SHIFT-2 INFRARED SPECTROCOMPARATOR

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We describe in detail the SPIF-2 spectrocomparator developed at the D. I. Mendeleev All-Union Scientific-Research Institute of Metrology, designed for dissemination of the temperature scale in the infrared region of the spectrum. We present the structural and basic optical schematics for the comparator. We describe a technique for comparison of radiators on the spectrocomparator.

The SPIF-2 spectrocomparator (called the comparator in the following) was designed with the goal of improving the system for dissemination of the temperature scale using infrared radiation in the high-temperature region. In the new comparator, there are no interference and absorbing filters, the use of which for dissemination of the temperature scale in the earlier version of the comparator (SPIF-1) led to large measurement errors. Therefore the SPIF-2 comparator has higher accuracy (by a factor of 2-3) and a higher temperature limit (up to 2500°C).

A PSK type spectrocomparator is currently used in calibration practice when comparing temperature-calibrated lamps in the visible and infrared regions of the spectrum to 2.5 μm [1]. The SPIF-2 comparator, in contrast to the PSK comparator, allows us to compare not only temperature-calibrated lamps but also blackbodies, including large ones with deep cavities; it also has a broader spectral range (up to 5.5 μm) and a higher level of automation.

The SPIF-2 comparator is designed for transfer of the temperature scale from standard copies to working standards and from working standards to master measurement devices, and is included within the calibration scheme in [2].

The structural diagram of the SPIF-2 comparator is presented in Fig. 1. The comparator includes: a spectral computer control complex SCC, consisting of a diffraction monochromator Mon of the MDR-23 type, a personal computer (PC) of the DVK-3 type, and an electronic console EC; entrance and exit optical blocks EnOB, ExOB; photodetector block PB; measuring amplifier-transducer MAT with brightness equally indicator BEI; low-frequency generator LFG of the G3-117 type.

The entrance optical block has two optical channels A and B with two optical entrances A1, A2, and B1, B2 in each. In front of the entrances A1 and A2 are mounted movable carriages C1 and C2 with holders for temperature-calibrated lamps L1, L2 (or blackbodies), three holders on each carriage, designed for efficiently interchanging the radiators to be compared (certified). Different blackbodies with their own alignment devices can be mounted in front of the exits B1 and B2.

The comparator operates on the null modulation principle [3]. The radiant heat fluxes from the two radiation sources to be compared (temperature-calibrated lamps or blackbodies), using the mirror modulator M located at the entrance to the optical block, are directed in turns (at a frequency of about 800 Hz) to the exit slit of the monochromator Mon. The radiant flux isolated by the monochromator in a narrow spectral interval is directed to the exit optical block and then to one of the radiation detectors of the photodetector block PB. Using the amplifier—transducer, the ac component of the signal from the detector is amplified and detected by the synchronous detector. One of the outputs of the low-frequency generator LFG is connected to the input of the modulator M, and the other is connected to the input of the reference channel of the synchronous detector MAT. The dc voltage from the output of the synchronous detector is supplied to the needle-type brightness equality indicator BEI. The SCC complex is designed to control the position of the diffraction grating of the monochromator and to control the block of interchangeable filters FB, located in front of the exit slit of the monochromator. Control can be accomplished both manually and automatically. Complete automation of the comparison process is possible, namely, the process of bringing the radiators to the specified temperature conditions, mounting the appropriate radiators in front of the optical entrance of the comparator, equalizing the brightness of the radiators to be compared, mathematically processing the results obtained.

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Fig. 1. Structural schematic for the SPIF-2 spectrocomparator.

The basic optical layout for the comparator is presented in Fig. 2. The two optical channels included in the layout for the entrance optical block have different reduction factors for the linear dimensions of the image of the radiator (in channel A, 2:1; in channel B, 4:1). This allows us to certify practically any radiation sources, from temperature-calibrated lamps to large stationary blackbodies with deep cavities.

The optical systems for the entrance and exit optical blocks in the measurement arms are built on mirrors, which provides for operation of the comparator in a broad region of the spectrum. For operation in channel A, the radiant heat fluxes from the standard source and the source to be calibrated are incident through the rotating mirror 1 to the spherical mirrors 2 (their illuminated dimensions are 84 × 84 mm, focal lengths 1124 mm).

Then the parallel radiant fluxes are incident on spherical mirrors 3, which focus the beams in the plane of the mirror of the modulator 4. The illuminated dimensions of the mirrors 3 are 86 × 86 mm, focal lengths 500 mm. Modulator 4 is a magnetoelectric loop made of thin tungsten wire (diameter 0.035 mm), drawn between the poles of a permanent magnet. On the loop is glued a 2 × 2 mm small mirror (a glass plate of thickness 0.12 mm with sputtered aluminum). The radiant flux reflected from the small mirror of the modulator through the system of two rotating mirrors (not shown on the diagram) is incident on the spherical mirror 5, and from it through the set of interchangeable slit lenses and light filters 6 onto the entrance slit of the monochromator 7. The mirror 6 has illuminated dimensions 116 × 116 mm, focal length 346 mm. An aperture stop corresponding to the relative aperture of the monochromator is placed on this mirror (see Table 1).

The lens with the light filters is changed in calibration of radiators, depending on the spectral range.

In certification of large blackbody radiators with a long distance from the aperture to the bottom, the optical channel B is used. In this case, the radiant fluxes from the standard source and the source to be calibrated, using the plane mirrors 8, are incident on the spherical mirrors 9 and through the plane mirrors 10 onto the spherical mirrors 3. Then the path of the beams is similar to the path of the beams of the optical channel A. The mirrors 9 have illuminated dimensions 84 × 84 mm, focal lengths 1990.5 mm.

The entrance optical block EnOB is built at two levels, therefore the optical elements used in the different channels do not interfere with each other (the elements indicated in Fig. 2 by the dashed lines are located in the upper level of the block).

The optical path of the beams in the monochromator is clear from Fig. 2 (the Fastie scheme is used); 11 and 15 are rotating plane mirrors; 12 and 14 are spherical objectives; 13 is the diffraction grating; 16 is the exit slit.

From the exit slit of the monochromator, the radiant heat flux through the set of interchangeable lenses 17 (which one is mounted depends on the spectral range) with the aid of the rotating mirror 18 is incident on the spherical objective 19, at the focus of which is located the exit slit 16. The parallel radiant flux from the mirror 19 is focused by the spherical objective 20 through the rotating plane mirror 21 onto the area of the photodetector 22. The diameters of the spherical mirrors 19 and 20 are 72 mm, the focal lengths are 420 and 252 mm respectively. Thus the exit slit of the monochromator is projected onto the area of the photodetector with 2:1 reduction.

Depending on the spectral range, we used as the radiation detectors: FÊU-28 and FÊU-100 photomultiplier tubes; FD-25K and FDK-293 silicon photodiodes; FD-2 germanium photodiode; FZ1DA detector cooled by liquid nitrogen.

The photodetector block is positioned on a movable cartridge on the upper plane of the exit optical block, which makes it possible to efficiently change detectors and mount the aligning illuminators (the LG-78 laser and the KTM 27-30-1 halogen lamp).