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Abstract

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PHYSICS

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APPLICATION OF AN ELECTRON-OPTICAL LIGHT AMPLIFIER WITH A FABRY-PEROT ETALON AND A MONOCHROMATOR FOR TIME SWEEPS OF A SPECTRUM

(Presented by Academician B. P. Konstantinov, February 26, 1962)

The high luminosity of installations with a Fabry-Perot interferometer and a monochromator of preliminary dispersion (1–5) accounts for attempts to use them for spectral studies of pulsed processes. However, the existing methods, based on scanning the spectrum by rapidly mechanically moving one of the plates of the etalon (6,7), do not make it possible to obtain contours of spectral lines in times substantially shorter than $5 \cdot 10^{-5}$ sec. (7).

The proposed method of jointly using an electron-optical amplifier (EOA) and a Fabry-Perot interferometer with a monochromator of preliminary dispersion makes it possible, on the one hand, to obtain contours over considerably shorter time intervals (the time resolution achieved with the aid of the EOA reaches $3 \cdot 10^{-12}$ sec. (8)), and, on the other hand, makes it possible to use a high-luminosity scheme. Moreover, it turns out that the luminosity of such an installation is approximately an order of magnitude greater than the luminosity of an ordinary installation with an interferometer, monochromator, and EOA, which is also very important in the study of low-intensity pulsed processes.

The number of contours recorded successively in time can be made considerably larger than in the schemes presently used.

In the proposed method the slit, over its entire height, is focused onto the photocathode of the EOA, which transfers the image of the slit and, simultaneously, the image of the rings to the output screen, photographed by an ordinary camera. Time sweeping is carried out by displacing, over the screen, the image of the slit intersected by rings in a direction perpendicular to the height of the slit. Displacement of the image is effected by applying a sawtooth voltage to the deflecting plates of the EOA.

Fig. 1. Photograph of a time sweep of two rings

Figure 1: Fig. 1. Photograph of a time sweep of two rings

In view of the fact that in our case the entire height of the slit is used and the number of orders $i = p/n$, rather than $1/n$ of an order as usual, is recorded simultaneously, the angular height of the monochromator slit β must be chosen so that

$$\beta = \psi_i \frac{d}{d_p}$$

(the complete filling of the interferometer plates and the grating is provided for).

Here $\psi_i \equiv \psi_{p/n} = 2\sqrt{\frac{\lambda}{t}\frac{p}{n}}$ is the angular diameter of the p-th ring with a width of $1/n$ order; d and d_p are the diameters of the interferometer and of the grating.

The maximum value of p is determined by matching the wavelength resolution of the interferometer to the linear resolution of the EOA photocathode. $p_m = \frac{1}{2}\left(\frac{l}{x}\right)$, where the quantity in parentheses is the number of resolvable intervals on the EOA photocathode.

The gain in light intensity in comparison with the usual method occurs owing to the considerably greater utilized height of the slit of the spectral instrument. The ratio of the energies recorded with the aid of an EOU and in the ordinary scheme with the aid of an FEU, for one and the same time, in one and the same wavelength interval (with the same number of orders), and with the same wavelength resolution, accurate to a factor close to unity, will be

$$\frac{\varepsilon_{\text{EOU}}}{\varepsilon_{\text{FEU}}} = \frac{\psi_{p_m/n}}{\psi_{1/n}} = \sqrt{\frac{1}{2}\frac{l}{\chi}}.$$

This gives a value of the order of 10. Calculation shows that such a gain due to the larger angle can be realized even for a thin interferometer, 0.3 mm thick, with the aid of a standard monochromator (DFS-12). For interferometers more than 40 mm thick, almost

Fig. 1. Photograph of a time sweep of two rings

all existing monochromators will prove suitable. To realize the maximum energy gain, it is convenient to choose the angular height of the monochromator slit according to the formula

$$\beta d_p \geq d_{\mathrm{e}}\sqrt{\frac{2\lambda}{tn}\left(\frac{l}{\delta l}\right)}.$$

Fig. 2. Line contours of the mercury lamp PRK-4, $\lambda 4047$ Å, for times $t_1 = 1.2$ msec, $t_2 = 1.5$ msec, $t_3 = 1.9$ msec from the beginning of the glow period (for I_m, the intensity at the maximum of the last contour was taken)

Figure 2: Fig. 2. Line contours of the mercury lamp PRK-4, $\lambda 4047$ Å, for times $t_1 = 1.2$ msec, $t_2 = 1.5$ msec, $t_3 = 1.9$ msec from the beginning of the glow period (for I_m, the intensity at the maximum of the last contour was taken)

The maximum width of the entrance slit of the spectral instrument a_m is found from the condition that the "smearing" of the rings as a result of the sweep, i.e., the unresolved part of the contour, be matched to the resolution of the EOU photocathode. It turns out that $a_m \ll h/\sqrt{p_m}$. A calculation shows that the restriction is not very severe and will play a substantial role only in rare cases.

The realization of the indicated energy advantage, of course, also depends on the comparative sensitivity of the EOU and FEU; however, as shown in work (^{9}), the sensitivity of the EOU is not lower than the sensitivity of the FEU.

In order to test the method, an experiment was carried out on the setup available to us* with a DFS-8 spectrograph. Photographs were obtained of sweeps of the emission of the $\lambda 4047$ Å line of a PRK-4 mercury lamp. In Fig. 1, as an example, a photograph is given of the time sweep of two rings. The width of the slit image on the photocathode was close to the resolved interval of the photocathode, which made it possible to obtain about 100 consecutive contours during the sweep time (1 msec). The time resolution was correspondingly about 10 μsec. Three contours for the times indicated in the photograph are shown in Fig. 2.

Fig. 2. Line contours of the mercury lamp PRK-4, $\lambda 4047$ Å, for times $t_1 = 1.2$ msec, $t_2 = 1.5$ msec, $t_3 = 1.9$ msec from the beginning of the glow period (for I_m, the intensity at the maximum of the last contour was taken).

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* The setup was developed by Prof. V. L. Kreitser, L. A. Peknyi, and V. A. Ilyin.

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