quency factor but it does assume that a first-order process is critically involved in the thermoluminescence. The log$I$ versus $1/T$ plots did not form completely straight lines when T and the related I values were taken from the beginning of the glow up to about one-half of the maximum and, indeed, it should not. In this case the peaks are probably not simple ones but are composed of more than one component. Peak resolution was achieved by "saw-tooth" annealing which is described by Ghormly and Levy.[21] Example of resolved peaks is given in Fig. 6 for an aged sample which was treated in exactly the same manner as the sample whose glow peaks are given by the dash curve in Fig. 3.

Our calculations were carried out by a method suggested by Urbach[22] and modified by Lushchik.[23] The activation energy, E, related to a glow peak is given as

$$E=kT_m^2/(T_2-T_m)\,. \qquad (3)$$

where k is the Boltzmann constant, T_m the absolute temperature of peak maximum, and T_2 the temperature at half the intensity on the fall off of the peak.

Use of Eq. (2) requires resolution of the leading edge of each glow peak from the interfering luminescence of preceding peaks. Equation (3) requires resolution of the fall-off edge from the interfering luminescence of succeeding peaks. Figures 2 through 5 indicate well-defined peaks where no further resolution was required. Trap energies calculated by Eqs. (2) and (3) are compared in Table II. The value of energies, when obtained from the Arrhenius plot, were lower (e.g., Table II; peak C, $E=0.72$ eV) for all peaks. Equation (3) gives an approximate "average" value of E for the three methods.

TABLE II. Activation energies calculated from Eq. 2 (E_2) and Eq. 3 (E_3): In each case the calculations result from average values taken from many glow curves. The dots signify that peak resolution was not good enough to be meaningful.

Sample	Peak	T_m (°K)	T_1 (°K)	T_2 (°K)	E_2 (eV)	E_3 (eV)
White sapphire	*A*	355	336	375	0.82	0.55
	B	419	400	435	1.15	0.95
	C	453	433	469	1.27	1.11
	D	500	480	517	1.56	1.20
	E	540	···	555	···	1.68
	F	573	···	···	···	···
Ruby	*A*	473	436	505	0.72	0.60
	B	503	474	532	1.07	0.75
	C	503	468	532	0.87	0.75

DISCUSSION

Additional work is needed before one tries to give a model for the observed effects. The luminescence results (glow curves) obtained in the present work show a complexity not resolved by many and repeated variations in the method of investigation and of the samples used. A measurement of the spectral distribution of the light for each peak can only help to establish a model to account for effects of γ irradiation and pressure. Also, two significant conclusions must be drawn from this and related work:

(1) In triboluminescence work, as well as in the high-pressure work reported here, it was determined that the application of pressure induces thermoluminescence peaks in some materials. Thus, the interpreted value of geological age-dating by measurements of radiation induced thermoluminescence from materials must take account of the past history for transient dynamic pressure changes on these materials.

(2) The heating of the ruby rod by a flash tube during laser[24,25] operation is a direct function of the average power in the system. Some preliminary investigations[26] show that either the heating of the rod caused by optical pumping while in laser configuration or simply the optical pumping itself anneals out the γ-induced traps responsible for the related glow curve at 473°K, Fig. 5. Thus, even though γ-damaged ruby may give rise to the visually observed broadening of near-field patterns and to laser action of higher efficiency at low pump energies, this effect would be gone after one pulse.

There is much similarity between the γ-ray-induced and pressure-induced glow peaks, Fig. 5. Perhaps faster pulse rates of reduced energy could be achieved on rods which are continuously subjected to changes in pressure (not yet known) that induces the glow peak at 503°K.

Mention should be made of some uncertainty as to whether, in ruby, changes in pressure induces triboluminescence,[27] metastable defects, or simply helps to fill existing defects. The absence of any glow peaks during the annealing cycle on "as-received" ruby, before and after exposure to the uv light, is suggestive of pressure-change-induced defects; however, further work is needed to prove this point.

Note added in proof. While this paper was in review, relative experimental data was published by W. Flowers and J. Jenney, Proc. IEEE, **51**, 858 (1963). Their data shows that the γ-ray damage is not annealed out of a rod after a single laser pulse, as we suggested, but that several pulses are required. We based our suggestion on a visual observation of the near-field pattern from a rod exposed at room temperature to pulses of nonfiltered light. Work done (by V. R. J., while the manuscript was in review) at liquid nitrogen temperatures and

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with pyrex tubing around the ruby rod indicates that Flowers and Jenney are, in fact, correct.

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