ON FIRST ORDER COHERENCE OF RADIATION OF A DYE-LASER

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The first order (space) coherence of the radiation of a pulse dye-laser with rhodamine 6 G solved in ethanol as active material has been determined as a function of the total energy of the pulse, of concentration of the dye, and of the energy of the lines (bands) of the spectrum of the laser pulse. It has been found that the minima of the degrees of coherence decrease with increasing total energy of the pulse, whereas the degrees of coherence pertaining to constant band energies monotonously increase with increasing concentration. The degrees of coherence as a function of the energy of the lines (bands) first steeply increase, then slowly decrease.

Introduction

For characterizing the coherence of the electromagnetic radiation field (EMRF), correlation functions of different order [1—4] are used. If the EMRF is comparatively strong, of not too high frequency (see [1] p. 2533), quasimonochromatic, stationary and ergodic, the degree of coherence of the field, of first order according to GLAUBERS definition, can be determined from the intensity distribution of the interference pattern obtained with an interferometer of YOUNG-type (*Y*), with the formula [5—6]

$$|\gamma_{12}(\tau)| = \frac{I_{\max}-I_{\min}}{I_{\max}+I_{\min}} \cdot \frac{I^{(1)}(Q)+I^{(2)}(Q)}{2\sqrt{I^{(1)}(Q)}\cdot\sqrt{I^{(2)}(Q)}}, \tag{1}$$

where $(I_{\max}-I_{\min})/(I_{\max}+I_{\min})$ is the visibility of the interference fringes; $I^{(1)}(Q)$ and $I^{(2)}(Q)$ are the light intensities which could be measured in the point Q of the screen on which the interference pattern is formed, if only one of the pinholes (1) and (2), respectively, were open. If the delay between the beams arriving to Q from (1) and (2) is small compared to the time of coherence of the light, then Eq (1) gives information about the spatial coherence of the EMRF. (In the following the notation $|\gamma_{12}(\tau)| \equiv \gamma$ is used.)

Experimental arrangement and method of measurement

As the spectrum of the EMRF produced by the dye-laser (*DL*) under investigation consists of several hundreds of "Fabry—Perot lines", in building up our arrangement we first had to determine the sequence of the interferometer *Y* and of the spectrograph S of Steinheil-type. If tnis sequence is DL, Y, S and the straight line determined by the two pinholes (1), (2) of Y is parallel to the entrance slit of S, then the narrow band cut out by the slit from the fringes perpendicular to the slit will be resolved by S according to wavelength. Such a system of fringes, a "coherence spectrum", is shown in Fig. 1.

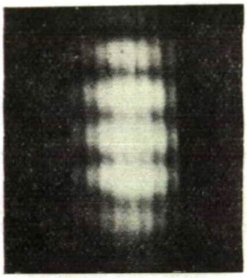

Fig. 1

As our dye-laser gives short pulses and so its power is comparatively high, therefore S may change the structure of the field (polarization, spectrum) both by linear and nonlinear effects; therefore the sequence DL, S, Y is not suitable.

Y itself may also cause changes in the structure of the EMRF, *e.g.* by reflecting part of the radiation from its surface back to the resonator; therefore Y must be made with a diffusely reflecting or black surface. On the edges of the pinholes of Y, not only diffraction but *e.g.* also Brillouin-scattering may occur, changing hereby the visibility of the fringes. Because of the circumstances mentioned above, the power density produced by DL and controlled by adjusting the pumping was chosen to be about 10^3 W/cm^2. The energy was measured by the microcalorimeter described in [7] or by the photodetector BPY 10 calibrated with the microcalorimeter, and the time with a cathode ray oscilloscope type EMG 1546. In the case of power densities of this order of magnitude relevant disturbing effects cannot occur.

The sequence DL, Y, S has the further experimental advantage that the interference pattern of all "Fabry—Perot lines" of a single pulse can be obtained with the same Y.

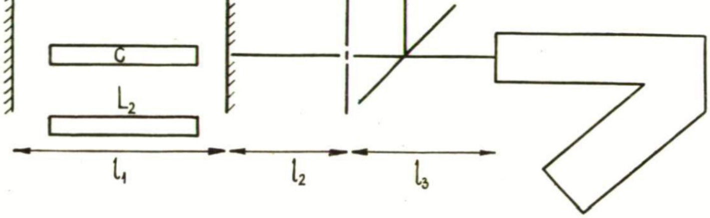

Fig. 2

A diagram of our arrangement is shown in Fig. 2. The cylindrical glass cell C containing the active dye solution was 10 cm long and of 0,8 cm inner diameter. L_1 and L_2 were Xe flash lamps type IFP-800, receiving the power supply from a condensor of 10 μF capacity loaded to 4—6 kV. The resonator consisted of the mirrors M_1 of 500 cm curvature radius, and of the plane mirror M_2, with reflection coefficients of 70% and 99%, respectively. The pinholes of the interferometer Y, reflected by the glass plate G were photographed by the camera CA to give blackenings, from which the light intensities $I^{(1)}(Q)$ and $I^{(2)}(Q)$, respectively, could be determined. Y consisted of a thin aluminium plate with two pinholes of 0.002 cm diameter, the distance between their centres being 0.01 cm. The lengths l_1, l_2, l_3 were 40 cm, 100 cm, 15 cm, respectively; l_2 and l_3 were chosen on the basis of trial measurements. According to these the visibility of the fringes did not show significant changes, and increased only slightly with l_2 gradually decreasing down to 1 cm. As the intensity of the light of the flash lamps passing through M_2 had to be decreased, l_2 was chosen to 100 cm.

An ORWO (Wolfen) film of 27 DIN sensitivity was used as detector and its blackening determined with a Zeiss photometer. To permit to conclude from the blackening to the intensity and the energy, the film was calibrated. The calibration was made with a lamp giving a flash commensurable with the halfwidth in time of the laser pulse. The energy measurements were checked by determining the energy of the same laser pulse — E_m and E_f — both with a microcalorimeter and photographically, respectively, for flashes of different energies. Supposing the correctness of both methods of measurement, E_f and E_m should be proportional. As it is to see from Fig. 3, this desired proportionality subsists with a mean absolute deviation of about ±10 units.

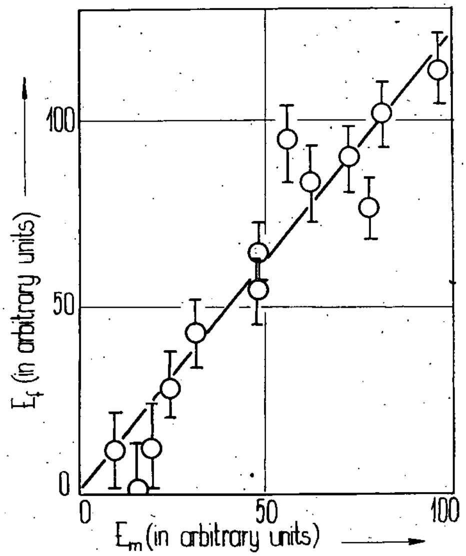

Fig. 3

The degree of coherence can be determined from γ calculated from Eq. (1) if the conditions of validity are fulfilled, *i.e.* if the field under investigation is quasi-monochromatic, stationary and ergodic. This last condition is essentially fulfilled, as the EMRF described by quantum electrodynamics is pseudoergodic; according to our estimation, our field is essentially stationary from the point of view of coherence.

For this estimation the shape of the pulse was photographed and found that it does not contain spikes. In the time interval most important for photography, in which the radiation is the most intensive, the changes in number of photons seem to be small enough, and so the field of the DL can be considered as approximately stationary from the point of view of the number of photons in this time interval. With regard to the definition of γ (see [6]), this also means that the correlation function is approximatively stationary from the point of view of coherence.

For calculating γ on the basis of Eq. (1), our field must be monochromatic. As the condition of monochromaticity consists in the mean half width $\Delta\nu$ of the beam being much less than its mean frequency $\bar{\nu}$ (see [6] p. 502) and the spectrum of the *DL* consisting of separate lines, a series of degrees of coherence according

Table I

c_M	$4\cdot10^{-5}$M		$5\cdot10^{-5}$M		$6\cdot10^{-5}$M		$7\cdot10^{-5}$M		$8\cdot10^{-5}$M		$9\cdot10^{-5}$M		$1\cdot10^{-4}$M		$2\cdot10^{-4}$M		$3\cdot10^{-4}$M		$4\cdot10^{-4}$M		$5\cdot10^{-4}$M		$6\cdot10^{-4}$M	
	E	γ	E	γ	E	γ	E	γ	E	γ	E	γ	E	γ	E	γ	E	γ	E	γ	E	γ	E	γ
E (in arbitrary units); γ (%)	7.8	51	16	45	54	75	14	58	6.5	32	37	46	43	64	38	73	19	72	22	73	56	64	13	63
	14	59	44	47	32	48	16	54	18	51	89	37	49	54	106	45	71	67	76	56	92	52	24	69
	12	52	87	29	60	41	32	54	37	55	117	16	69	53	127	23	103	42	105	47	100	53	63	62
	9.6	54	102	25	74	38	72	58	30	43	123	24	95	43	136	19	133	31	123	36	118	45	71	66
	11	58	100	24	81	34	32	51	43	43	125	19	125	33	104	26	145	25	138	36	138	32	62	68
	7.9	48	110	26	79	35	51	51	21	51	129	20	120	26	122	30	169	26	129	42	141	39	43	65
	7.8	51	118	25	88	35	27	56	35	54	106	31	129	27	118	34	196	22	145	28	93	50	23	70
	5.6	48	96	30	93	37	36	55	18	51	74	48	128	29	76	52	205	27	170	32	110	59	21	66
					72	43	17	43	7.1	53	13	52	126	31	36	70	171	26	133	34	36	70		
					93	34	7.9	30					128	39			138	34	129	39				
					56	45							127	39			109	48	86	54				
					50	62							110	52			52	67	77	61				
					47	57							78	61					70	62				
					25	49							58	67					18	68				
					6.5	44																		

Table II

c_M	$4\cdot10^{-5}$M		$5\cdot10^{-5}$M		$6\cdot10^{-5}$M		$7\cdot10^{-5}$M		$8\cdot10^{-5}$M		$9\cdot10^{-5}$M		$1\cdot10^{-4}$M		$2\cdot10^{-4}$M		$3\cdot10^{-4}$M		$4\cdot10^{-4}$M		$5\cdot10^{-4}$M		$6\cdot10^{-4}$M	
	E	γ	E	γ	E	γ	E	γ	E	γ	E	γ	E	γ	E	γ	E	γ	E	γ	E	γ	E	γ
E (in arbitrary units); γ (%)	5.6	48	16	45	6.5	44	7.9	30	6.5	32	13	52	43	64	36	70	19	72	18	68	36	70	13	63
	7.8	51	44	47	25	49	140	58	7.1	53	37	46	49	54	38	73	52	67	22	73	56	64	21	66
	7.8	51	87	29	32	48	16	54	18	51	74	48	58	67	76	52	71	67	70	62	92	52	23	70
	7.9	48	96	30	47	57	17	43	18	51	89	37	69	53	104	26	103	42	76	56	93	50	24	69
	9.6	54	100	24	50	62	27	56	21	51	106	31	78	61	106	45	109	48	77	61	100	53	43	65
	11.0	58	102	25	54	75	32	51	30	43	117	16	95	43	118	34	133	31	86	54	110	59	62	68
	12.0	52	110	26	56	45	32	54	35	54	123	24	110	52	122	30	138	34	105	47	118	45	63	62
	14	59	118	25	60	41	36	55	37	55	125	19	120	26	127	23	145	25	123	36	138	32	71	66
					72	43	51	51	43	43	129	20	125	33	136	19	169	26	129	42	141	39		
					74	38	72	58					126	31			171	26	129	39				
					79	35							127	39			196	22	133	34				
					81	34							128	29			205	27	138	36				
					88	35							128	39					145	28				
					93	37							129	27					170	32				
					93	34																		
$\bar{E}$ (in a.u)	15		45		35		21		18		52		40		54		57		35		25		12	
γ_{100} (%)	—		28		30		—		—		33		46		44		50		52		53		—	
$\gamma_{\min}$ (%)	—		24		35		—		—		20		32		21		22		30		36		—	

to frequency ν can be associated with each pulse. The dispersion of the spectrograph used was 12 Å/mm in the spectral range employed. The width of the spectrum photographed from the laser pulse was about 20 Å. The photometer used enabled us to divide this interval of 20 Å into about 20 parts, the halfwidth of each band being less than 1 Å, which also complies with the requirement of monochromaticity. Thus a series of the mean degree of coherence of a few "Fabry—Perot lines" of this narrow wavelength interval, ordered according to wavelength, could be coordinated to each pulse.

Results of measurements

Using the arrangement and method described, we determined the coherence spectra of the EMRF produced by our dye-laser in the axis of the laser beams. As active dye, different concentrations of rhodamine 6 G solved in ethanol were used, with 6% acetic acid added. Table I contains the coherence spectrum. The degrees of coherence pertaining to the same concentration expressed in per cents are arranged according to increasing wavelengths. With increasing concentration the mean wavelength of generation is shifted towards greater wavelengths [8]. This slight change is not shown in our table. With each degree of coherence also the energy of its band is given.

In Table II the sequences of the degrees of coherence are arranged according to the energy of the band. The three lowest lines of Table II give the total energy $\bar{E}$ measured with the photodetector, the degree of coherence γ_{100} pertaining to 100 units of band energy and γ_{min}, the minimum of the degree of coherence for the given concentration.

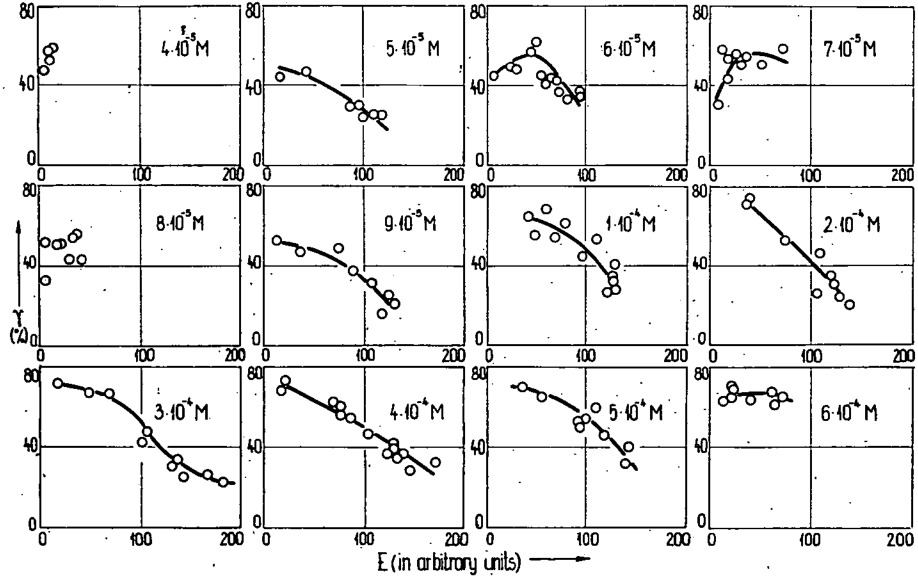

Fig. 4

Arranging the degrees of coherence for the same concentration according to the band energies, the curves shown in Fig. 4 are obtained. γ_{100} as a function of concentration is plotted in Fig. 5, whereas in Fig. 6 $\gamma_{\min}$ as a function of the total energy of the pulse is shown.

According to our measurements, the dependence of γ on the band energy E for a given concentration is described by a function steeply increasing in the range of small energies, then monotonously decreasing after a not too sharp maximum. The degrees of coherence of the decreasing sections pertaining to constant band

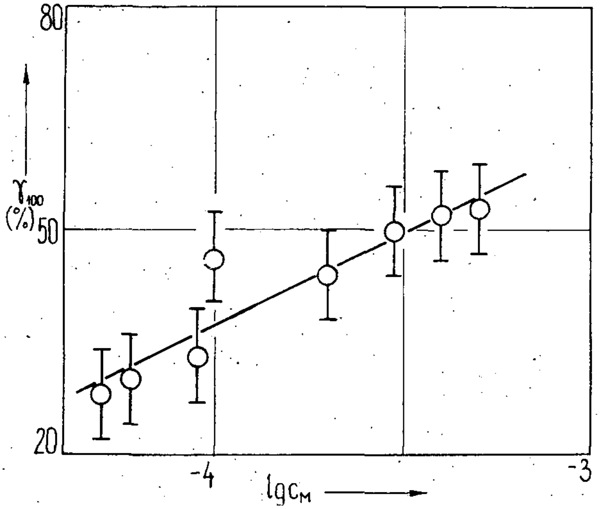

Fig. 5

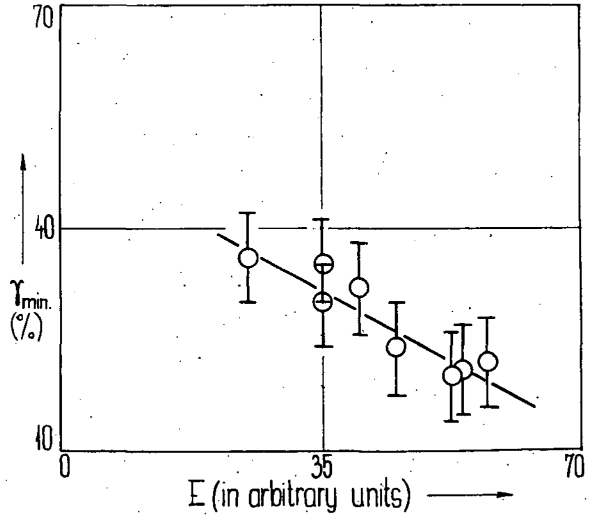

Fig. 6

energies show a monotonous increase as a function of concentration in the given concentration range. The minima of the degree of coherence of the same decreasing range decrease monotonously when plotted as a function of the total energy of the laser beam.

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О КОГЕРЕНТНОСТИ ПЕРВОГО РОДА ИЗЛУЧЕНИЯ ЛАЗЕРА НА КРАСИТЕЛЕ

Л. Визе, Ф. Пинтер и Л. Гати

Определена зависимость когерентности (пространственной) первого рода излучения импульсного лазера на красителе родамин 6Ж в этиловом спирте от энергии лазерного импульса, концентрации активного вещества и энергии отдельных линий (полос) в спектре излучения. Получено, что с возрастанием энергии импульса минимальная степень когерентности уменьшается, а с увеличением концентрации при неизменных энергиях полос возрастает. С ростом энергии полос степень когерентности сначала быстро увеличивается, а затем медленно уменьшается.