≥0.6 mm) temperature (T). PD parameters are taken from www.ioffeled.com.