Leonov, Izv. vuzov Radiofizika 10, 145 (1967); A. P. Aleksandrov, V. N. Genkin, and V. A. Samylin, Nelineinaya optika (Nonlinear Optics), Novosibirsk, 1968.
[4] B. Honig, J. Jorther, and A. Szoke, J. Chem. Phys. 46, 2714 (1967).
[5] R. Meeke, W. Brunn, A. Chafik, and Z. Naturforsch. 19 A, 41 (1964).
[6] A. Bree and R. Kygg, J. Chem. Phys. 48, 5319 (1968).

NEW GENERATION AND SUPERRADIANCE LINES OF LEAD VAPOR

A. A. Isaev and G. G. Petrash
P. N. Lebedev Physics Institute, USSR Academy of Sciences
Submitted 16 July 1969
ZhETF Pis. Red. 10, No. 4, 188 - 192 (20 August 1969)

Pulsed generation or superradiance in transitions from a resonant to a metastable level is of great interest, for the maximum efficiency is quite high (up to 47%) for many transitions of this kind. Generation of this kind was obtained first with lead atoms [1], λ = 7229 Å, transition $7s\,^3P_1^0 \rightarrow 6p^2\,^1D_2$. A record gain of 600 dB/m was obtained with the same transition [2]. The lead atom (see Fig. 1) has several other transitions from resonant to metastable levels. The table lists their characteristics. It is known that the gain for the center of a Doppler-broadened line, neglecting the population of the lower level, is proportional to the product $\lambda^3 A_{ik}$. It is seen from the table that of all the three lines starting from the $^3P_1^0$ level, the largest gain should be possessed by the 4057 Å line, and the lines 3639 and 7229 Å have comparable gains. However, only the 7229 Å generation was observed experimentally [1 - 3]. Yet it would be of great interest to obtain generation on the other lines, since their wavelengths are shorter, they should have no less a gain, and their maximum efficiency is higher. It might be assumed that the absence of generation on these lines is connected not with the population of the lower levels, but with the insufficiently steep leading front of the current pulse. We recall that inversion is effectively produced only when the pump time is shorter than the lifetime of the upper level. In the case considered here, generation at 7229 Å occurred after capture of radiation of other transitions. We have

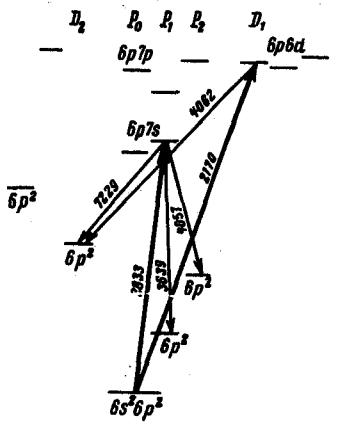

Fig. 1. Energy level scheme of lead atom.

λ, Å	Transition	f_{ik}	A_{ik}	τ_{ik}, nsec	$\lambda^3 A_{ik}$	$h\nu/E_u$	η_{max}, %
2833	$6p7s\,^3P_1^\circ \rightarrow 6p^2\,^3P_0$	0.21	0.57	18	pump		
4057	$6p7s\,^3P_1^\circ \rightarrow 6p^2\,^3P_2$	0.15	1.05	9	6.95	0.70	44
3639	$6p7s\,^3P_1^\circ \rightarrow 6p^2\,^3P_1$	0.06	0.32	31	1.52	0.78	39
7229	$6p7s\,^3P_1^\circ \rightarrow 6p^2\,^1D_2$	0.02	0.04	250	1.60	0.39	24
2170	$6p6d\,^3D_1^\circ \rightarrow 6p^2\,^3P_0$	0.39	1.84	5.5	pump		
4062	$6p6d\,^3D_1^\circ \rightarrow 6p^2\,^1D_2$	0.26	1.10	9	7.4	0.53	33
2613	$6p6d\,^3D_1^\circ \rightarrow 6p^2\,^3P_1$	0.02	0.19	53	0.33	0.83	42

Note:
f_{ik} - oscillator strength, A_{ik} - transition probability $\tau_{ik} = 1/A_{ik}$, E_u - energy of upper level, $h\nu$ - energy of working quantum, $\eta_{max} = (h\nu/E_u)(g_\ell/(g_\ell + g_u))$ - maximum efficiency of transition, g_ℓ and g_u - statistical weights of lower and upper levels. Data taken from [4], and for lines marked with an asterisk from [5].

therefore undertaken an experimental investigation of generation in lead vapor excited by-pulses with steep leading fronts.

The lead isotope Pb^{208} was placed in the central part of a tube of 2 mm diameter and 30 cm length, heated in an oven. Helium, neon, and argon were used as buffer gases. The discharge was excited with the aid of a cable pulse transformer (CPT) [6, 7]. The wavelengths were measured photographically with an STE-1 instrument having an estimated error ± 0.06 Å. Generation and superradiance were obtained on three new lines

$$4062{,}13 \pm 0{,}06\ \text{Å} \text{ transition } 6p\,6d\,^3D_1^\circ \rightarrow 6p^2\,^1D_2$$
$$4057{,}79 \pm 0{,}06\ \text{Å} \text{ transition } 6p\,7s\,^3P_1 \rightarrow 6p^2\,^3P_2$$
$$3639{,}54 \pm 0{,}06\ \text{Å} \text{ transition } 6p7s\,^3P_1^\circ \rightarrow 6p^2\,^3P_1$$

and on the already known 7229 Å line [1 - 3]. The generation and superradiance output powers for the different lines depended differently on the tube temperature and on the CPT voltage. With increasing temperature, starting with ∿ 800°C, the first to appear was superradiance at 4057 Å. At ∿ 850°C, superradiance appeared at 3639 Å, as well as generation and superradiance at 4062 Å. At the same time, only weak generations was observed at 7229 Å. With further increase of temperature, the generation and superradiance on all lines increased and at ∿ 900°C superradiance could be observed on all lines. A typical dependence of the peak power on various lines on the CPT voltage is shown in Figs. 2a and 2b for two temperatures. It is seen that generation at 4057 and 3639 Å appears at a higher voltage than at 7229 Å. With increasing temperature, the voltage at which superradiance appears at 4057 and 3639 Å becomes higher, and the power of the generation at 7229 Å ceases to depend on the voltage. The duration of the generation and superradiance pulses was measured with an FEU-36 photomultiplier and an S1-11 oscilloscope. It amounted to about 20 nsec at the base when the CPT voltage was 4 - 6 kV, and decreased rapidly with increasing voltage, to ∿ 10 nsec, and possibly even less, since the time resolution of the registration system is of the same order. The generation power peak at 7229 Å appeared somewhat later than at 4057 and 3639 Å. This delay increases with increasing voltage and decreases with increasing temperature. At 850°C and at CPT voltage 11 kV, it equals 8 nsec. Measurement of the current pulse with a Rogowski loop operating in the current-tranformer mode has shown that the current pulse has the form of a damped oscillation. The rise time of the first half-wave was about 10 nsec at 4 kV on the CPT, and decreased to several nanoseconds with increasing voltage. The current amplitude

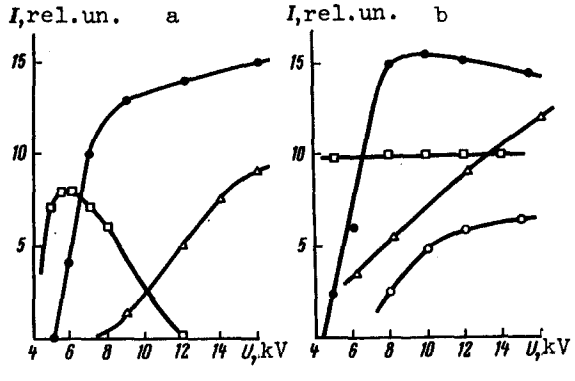

Fig. 2. Generation and superradiance spark power at different lines vs. CPT voltage: a - temperature 850°C, buffer-gas (helium) pressure 2 torr; b - 900°C and 2 torr. The points, triangles, circles, and squares represent the lines 4062, 4057, 3639, and 7229 Å.

increased approximately linearly with the CPT voltage.

The appreciable differences observed experimentally in the behavior of various lines show that the rise time of the excitation pulse, as expected, plays a decisive role in the creation of inversion in transitions in which the lifetime of the upper level is low. The fact that the 4057 Å line is the first to appear indicates that this line has the largest gain. On the other hand, the differences in the dependence of the output power of various lines on the voltage can be attributed to the increase of the slope of the leading front of the pulse with increasing voltage, and to competition of the transitions.

In conclusion we note that the obtained new generation lines can serve as a basis for developing pulsed lasers having good characteristics. The large limiting efficiency gives hope for reaching efficiencies on the order of several per cent in the visible and ultraviolet regions. The gain at these lines is very high, making it possible to develop systems with small dimensions. The possibility of going from one line to another by changing the current rise time or simply the voltage of the CPT is also of interest. All this makes a lead-vapor laser a good companion to lasers using copper [8] and thallium vapor [6]. Lead, however, has also certain advantages. It permits generation on several lines in different regions of the spectrum. There is a readily available even isotcpe having no hyperfine structure. On the other hand, it is possible to work with it at a lower temperature than in copper, a very important practical consideration.

[1] G. R. Fowles and W. T. Silfvast, Appl. Phys. Lett. 6, 236 (1965).
[2] W. T. Silfvast and J. S. Deech, Appl. Phys. Lett. 11, 97 (1967).
[3] J. S. Deech, J. B. Cole, and J. H. Sanders, J. Phys. B. Sec 2, 1, 147 (1969).
[4] N. P. Penkin and P. Yu. Yu. Slavenas, Opt. spektr. 15, 154 (1963).
[5] Ch. Corliss and W. Bozeman, Transition Probabilities and Oscillator Strengths of 70 elements (Russ. transl.), Mir, 1968.
[6] A. A. Isaev, P. I. Ishchenko, and G. G. Petrash, ZhETF Pis. Red. 6, 619 (1967) [JETP Lett. 6, 118 (1967)].
[7] A. A. Isaev and G. G. Betrash, ibid. 7, 204 (1968) [7, 156 (1968)].
[8] W. T. Walter, Bull. Am. Phys. Soc. 12, 90 (1967).

MIXED SURFACE STATE OF A SUPERCONDUCTOR OF THE FIRST KIND

I. L. Landau and Yu. V. Sharvin
Institute of Physics Problems, USSR Academy of Sciences

Submitted 18 July 1969
ZhETF Pis. Red. 10, 192 - 196 (20 August 1969)

In an analysis of various models of intermediate-state structures, L. D. Landau pointed out the possible occurrence, on the surface of a metal, of a thin layer in which the superconducting (s) and normal (n) state are so closely "intermixed," that a certain new state is produced, which he called "mixed." It is known that the proposed [1, 2] existence of a mixed state on the surface of samples placed in a constant magnetic field was not verified (see [3 - 5]).

There is, however, another possibility noted by Landau [6] for the occurrence of the mixed state, in the case when the destruction of the superconductivity is produced by a current flowing through the sample, while the magnetic field on the considered section of the surface remains lower than the critical field H_c. Such conditions arise, for example, in the