Jaroslav Pospíšil, Václav Bumba**

Report on Measurement of the Modulation Transfer Function of Photographic Materials

This paper introduces a device for measuring the modulation transfer function of ordinary photographic materials. Some results of measurements are also shown.

1. Introduction

Various methods were developed for measuring the modulation transfer function of photographic materials (see, for example, [1] and [2]). This article introduces the method and device based on the incoherent imaging of a rectangular parallel wave grating where spatial frequency is varied continuously in space (Fig. 1).

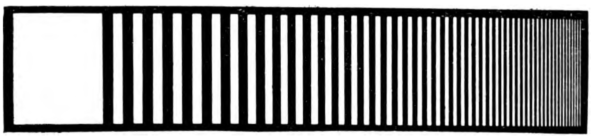

Fig. 1. The rectangular parallel wave grating with warying spacial frequency in space, which was utilizing for measurement of the modulation transfer function of photographic materials

2. Principle of Measurement and Basic Equations

The principle of the realized method is in the incoherent imaging of a rectangular parallel wave grating with continuously varying spatial frequency in space on the photographic material under test by means of an auxiliary photographic objective of known propertie*s*. The developed distribution of the image-transmittance is measured by the recording microphotometer and transformed into the distribution of the effective exposure [2]. The modulations (contrasts) of the effective exposure distributions were determined for individual effective spatial frequencies of the imaged grating and the sought values of the modulation transfer function $\tau_e(\sigma)$ of the tested photographic material were calculated.

The equation for transfer function values $\tau_e(\sigma)$ of the photographic material under test is as follows

$$\tau_e(\sigma) = \frac{\tau(\sigma)}{\tau_{ob}(\sigma)\,\tau_{ph}(\sigma)},$$

where $\tau(\sigma)$ is the over-all modulation transfer function of the whole measuring device, $\tau_{ob}(\sigma)$ and $\tau_{ph}(\sigma)$ are the modulation transfer functions of the auxiliary photographic objective and of the used recording microphotometer.

The functions $\tau_{ob}(\sigma)$ and $\tau_{ph}(\sigma)$ were already known, while the values of the function $\tau(\sigma)$ were obtained by the Coltman's formula [3] expressed in the suitable form

$$\tau(\sigma) = \frac{\pi}{3.815}\left\{\tau(\sigma)_r + \sum_{j=2}^{\infty} \frac{(-1)^j\,\tau[(2j-1)\sigma]_r}{2j-1}\right\}$$

$\tau[(2j-1)\sigma]_r$ are the values of the rectangular-wave modulation transfer function. They are obtainable by equations of the following form

$$\tau[(2j-1)\sigma]_r = \frac{E_{max}-E_{min}}{E_{max}+E_{min}}\,\frac{L_{max}+L_{min}}{L_{max}-L_{min}},$$

where E_{max} and E_{min} are the maximum and minimum values of the periodical distribution of the effective exposure relating to the maximum und minimum values L_{max} and L_{min} of the light distribution produced by the imaged rectangular wave grating of effective spatial frequencies $(2j-1)\sigma$, $j = 1, 2, 3, \ldots$

*) Faculty of Science, Palacký University, Olomouc, Czechoslovakia.

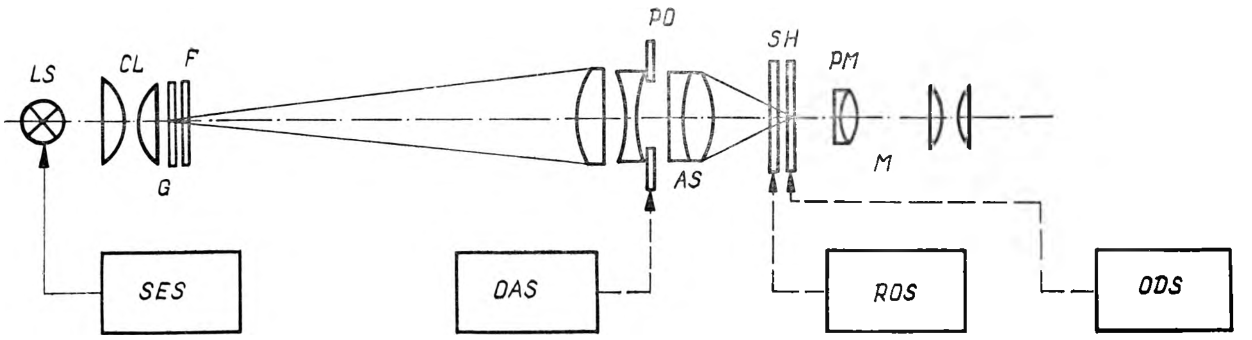

Fig. 2. Schematic representation of the imaging system of the device for measuring the modulation transfer function of photographic materials

3. Description of the Measuring Device

The measuring device consisting of the imaging device and of the recording microphotometer was realized for the service measurements of the modulation transfer function of various ordinary photographic materials. The imaged rectangular parallel wave grating has actual spatial frequencies varying continuously in space with geometrical progression from O.O L/mm up to 5.181 L/mm. Its effective spatial frequencies σ for the utilized transverse magnification $\beta = 1/51.2$ of the imaging system are from O.O L/mm up to 265.3 L/mm. However, the resolving power of the used auxiliary photographic objective (Tessar Carl Zeiss Jena 1:2.8, $f = 50$ mm) is below the mentioned maximum frequency, we can practically utilize the effective spatial frequencies from 0.0 L/mm up to about 111 L/mm.

The set-up of the imaging system is schematically introduced in Fig. 2. It consists of the interchangeable light source *LS* (metal filament bulb Tesla 220 V, 100 W, or 24 V, 15 W) supplied by a stabilized electrical power supply (block *SES* in Fig. 2). *CL* is the condenser, *G* is the rectangular parallel wave grating and *F* is the interchangeable colour filter for measuring in light of a required spectral composition. *PO* denotes the auxiliary photographic objective and *AS* is the aperture stop, operated manually (block *OAS*) for setting of the required value of the relative aperture of the objective *PO*. *SH* is the central shutter operated remotely by a special electric device (block *ROS*). The exposure time was always chosen in such a way that the time necessary for opening and closing the shutter was negligible in comparison with the exposure time. Thus, the influence of the shutter action upon measuring results can be practically assumed as negligible [4]. *PM* denotes the photographic material under test which has been placed in a frame and could be shifted longitudinally by means of an operating device for shifting (block *ODS*). The focusing microscope *M* ensures the best visual focusing control of the image on the plane of the tested photographic material.

The imaging system is located on the optical bench in the light impermeable metal cover the length of which is 3.2 m while its transverse dimensions are 0.5 m and 0.35 m. The metal cover is firmly fixed to a heavy carrier. The height of the entire imaging device is 1 m. It is shown in Fig. 3 together with the operating devices.

The second part of the device for measurement of the modulation transfer function of photographic materials consists of a recording microphotometer. The recording microphotometer type: Schnellphotometer *G* II mit Standard - Kompensationsschreiber Carl Zeiss Jena [5], was used in our measurements (Fig. 4).

4. Some Measuring Results

The introduced results are related to the reverse black-and-white photographic films FOMAPAN 17 (em. no 013-8) and ORWO UP 15 (em. no 144) for white light and processing conditions in accordance with factory instructions (Table 1 and Fig. 5) and also to the negative colour photographic films FOMACOLOR ND 17 (em. no 00012-1) and ORWOCOLOR NC 16 (em. no 439685) for white light and for processing conditions suggested by the factories (Table 2 and Fig. 5).

For the quantitative comparison of the measured samples the normalized criterion of quality

$$QC = 100 \frac{\int\limits_0^{\sigma_m} \tau_e(\sigma)\, d\sigma}{\int\limits_0^{\sigma_l} \tau(\sigma)_i\, d\sigma} \quad [\%]$$

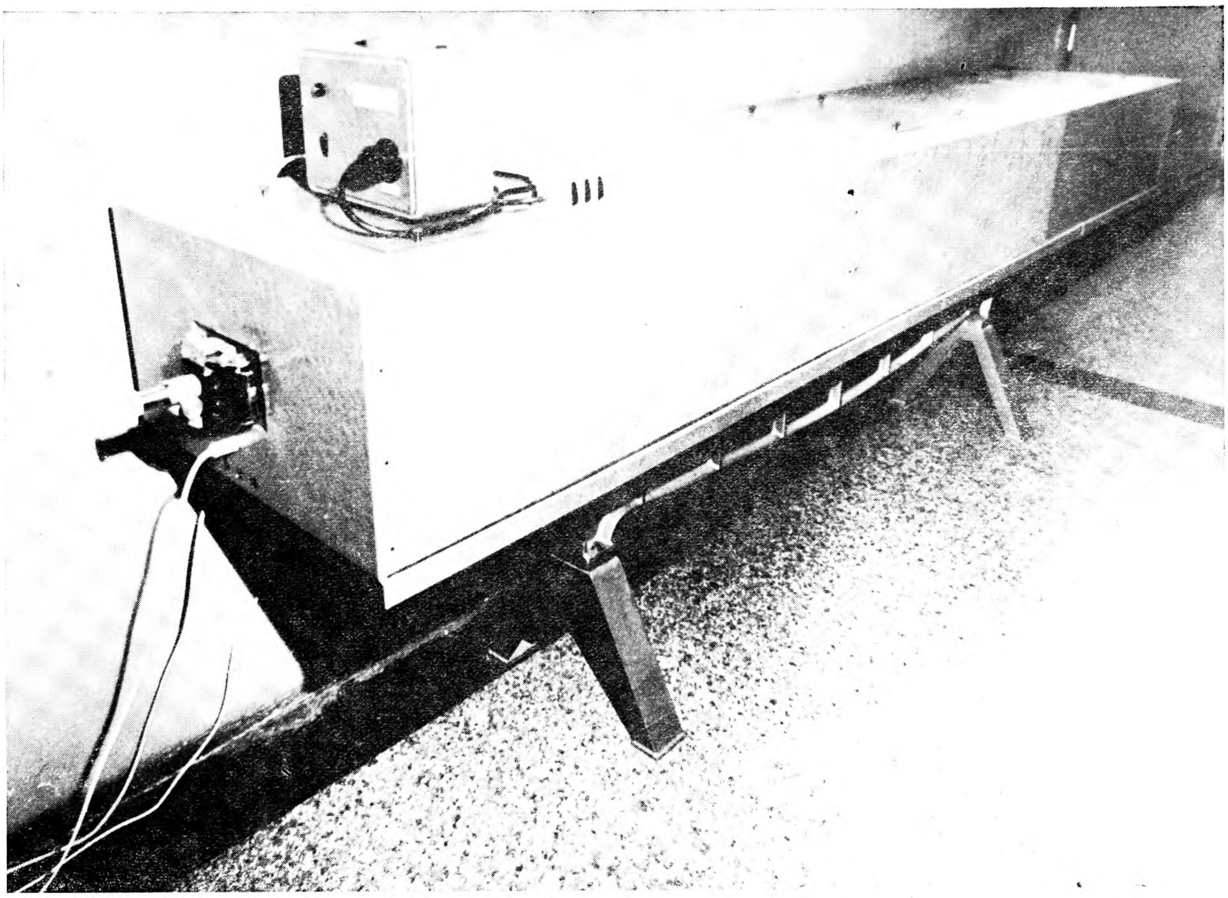

Fig. 3. Photography of the imaging device together with the operating devices

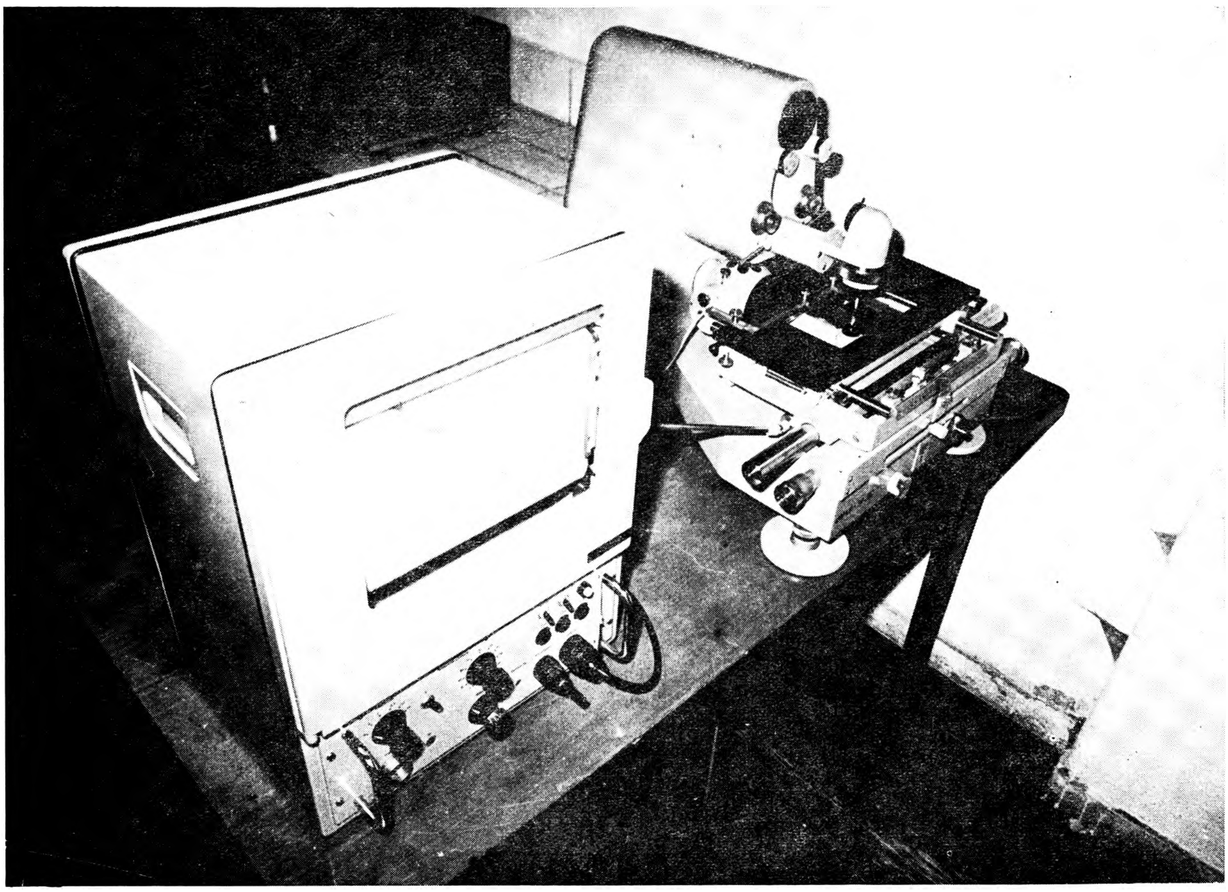

Fig. 4. Photography of the recording microphotometer used for measurements of the modulation transfer function of photographic materials

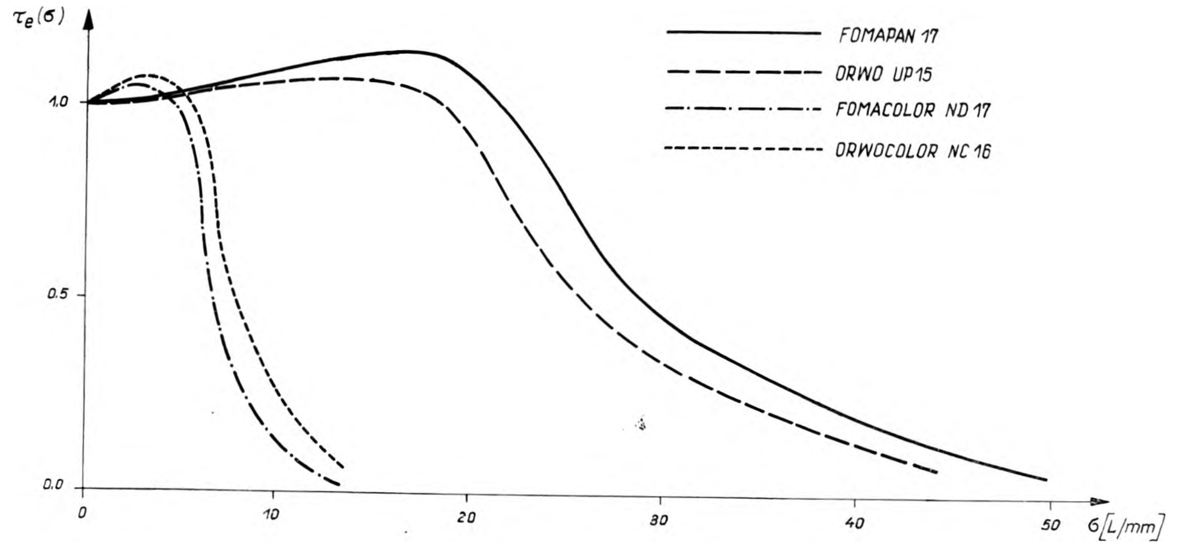

Fig. 5. Graphical representations of the modulation transfer functions $\tau_e(\sigma)$ of the measured photographic films FOMAPAN 17 ORWO UP 15, FOMACOLOR ND 17 and ORWOCOLOR NC 16 for white light

Table 1. The modulation transfer function values of tested reverse black-and-white photographic films FOMAPAN 17 and ORWO UP 15 for white light

σ[L/mm]	FOMAPAN 17 $\tau_e(\sigma)$	ORWO UP 15 $\tau_e(\sigma)$
0	1.000	1.000
19	1.109	0.989
25	0.755	0.542
29	0.490	0.375
34	0.345	0.260
39	0.225	0.155
44	0.131	0.085
50	0.070	
QC[%]	65.5	58.0

was utilized. The function $\tau(\sigma)_i$ represents the modulation transfer function of an ideal imaging system whose values are

Table 2. The values of the modulation transfer functions of negative colour photographic films FOMACOLOR ND 17 and ORWOCOLOR NC 16 for white light

σ[L/mm]	FOMACOLOR ND 17 $\tau_e(\sigma)$	ORWOCOLOR NC 16 $\tau_e(\sigma)$
0	1.000	1.000
5	0.963	1.021
6	0.688	0.954
7	0.415	0.641
8	0.279	0.489
9	0.198	0.355
10	0.127	0.270
11	0.071	0.195
12	0.051	0.130
13	0.036	0.090
QC[%]	15.2	16.9

$$\tau(\sigma)_i = \tau(0)_i = 1\,.$$

The quantities σ_m are the maximum spatial frequencies up to which the reproducibility of values $\tau_e(\sigma)$ and the possibility of their easy determination is still vouched. σ_i is the maximum of values σ_m which are related to the compared samples.

The introduced criterion of quality shows that the tested colour photographic films are worse in quality in comparison with the tested reverse black-and-white photographic films.

5. Conclusions

The introduced method and measuring device are suitable for comparative measurements of the modulation transfer function of various ordinary photographic materials. The reproducibility of the modulation transfer function values is in the case of identical imaging, exposure, processing and microphotometrical conditions as well as precise and correct measurements within ± 0.03 up to the maximum spatial frequencies in which the obtained results are still clearly distinguishable.

References

[1] Ooue S., *The Photographic Image*, Progress in Optica, Vol. VII (1969), North-Holland Publ. Comp. Amsterdam, 325.
[2] Dainty J. C., Optica Acta **18** (1971), 795.
[3] Coltman J. W., J. Opt. Soc. Am. **44** (1954), 468.
[4] Shack R. V., Applied Optica **3** (1964), 1171.
[5] Schnellphotometer G II mit Standard - Kompensationsschreiber, Gebrauchsanweisung, Carl Zeiss Jena, 1964.