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Photography — Root mean square granularity of photographic films — Method of measurement

Photographie — Moyenne quadratique granulaire de films photographiques — Méthode de mesure

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Foreword

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International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 10505 was prepared by Technical Committee ISO/TC 42, *Photography*.

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Introduction

This International Standard specifies procedures for measuring and computing the root mean square granularity (rms-granularity) of photographic films. Its purpose is to provide guidance in making accurate measurements, and also to provide an objective basis for comparing films. This International Standard describes a method for making accurate rms-granularity measurements in the presence of instrument noise and minor sample imperfections.

In principle, the measurement of rms-granularity is straightforward, but its determination with accuracy is not a trivial matter. Experience has shown that the preparation of an imperfection-free sample is virtually impossible in usual practice. Therefore, considerable attention has been devoted to the definition of a method of accurately estimating the rms-granularity of a film in the presence of density fluctuations not caused by the intrinsic grain structure of the film.

Research in rms-granularity (see Reference [10]) has pointed out that the inclusion of several “artefact-induced” data values in a set of several thousand “grain-produced” data values may result in large errors in the rms-granularity estimate. Under these circumstances, the traditional method for estimating rms-granularity produces higher rms-granularity estimates than the new method. It can also be shown that this method produces results that are identical to those produced by the traditional method when using artefact-free data.

In either case, it is important to bear in mind that rms-granularity is a statistical estimate which is necessarily reported with its associated confidence intervals. In addition, the measurement process recognizes and accounts for the presence of instrument noise that can affect the accuracy of the rms-granularity estimate.

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Photography — Root mean square granularity of photographic films — Method of measurement

1 Scope

This International Standard describes a method for determining the intrinsic root mean square granularity (rms-granularity) of photographic films. Intrinsic rms-granularity refers to those density fluctuations produced solely by the distribution of developed image forming centres in the photographic emulsion.

Continuous-tone monochrome (silver absorbing species) and colour (dye absorbing species) materials coated on a transmitting support can be measured by the procedures described in this International Standard. This International Standard is intended for imaging systems with viewing magnifications between 5× and 12× (see Annex A).

The following kinds of granularity measurements are not covered by this International Standard, even though they are photographically important:

— reflecting materials (photographic papers);

— materials having emulsion coated on both sides of the support (e.g. some X-ray films);

— the estimation of the noise power spectrum (Wiener spectrum).

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2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 5-2, *Photography — Density measurements — Part 2: Geometric conditions for transmission density*

ISO 5-3, *Photography — Density measurements — Part 3: Spectral conditions*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1
transmittance factor
T
ratio of the measured flux transmitted by a specimen to the measured flux when the specimen is removed from the sampling aperture of the measuring device

NOTE $T = \frac{\phi_T}{\phi_J}$

where

ϕ_T is the transmitted flux;

ϕ_J is the aperture flux.

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3.2
transmission density
D_T
logarithm to the base 10 of the reciprocal of the transmittance factor, T

NOTE $D_T = \log_{10} 1/T$.

3.3
microtransmittance factor
transmittance factor of a small area of a film or plate, measured using a suitable instrument such as a microphotometer

NOTE In general, the microtransmittance factor of a uniformly exposed and developed film sample varies from point-to-point on the surface. The measured microtransmittance factor of a given film or plate can depend on the optical geometry of the instrument in which it is measured.

3.4
microdensity
D
transform of the microtransmittance factor in accordance with the usual relation $D = \log_{10} 1/T$

3.5
graininess
sensation produced, in the mind of an observer viewing a photographic image, by random inhomogeneity in what should be structureless areas

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NOTE Graininess is a subjective quantity that is necessarily measured by psychophysical methods and, as such, is outside the scope of this International Standard.

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3.6
root mean square granularity
rms-granularity
σ_D
objective characterization of the spatial microdensity fluctuation of a uniformly exposed and developed photographic layer, determined in accordance with this International Standard

NOTE 1 See Reference [3].

NOTE 2 In contrast to graininess, rms-granularity is an objective quantity.

NOTE 3 The spatial fluctuation is observed when the microdensity of the layer is measured at various points over the surface and is the result of the random distribution of the absorbent species in the layer. The fluctuation in the microdensity over an area of a specimen is characterized by its standard deviation, σ_D, and is generally a function of the specimen's macrodensity. This quantity is termed the "rms-granularity" and in all conceivable cases of interest, this population parameter cannot be determined exactly because of finite sample size. The method for estimating σ_D is described in Clause 9.

NOTE 4 The relation between graininess and rms-granularity is as follows: rms-granularity is intended to be an objective correlate of graininess. The methods of measuring film rms-granularity as defined in 3.6 have been found to give values that generally correlate with the magnitude of the graininess sensation produced when images produced by the film are viewed under suitable conditions. The just-noticeable differences in graininess, detectable by observers viewing areas having a visual density of about 1,0, correspond to differences in rms-granularity of 6 % for a uniform field, of 16 % for an average scene and of 30 % for a complex or busy scene[4]. Because rms-granularity does not account for effects encountered in multiple stage imaging processes, methods for evaluating the graininess of final images have been developed[11]. These methods are particularly useful for comparing the image graininess of different final print formats when produced from different negative formats and film types.

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3.7
specimen
piece of photographic film or photographic plate on which rms-granularity measurements are made

NOTE The specimen can be specific or constitute a sample from a population whose rms-granularity is being determined.

3.8
diffuse conversion factor
g
factor used to convert small transmission (projection) density differences produced by most microdensitometers to small diffuse density differences, as determined in accordance with 6.2

3.9
spatial frequency passband
part of the spatial frequency spectrum that passes through the measuring system

NOTE The spatial frequency passband is determined by the cut-off frequencies of the system on the low side and the high side of the spatial frequency. The passband characteristics required for the measuring instrument are specified in 5.2.

4 Measurement instrument

4.1 General

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This clause describes the basic elements of an instrument suitable for the measurement of rms-granularity. The generic instrument described in this clause follows the general principles for a linear, incoherent microdensitometer used in an overfilled, image-scanning mode. Microdensitometers of different designs may be employed, provided they are shown to conform to the physical optics principles required for linearity and incoherent illumination, as described in References [6], [7], [8] and [9].

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4.2 Microdensitometer

4.2.1 Apparatus

A typical microdensitometer is shown schematically in Figure 1. Its key elements are as follows:

- light source (1): an incoherent source of suitable spectral power distribution;
- illumination filter (2), which produces spectral transmittance necessary to conform to 4.2.2;
- condenser lens (3): optics that fill the influx aperture uniformly with light;
- influx aperture (4): in the optical system shown in Figure 1, this aperture limits the area of the specimen that is illuminated in order to minimize stray light in the optical system;
- influx optics (5), which images the influx aperture (4) on the specimen at point 6;
- specimen (6): emulsion (7) facing the efflux optics;
- efflux optics (8), which collects the light transmitted by the specimen and focuses it upon the efflux aperture of the instrument;
- efflux (measuring) aperture (9): this aperture, projected back onto the specimen, determines the area of the specimen whose density is being measured; its effective size at the specimen is determined by its physical size divided by the optical magnification from the plane at point 6 to the plane at point 9;

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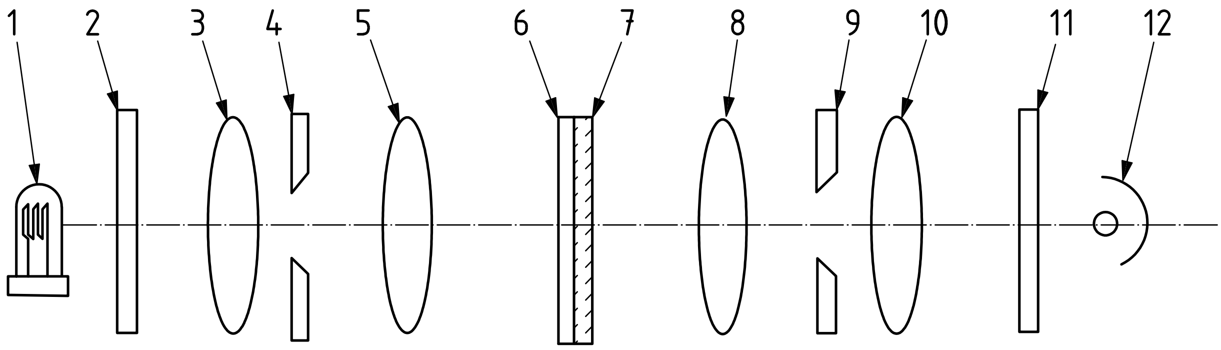
— collecting lens (10), which collects the light transmitted by the aperture (9) and relays it to the photodetector;

NOTE The collecting lens is omitted in some designs.

— efflux optical filter (11): spectral transmittance determined by density measurement type;

— photodetector (12), which shall have a spectral responsivity consistent with the spectral products required to produce one or more of the density measurement spectral types defined in ISO 5-3.



Key

1 light source
2 illumination filter
3 condenser lens
4 influx aperture
5 influx optics
6 specimen
7 emulsion
8 efflux optics
9 efflux (measuring) aperture
10 collecting lens
11 efflux optical filter
12 photodetector

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Figure 1 — Schematic representation of a typical rms-granularity measuring microdensitometer

4.2.2 Influx spectrum

The influx spectrum for rms-granularity measurements shall be as specified for transmission densitometry in ISO 5-3.

For transmission density measurements, if either the densitometer manufacturer or the user is not sure of the absence of fluorescence in the sample to be measured, the relative spectral power distribution of the incident flux S_H shall be that of the CIE standard illuminant A (ISO 5-3), modified in the infrared region to protect the sample and optical elements from excessive heat, which is typical for most transmission densitometers.

4.2.3 Influx aperture

The influx aperture shall be circular or square in shape and its image shall be concentric with that of the efflux aperture. When both apertures are referred to the plane of the specimen, the linear size of the influx aperture shall not be less than 1,5 times, nor more than 2 times, the linear size of the efflux aperture.

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4.2.4 Microdensitometer optics

4.2.4.1 General

The microscope objectives specified in 4.2.4.2 to 4.2.4.4 are the basic objectives for the measurement of rms-granularity and shall be used unless there is a specific reason to employ objectives of different characteristics. The use of alternate objectives is discussed in 4.2.5.3. An analysis of the effects of the microdensitometer optics on the measurement of rms-granularity is presented in Annex B.

4.2.4.2 Influx objective

When films are being measured, the influx objective shall be a high quality microscope objective having a numerical aperture (N_{AI}) of 0,3 ± 0,1. It shall not have the same numerical aperture as the efflux objective. If photographic plates are to be measured, the N_{AI} of the influx objective shall be no greater than 0,25, and the optical system shall be carefully focused to accommodate the thickness of the glass support.

4.2.4.3 Efflux objective

The efflux objective of the microdensitometer shall be a high quality microscope objective having a numerical aperture (N_{AE}) equal to 0,25 ± 0,10. It shall not have the same numerical aperture as the influx objective (4.2.4.4).

4.2.4.4 Mismatching the numerical apertures of the influx and efflux objectives

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In order to maintain incoherence in the optical system over the spatial frequencies of interest, it is necessary to mismatch the numerical aperture of the influx objective, N_{AI}, and the numerical aperture of the efflux objective, N_{AE}. The mismatch criteria are given in References [6], [7], [8] and [9] for the following two cases of interest:

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— **Case 1:** overfilled efflux objective, $N_{AI} > N_{AE}$

$$N_{AI} / N_{AE} > 1 + \left(u_{max} / u_{co}\right) \tag{1}$$

— **Case 2:** underfilled efflux objective, $N_{AE} > N_{AI}$

$$N_{AE} / N_{AI} > 1 + \left(u_{max} / u_{co}\right) \tag{2}$$

where

u_{max} is the maximum sample frequency ($u_{max} = 100\ \text{mm}^{-1}$);

u_{co} is the spatial frequency cut-off of the objective with the smaller numerical aperture, N_A (i.e. $u_{co} = 2N_A/\lambda$).

EXAMPLE If the efflux objective is underfilled and $N_{AI} = 0{,}30$, then $N_{AE} > 0{,}30\ (1 + 100/1\ 090) = 0{,}327$ when λ equals 550 nm.

It can happen then that the mismatch criteria for the numerical apertures of the influx and efflux optics lead to numerical aperture values which are outside the ranges of 0,3 ± 0,1 for the influx objective and 0,25 ± 0,10 for the efflux objective respectively. Keeping the numerical apertures within their respective ranges would then result in a non-linear behaviour of the microdensitometer leading to a corresponding additional uncertainty.

NOTE The above-mentioned maximum sample frequency, $u_{max} = 100\ \text{mm}^{-1}$, is true for colour films. However, in the case of black-and-white films, the noise power spectrum can have different contributions well beyond this limit (e.g. microfilm)[18].

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4.2.5 Objectives

4.2.5.1 Objective lens aberrations

The influx and efflux objectives may be achromatic or apochromatic; apochromatic objectives are recommended for use with colour materials. Achromatic objectives can be used either with or without eyepieces, depending on the optical design of the microdensitometer. If achromatic objectives are used to scan colour films, special care shall be taken to optimize the focal settings for each individual colour response.

4.2.5.2 Eyepieces

In some cases, notably that of apochromatic objectives, the optical design is such that the objectives need to be used with certain eyepieces for optimum results. If apochromatic objectives are used in the optical design, they shall be used with eyepieces as directed by the manufacturer. The powers of the eyepieces used may be varied as needed to meet the requirements for the optical magnification. When eyepieces are used, the “tube length” (i.e. the distance between objective and eyepiece) shall be optimized for the objective and eyepiece combination.

4.2.5.3 Use of objectives having other numerical apertures

In general, the purpose of measuring the rms-granularity of the specimen is to predict its behaviour in an imaging application. In some cases, where the film or plate is to be used with an optical system, the numerical apertures of the imaging system will be known and may be significantly different from the values given above. The numerical apertures of a measurement instrument optical system can be changed to simulate a specific imaging application more closely. However, in such cases the simulated application shall be stated and the numerical apertures used shall also be stated.

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4.2.6 Efflux aperture

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The efflux aperture should be circular in shape. Alternatively, a rectangular or square aperture of similar dimensions (resulting in the same aperture surface) can be used. The effective diameter of the image of the circular efflux aperture at the specimen plane shall be (48,0 ± 0,5) µm when calculated via the magnification. A 42,5 µm square image of the efflux aperture gives comparable results (within 5 %). The physical size of the aperture may be any convenient size.

NOTE In this International Standard, further detailed analyses will all refer to circular apertures.

4.2.7 Photodetector

Any photodetector may be used in the granularity measurement instrument provided that it meets the following requirements:

a) its spectral responsivity range covers the wavelength range of interest and is continuous over this range,

b) its frequency response is adequate to evaluate the incoming flux variations,

c) its sensitivity is sufficient for operation over the required density range (including filters for colour materials), and

d) the electronic noise it adds to the granularity signal is stable and measurable.

4.3 Spectral products

4.3.1 Specification

The spectral product of the system will depend on the type of measurement desired. ISO 5-3 specifies the spectral products of the types of density referenced below.

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