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CALIBRATION OF SPECTROPHOTOMETER, HAVING THE CHARACTERISTICS OF A MONOCHROMATOR

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Abstract:

With purpose of receiving the most accuracy and volume of information for the upper theoretical calculations arise the necessity of spectrophotometric apparatus development working in the ultraviolet part of the optic specter and the visible area, holding high resolution at wavelength [1-6]. In this relation is very important the ability of spectrophotometer characterizing itself with the features of real monochromator describing with fully apparatus function. The development of theory of linkage for the whole approach method with description of the linear systems features is based of functional relation known as integral of superposition.

In practice is the important question what fullness with is necessity the knowledge of the apparatus function of monochromator to be used the relation as a basis for quantity description of monochromator features regards to the wide class of input signals with linear and continuous spectrum which ensures the solution of the given equations and with a definite resolution.

For a more vivid representation of the matter, a model experiment has been made. For a given monochromer it must be definite its apparatus function and features in relation to the spectrum describing fully by the given equations. The monochromator is with equal sizes of the input and output shafts, has an equal scanning and linear scale of wavelengths.

The development of theory of linkage for the whole approach method with description of the linear systems features is based of functional relation known as integral of superposition [2]:

(1)
$$F(x_2) = \int_{-\infty}^{\infty} f(x_1) h(x_1, x_2) dx_1 ,$$

where $f(x_1)$ - input signal;

$F(x_2)$ - output signal;

$h(x_1, x_2)$ - function describing the features of system when the h for every x_1 and x_2 is known.

The signal in the time is described as follows:

(2)
$$F(t) = \int_{-\infty}^{\infty} f(\tau) h(\tau, t) dt ,$$

when the function $h(\tau,t)$ is impulse transmission characteristics of system.

The function h is a consequence of (1) and has transmission system characteristics for the input signal in the form of δ-function:

(3) $$h(t)=F(t),\ \text{if}\ f(t)=\delta(\tau),$$

as:

(4) $$F(t)=\int_{-\infty}^{\infty}\delta(\tau)h(\tau,t)d\tau=h(t),$$

In examining of an optical system in (1) is defined the spectral coordinates (wavelengths) and f and F are respectively spectral distributing intensities illumination etc.). The function h in this case is apparatus function.

In practice is the important question what fullness with is nessecity the knowledge of the apparatus function of monochromator to be used the relation (1) as a basis for quantity description of monochromator features regards to the wide class of input signals with linear and continuous spectrum $f(x)$, providing the (1) equation decision in given resolution. A model experiment has been made. For given monochrmator it must be definite its apparatus function and features in relation to the spectrum $f(x)$ describing fully by (1). The monochromator is with equal sizes of the input and output shafts, has an equal scanning and linear scale of wavelenghts in division from n_{min} to n_{max}. Including the new variables the (1) is as follows:

(5) $$F(n)=\int_{-\infty}^{\infty}f(\lambda)h(\lambda,t)d\lambda,$$

when: λ - radiation wavelenght;

n - monochromer spectral scale division.

Defining from the registered radiation $f(\lambda)$-component (monochromating enough to be a δ-function), the input shift is opening and registered the change of flux, transpassing through the output shift in the scanning in work range from n_{min} to n_{max}. It is received a registrogramme which is an apparatus function $h_{\lambda_1}(n)$ of monochromer for λ_1 wavelenght (fig.1). In the contour of the apparatus functioncan be separated a main part- a maximum range of divisions of the scale n_1, in accordance with the transportation of the image fro input to the output shift in the scanning process. The form of the main part of the apparatus function contour can be non-symmetric if the shifts are narrow and vital importance is the aberations and disturb adjustment. The rets part of contour- the stretched part can be explained with dispersing of radiationfro the optical elements. The signal from such of this light dispersing can gradually increase at the shifts

It continuos the illumination of input shift with almost monochromatic flux $\delta(\lambda_i)$ with continuously increasing values in (λ_i) wavelenght and registering of the corresponding apparatus functions. In this case can be received a range of situations. For example for some apparatus function (λ_2) may has an appearance of a second maximum received from the radiation passing from the first and higher degrees defractions. The maximums appear at division $n = mn_i$ of the scale (when m = 2, 3, 4... - position 2 of fig. 1). Besides the main part of contour can own different forms depending on the wavelenght and shift width. At sufficient wide shift the apparatus function form is triangle, (position 6 of fig.I), at shift narrowing can be received diffraction widening and contour approximate to the Gauss (positions 3, 4 and 5 of fig. 1).

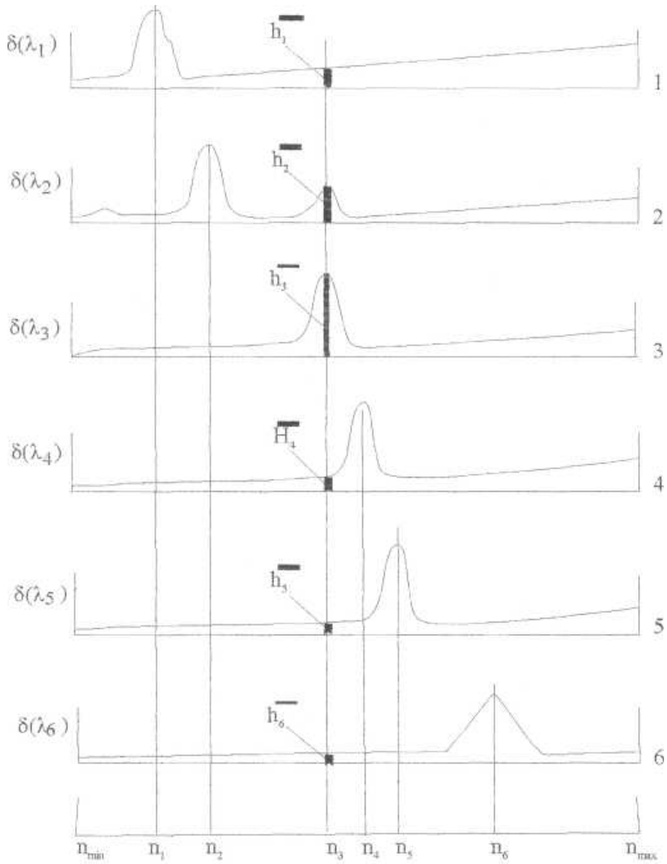

Fig. 1 The graphics illustrates the type of the apparatus function h_{λ_1} of the monochrometer at (λ_i) entrance influence. At the horizontal axis the monochromator scale length is put. The vertical coordinates of the apparatus function of the horizontal n_3 are marked by the short symbols $h_1^{(3)}$, instead of the full version

From fig. 1 it can be seen the monochromator features with respect to every component $\delta(\lambda_i)$ in the continuous spectrum examination $f(\lambda)$ can be essentially different and for their full description is necessity to make an attention to the whole combination of apparatus functions $h_{\lambda_1}(n)$ for every wavelenghts including in the radiation from n_{min} to n_{max}. This combination can be present in graphic as a three-dimentional continuous surface $h(\lambda, n)$ representing the full monochromator apparatus function. Exactly this function is described from the integral in position 2 in fig. 1. The separated monochromatic apparatus functions are observed as sectionsof the

For the monochromator with an ideal precise scale is valid the equality $n_i = \lambda_i$ for the coordinate n_i with maximum - the main part of the contour of the apparatus function. In the real case this is impossible (and not necessarily) and the difference estimation $\beta_i = n_i - \lambda_i$ as a printing of dependence $\beta(n)$ or $\beta(\lambda)$ a curve of corrections.

The linear system describing the relation (1) is defining like invariant if the function $h(h_1, x_2)$ depends on the distance $x_1 - x_2$

(6) $$h(h_1, x_2) = h(h_1 - x_2),$$

For optical systems creating an image, the variable x has a spatial coordianteand the condition (6) is expressed with the spatial invariation of the system. In the case the variable x has a spectral coordinate and we have a spectral invariation of the system:

(7) $$h(\lambda, n) = h(\lambda - n),$$

Having an attention to the fact that the main part of the apparatus function can be described in $h(\lambda - n)$ with definition for the coordinate start λ instead (5) is received:

(8) $$F(n) = \int_{-\infty}^{\infty} f(\lambda)(\lambda - n) d\lambda,$$

and significantly simplify the calculations i
ideal apparatus and in other cases. From fig.I can be seen that the widerangedscanning monochromators do not possessed the feature of spectral invariation because of what one of the important topics of the metrological atestation of monochromators is receiving an answer of the question how much stable is the main part form for the concrete apparatus with the change of λ in input with change of shift widht. The most complete is the answer the most correct is the decision of the question for the border applications of the function (8) for the concrete apparatus, e.g. determination of the borders in which the apparatus functions can be in a given permission approximating to the triangle or Gauss contour.

Continuously with the model experiment we illuminate the monochromator with radiation in continuous spectrum as the scanning is fixed in example on position n_3 (fig. 1). What will be the spectral composition for the output flux- the flux will contain spectral components in three basic types;

- flux $h_3^{(3)}$ will correspondence to the wavelength of setting-up $\lambda_3 = n_3$ (in case that the scale of apparatus is precise) and fluxes $h_4^{(3)}$ and $h_5^{(3)}$ are close values for the two sides to λ_3;
- flux $h_2^{(3)}$ from the radiation λ_2, trespassing with its high degree of detraction;
- fluxes $h_1^{(3)}$ and $h_6^{(3)}$ - dispersed radiation from different wavelengths

The sum from every $h_i^{(3)}$ makes a spectrum presented in fig. 2. The spectrum can be widely from the range for which is calculated the scale. In the spectrum contour of the output flux is observed the main part around /I3 which is the useful flux (signal) in contrast from the rest part- wing representing perturbing radiation of the other wavelengths The printing of fig. 2 is the section of three-dimensional whole apparatus function $h(\lambda, n)$ for plane $n_3 = const$ characterizing the section with its fixed spectral function

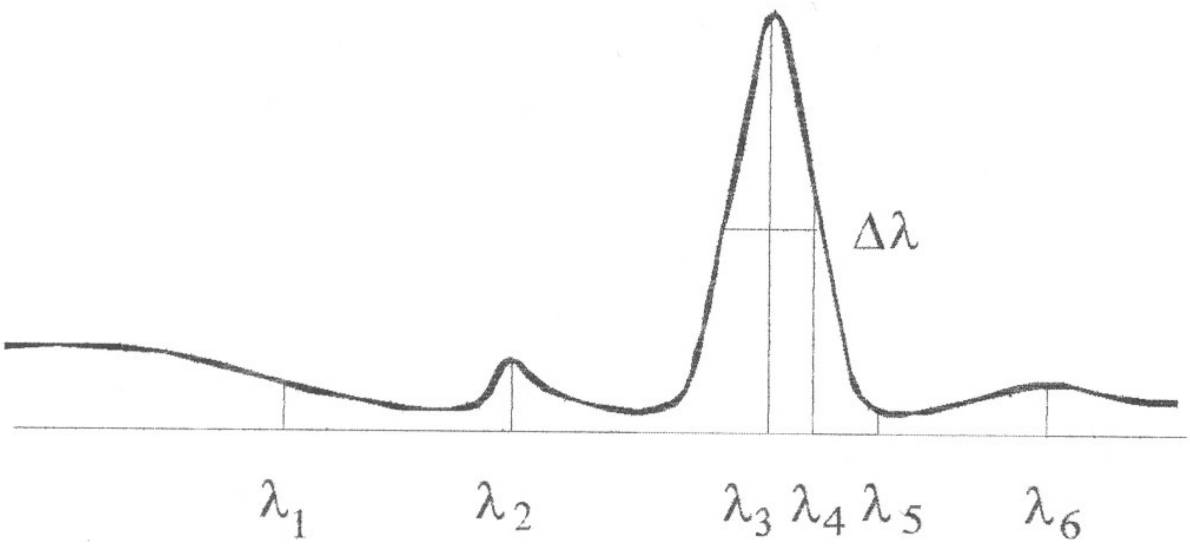

Fig. 2. Stream specter which passes through the monochromator entrance hole (spectral function of the monochromer) at found scanning of scale division n_3

The whole composition of apparatus functions for every λ and the whole composition of spectral functions for every n consist information about the features of monochromer, e.g. give the whole $h(\lambda, n)$ but in essential different form. The contour of every spectral function characterize the ability of monochromator to separate the spectral intervals from an continuous spectrum, e.g. to possess selectiveness and express its quantity relation $\lambda / \Delta\lambda$ when $\Delta\lambda$ is the separate spectral interval defining the width of the spectral function main part. The contour of the apparatus function characterize mostly the ability of the monochromer to separate closely wavelength (without setting of side-wavelength λ*)*, what for the definition resolution of monochromer is connect exactly with the apparatus function contour and is estimated through the quantity relation $n / \Delta n$ when Δn is width of the apparatus function main part which can be compared to calculated values of the effective width of shifts giving an account to linear dispersion and the influence of diffraction and aberrations.

As a conclusion it must be noted that for accurately prognostication and giving an account for the ultraviolet athmospheric radiation change is very important the using of high accuracy spectrophotometric apparatus providing the determination of aerosols concentration in the athmosphere with high resolution. The presented analyses help for realisation of this apparatus.

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