Application of K008 Camera in non-stationary Spectroscopy

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Introduction

Since August 2003 the K008 camera /1,2/ being coupled with a MS 3504i monochromator/ spectrograph /3/ has been used in the International Laser Center in Bratislava (Slovak Republic) for investigations in the field of non-stationary spectroscopy, in particular, for the study of fluorescence processes in different dyes. When putting the camera into operation its limiting temporal resolution was preliminarily checked and was found to be 20 ps. The results of trial experiments on the study of dynamics of Rhodamin B fluorescence are given below.

The camera tests and the first results of trial experiments

As a result of the indicated coupling performed by the BIFO Company together with the International Laser Center of the Moscow State University a new device has been obtained that was called the SVA-01 imaging temporal-analyzing monochromator/spectrograph /4/ (Fig.1).

Fig.1. An appearance of the SVA-01 imaging temporal-analyzing monochromator/spectrograph.

The main parameters of the new device are listed in the Table.

Table

No.	Parameter's name and dimension	Parameter's value
1	Spectral range is defined by image converter tube (ICT) spectral sensitivity range, nm	≤400 to ≥800
2	Inverse linear dispersion, nm/mm	2.37
3	Spectral resolution, nm	0.08
4	Step of wavelength retuning, nm	0.01
5	Frame size on ICT photocathode, mm, not less than	12.5 x 11.2
6	Frame duration: from, ns to, µs	8 to 12 600 to 660
7	Maximum slit image length on ICT photocathode, mm	≥11.2
8	Effective sweep route length on ICT screen, mm	18 to 21
9	Linear sweep coefficient on ICT screen: from, ns/cm to, µs/cm	 1 300
10	Spatial resolution on ICT photocathode, l.p./mm	≥10
11	K008 camera temporal resolution with 0.05 mm slit width: from, ps to, µs	20 6

The remotely controlled MS3504i monochromator/spectrograph allows separating either a spectral range interesting for the investigator or to select a spectral line needed for an analysis. The camera performs a time sweep of a spectrum image with a necessary temporal resolution, records a swept image with the aid of a CCD television camera and enters it into a computer. As a result of analyzing this image, one can obtain a temporal and spatial (spectral) profile of the intensity of recorded radiation for the selected spectral range, profiles of several spectral components or an individual spectral line and measure the duration of recorded radiation at any level of its intensity.

Correction of all the geometric and photometric distortions including light-signal characteristics and sweep nonlinearity has been carried out with the aid of camera software in order to increase the accuracy of measuring spatial (spectral) and time intervals as well as relative intensities of input signals in both modes of camera operation. As a result of correction, geometric distortions were decreased from $4\%_{max}$ to not more than 1% and sweep nonlinearity was decreased from $10\%_{max}$ to not more than 1%. Correction of photometric distortions resulted in decrease of conversion coefficient nonuniformity across an image field from $30\%_{max}$ to not more than 5%.

Dyes can be excited by laser pulses of different wavelengths and of femto-, pico-, and nanosecond durations in the International Laser Center in Bratislava.

When putting the SVA-01device into operation there was preliminarily and separately checked a limiting temporal resolution of the K008 camera. To do this radiation of a $Ti:Al_2O_3$ laser generating a continuous sequence of femtosecond pulses at a 800 nm wavelength was directed to a camera slit of a 50µm width. A pulse repetition period was equal to 12.5 ns (Fig. 2), a single pulse duration measured by an autocorrelator was equal to 60 fs.

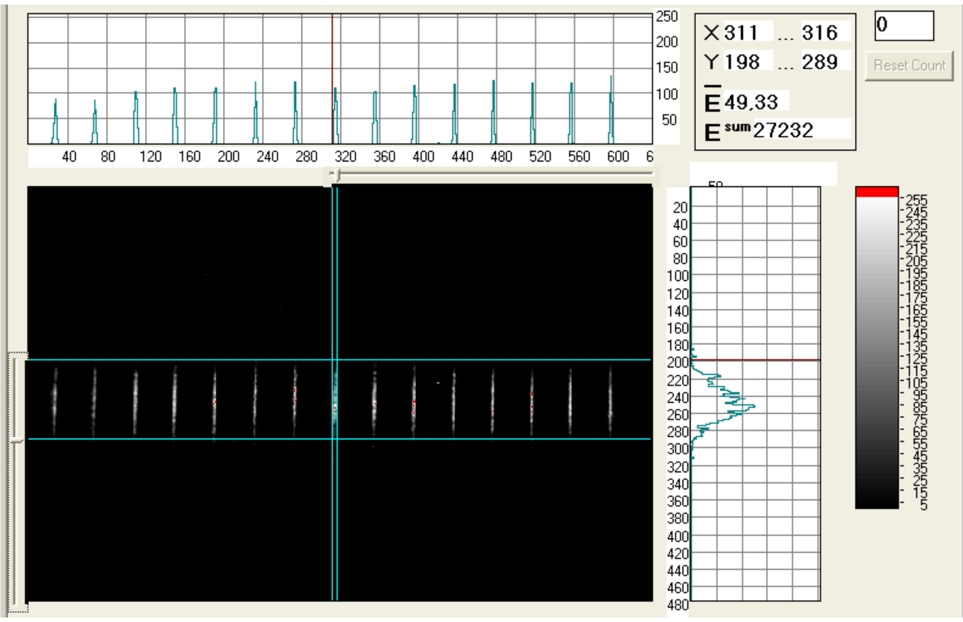

Fig. 2.A femtosecond laser pulse sequence; a sweep coefficient is 100 ns/cm.

Fig. 3 shows a camera response to the input pulse of 60 fs duration.
A half-width of this response representing the limiting temporal resolution of the camera (or its temporal instrument function) at a 800 nm wavelength was equal to 20 ps.

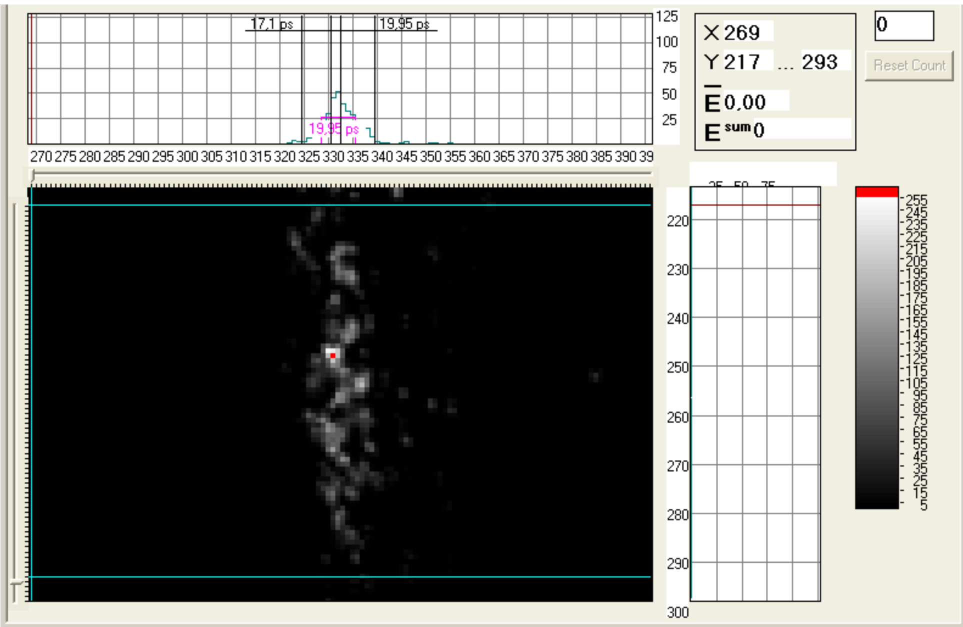

Fig. 3. A temporal instrument function of the K008 at a 800 nm wavelength; a sweep coefficient is 1 ns/cm.

The limiting temporal resolution t_0 of the SVA-01 new device is defined by two independent quantities: the limiting temporal resolution t_1 of the K008 camera and the limiting temporal resolution t_2 of the MS 3504i device and, therefore, can be calculated by the known formula: $t_0 = \sqrt{t_1^{\,2} + t_2^{\,2}}$.

The limiting temporal resolution of the camera K008 depends on the wavelength of recorded radiation since an image converter tube without an accelerating grid near the photocathode is used in the camera. As a result, an electric field strength near the photocathode is insufficient for providing the limiting temporal resolution of 20 ps throughout the whole spectral sensitivity range of the image converter tube. During K008 camera tests in the International Laser Center of the Moscow State University its limiting temporal resolution was equal to: 20 ps at 800 nm, 53 ps at 616 nm and 93 ps at 400 nm.

As to the limiting temporal resolution t_2 of the MS 3504i monochromator/spectrograph (the maximum increase in duration of radiation pulses to be recorded) it should be noted the following. It is defined by the maximum path difference of the beams in this device and also depends on the radiation wavelength to be recorded. When radiation fills in the full length of a diffraction grid the limiting temporal resolution may be estimated by the maximum of the possible value according to the formula: $t_{2max} = \lambda L/cd$, where λ is the wavelength, L is the full length of the diffraction grid (70 mm), c is the light velocity, d is the diffraction grid constant (833 nm). A filling in of the full diffraction grid length with radiation to be recorded is possible when a source of this radiation (an object under study) is set closely to an entrance slit of the device and radiates in a rather wide angle. Such a source may be, for example, fluorescent radiation of dyes. In this case a cell with a dye must be set at the device entrance slit. For this case the value t_{2max} at 800 nm, 616 nm, and 400 nm wavelengths mentioned above for the K008 camera is equal, respectively, to 224 ps, 173 ps, and 112 ps.

The estimation of t_{0max} for the SVA-01 device according to the formula for t_0 with taking account of the indicated above figures measured for the K008 and calculated for the MS3504i gives the following results: 225 ps at 800 nm, 181 ps at 616 nm, and 146 ps at 400 nm.

In case of low divergence of radiation to be recorded (collimated beams or direct laser radiation except for semiconductor laser radiation) not the full diffraction grid length will be act. In this case the increase of duration will be less (is proportional to *l*/L, where *l* is the acting grid length). However one must keep in mind that in this case a spatial resolution of the device will also be less.

An actual limiting temporal resolution of the temporal-analyzing monochromator/spectrograph has not yet been measured since the primary interests of the scientists of the International Laser Center in Bratislava are lying in the meantime in a nanosecond time range.

The results of measuring a fluorescence lifetime in a solution of Rhodamin B in ethanol can be presented as an example of such investigations. A second harmonic of a Q-switched Nd-laser radiation was used for solution excitation (wavelength 532 nm, exciting pulse half-width t_{ex} = 9.91 ns, see Fig.4).

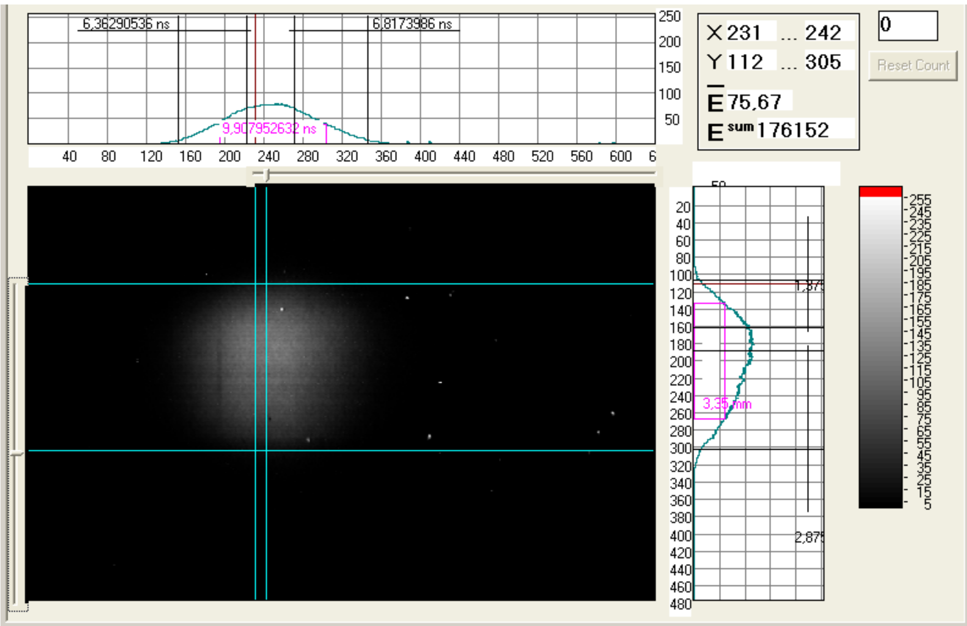

Fig.4.Time profile of exciting pulse; sweep coefficient is 30 ns/cm.

Fluorescence dynamics was recorded at a 585 nm wavelength (Fig.5).

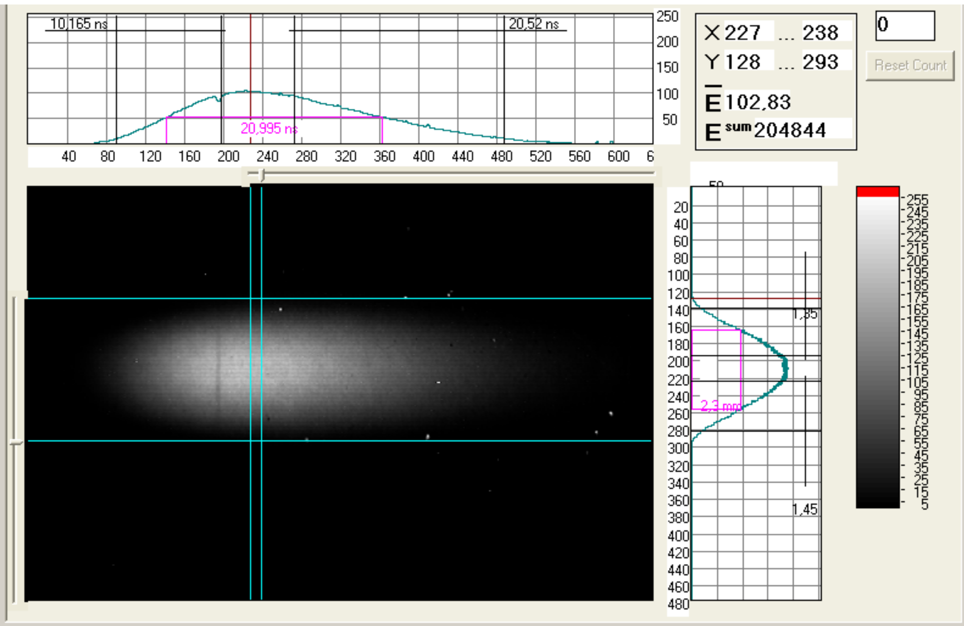

Fig.5. Time profile of luminescence of Rhodamin B solution
in ethanol; sweep coefficient is 30 ns/cm.

A pulse half-width t in Fig.5 is equal to 21 ns. Since t_{ex} is not an infinitesimal in comparison with t, duration of fluorescence lifetime t_{fl} of Rhodamin B can be defined by the formula: $t_{fl} = \sqrt{t^2 - t_{ex}{}^2}$. As a result of calculations we obtain t_{fl} = 18.52 ns.

Conclusion

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References

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