Dual band radiometric temperature measurements using InAs and InAsSb based photodiodes

B.A.Matveev[1, 2], S.E.Aleksandrov[1], G.A.Gavrilov[1], A.A.Kapralov[1], M.A.Remennyi[1, 2] and G.Yu.Sotnikova[1*]

[1] *Ioffe Institute, Polytekhnicheskaya 26, 194021, St.Petersburg, Russia*
[2] *IoffeLED, Ltd. , Polytekhnicheskaya 26, 194021, St.Petersburg, Russia*

There is curtain amount of processes, like micro-structuration of thin metal film deposited onto plastic substrate, which needs fast and reliable radiometric temperature measurements of substances in the “low” range of temperatures, that is, in the 0-300^{o}C interval. Analysis showed that photodiodes (PDs) with narrow-band responsivity in the 3-5 um spectral range, e.g. immersion lens back-side illuminate (BSI) PDs based on A^3B^5 semiconductors, are optimal for the above job.

Our report describes performance and some of the applications of two dual band (or “two color”) pyrometers with sensor head composed of two narrow gap A^3B^5 photodiodes (PDs) placed along single optical axis. In fact two “back-to-back” BSI InAsSbP/InAs (λ_c=3.4 μm) [1] and InAsSbP/InAsSb (λ_c=4.2 μm) [2] double heterostructure PDs have been joined together by a transparent chalcogenide glue and mounted onto a hyperhemispherical Si immersion lens (D_{lens}=3.5 mm). Both sensor head and amplifier were placed into a sealed case onto a TEC plate (t=20±0.1^{o}C). For long-distant measurements (2 meters) of a small area objects spherical (D_1= 60 mm) and plane (D_2 = 25 mm) mirrors have been added for providing sighting index of about 100 (measuring spot dimensions was of about 2 cm). Second pyrometer was equipped with fiber allowing “near field” temperature measurements. Owing to narrow spectral response of the BSI PDs used in the sensor the transmission function of the sensor was directly derived from the Planck’s law adjusted to PD spectral response [3].

Simulated sensor noise values constituted to $4.5\cdot10^{-3}$ $nA\sqrt{Hz}$ and $5.4\cdot10^{-2}$ $nA\sqrt{Hz}$ for amplified output of InAs and InAsSb PD respectively, the above numbers matched measured dispersion values of ±1 nA and ±10 nA at the 30 kHz detection band (the corresponding response time τ~30 μs). High signal-to-noise ratio (SNR) value allows measurement of significantly lower temperature with higher accuracy and/or extremely smaller response time (e.g. around 0^{o}C with accuracy of 2-5 degrees at a response time of τ~30 μs) compared to other uncooled mid-infrared sensors.

References

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2. N. D. Il’inskaya et al, Semiconductors, (2012), Vol. 46, No. 5, pp. 690–695.
3. G.Yu. Sotnikova, S.E. Aleksandrov, G.A. Gavrilov, Proc. SPIE, vol. 8073, 80731A (2011).

*corresponding author: G.Sotnikova@mail.ioffe.ru

Figures

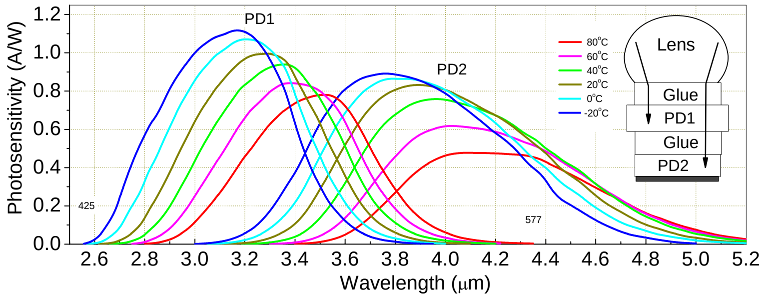

Fig. 1. Photoresponse spectra of the dual band photodiode with InAs (PD1) and InAsSb (PD2) active layers at several photodiode temperatures. In the insert – schematic of the dual band sensor head.

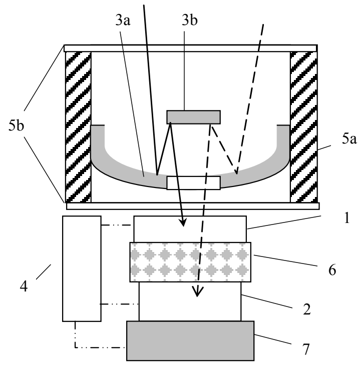

Fig.2 Schematic of the dual band pyrometer, 1- InAs based PD, 2- InAsSb based PD, 3a – spherical mirror, 3b – plane mirror, 4 – read-out and TEC control circuits, amplifiers, A/D converters, microprocessor and display, 5a – hermetically sealed case, 5b – windows, 6- chalcogenide glue, 7-TEC. (Immersion lens is not shown).

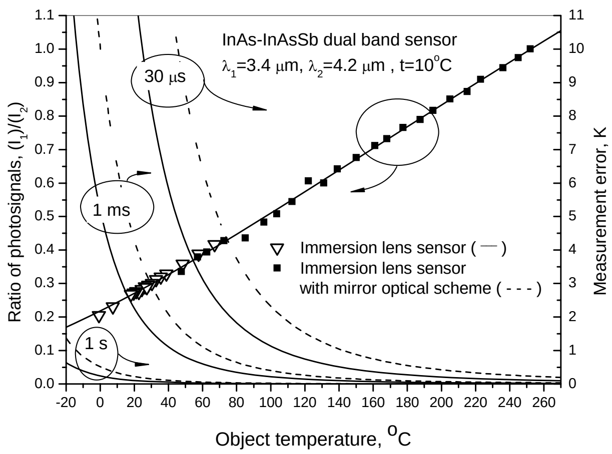

Fig.3 Ratio of photosignals and measuring error in two-color pyrometer vs object temperature for single immersion lens sensor (open triangles) and sensor equipped with immersion lens and mirror optics (filled squares). Error magnitude is presented for three integration times of 30 μs, 1 ms and 1 s.