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# EXCITED-STATE ELECTRONIC SPECTRUM OF RUBY*

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Two new sharp absorption systems have been observed in the excited-state electronic spectrum of ruby. Both systems originate from the lowest spin doublet state of chromium ion $^2E$ and are found at 15 006 and 27 465 $cm^{-1}$ above the originating level. Both of the sharp systems are completely polarized perpendicular to the principal optic axis.

We have recently observed two new quite sharp electronic systems in the electronic spectrum of excited-state ruby (line half-width ~8 $cm^{-1}$). The spectra were observed in absorption after the flash excitation of a 1-cm cube of 0.05% ruby, polished parallel and perpendicular to the principal optic $c$ axis. The flash system discharged 800 J in 1 msec and was "crowbarred" after 0.85 msec, the background flash being fired 0.25 msec later to record the spectrum photographically on a 1.5-m Bausch and Lomb model No. 11 spectrograph. The spectra from 2300 to 3750 Å and from 3750 to 8000 Å were recorded consecutively in the second and first orders, respectively, where the reciprocal dispersion is approximately 7.5 and 15 Å $mm^{-1}$, respectively.

The spectra obtained are basically similar, consisting of pairs of lines separated by approximately 29 $cm^{-1}$. The experiments were carried out at 77°K and the $R_1$ and $R_2$ emission lines were observed simultaneously, $R_1$ being somewhat more intense than $R_2$ for $E$ perpendicular to $c$. The absorption spectra show pairs of lines separated by what is obviously the difference of the $R_2$, $R_1$ frequencies and the higher-frequency component is the stronger. Thus, there are relatively sharp absorption lines at 6662.0 and 6674.4 Å in the low-frequency system while there are lines at 3640.0 and 3643.8 Å in the high-frequency system. In addition, there is a progression of approximately 180 $cm^{-1}$ observable in the high-frequency system running to three, and possibly four, members. Using only the frequency of the highest-frequency component, i.e., that arising from the emitting level of the $R_1$ line, the two systems are to be found at 29 425 and 41 883 $cm^{-1}$ with respect to the ground state $^4A_2$; i.e., in the excited-state electronic spectrum they occur at 15 006 and 27 465 $cm^{-1}$, respectively, above the originating level of the $R_1$ emission line.

The ruby sample was optically pumped both parallel and perpendicular to the $c$ axis in separate experiments and the polarized components of the absorption were observed under both of these conditions in mutually perpendicular directions, suitably oriented with respect to the principal optic axis. Both sharp systems show complete polarization in the direction $E$ perpendicular to $c$ and, experimentally, there is no trace of sharp absorption bands polarized parallel to $c$. It is quite clear from the microdensitometer traces of the spectra that there is somewhat diffuse absorption to higher frequencies of these two sharp band systems; this is not well defined in the case of the low-frequency system, but is much stronger in the high-frequency one. With $E$ perpendicular to $c$ the high-frequency system finishes at about 30 000 $cm^{-1}$, whereas with $E$ parallel to $c$ it is undetectable higher than about 28 000 $cm^{-1}$. Using the photographic method, it is more difficult to detect diffuse absorption over large wavelength ranges than it is using photoelectric systems such as have been used by Ku-

shida[1] and by Moos, Opal, and Huang,[2] but, on the other hand, their methods are not very conducive to the detection of very fine absorption lines. These differences may explain the discrepancies between the present work and the work published by Kushida,[1] although Kushida's spectrum does show some small "kinks" at around 15 000 $cm^{-1}$ in the $E$ perpendicular to $c$ spectrum but very little similarity in the region of 27 500 $cm^{-1}$. The spectra of Huang and Moos[3] show a weak feature near 3600 Å. See Figs. 6 and 7 of that paper.

Based upon the polarization of the spectra, the clear connection between the lower common state of the two systems with the originating levels of the $R_1$ and $R_2$ lines, the fact that the origins consist of a simple pair of lines in each case, and, finally, the energies at which the two transitions occur, we assign the terminating level of the lower-frequency transition as $t_2^2(^1E)e\ ^2A_1$ and the originating level of the higher-frequency transition as $t_2^2(^1E)e\ ^2A_2$. The latter might, alternatively, possibly form the $E$ part of the $t_2^2(^1T_2)e\ ^2T_2$ level since there is some intensity polarized parallel to $c$ as would be expected from the $E \leftarrow E$ transition in this case ($C_{3v}$ notation).

More complete details of the apparatus and related studies will be published elsewhere.

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## COMPUTATIONS ON ANOMALOUS RESISTANCE*

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Results of computer simulations of electrostatic "anomalous resistivity" are reported. One- and two-dimensional plasma simulations were performed in which an external (nonself-consistent) spatially constant electric field was imposed to drive a current in the plasma. In these calculations the electron distribution is subject to collective runaway with beaming and thermal energy increasing about equally.

The data described here were produced by two different plasma simulation programs. The GALAXY programs, described in earlier papers,[1-3] perform two-dimensional plasma simulations on a square region with 64×64 cells. The one-dimensional simulations were performed using the finite-sized particle model in a program developed originally at Princeton[4,5] and adapted the Naval Research Laboratory for these calculations. The one-dimensional simulations extend the two-dimensional calculations to include cases having larger mass ratios, more particles, smaller driving fields, and systems containing more unstable modes, but they are less complete in the sense that they are one-dimensional. The earlier two-dimensional calculations indicate that with only a few modes in the system the motions tend to become one-dimensional with only waves parallel to $\vec{E}$ being strongly excited. This tendency toward alignment is a result requiring further investigation but suggests that one-dimensionality may not be a serious limitation.

Figure 1 shows results from a two-dimensional calculation in which the ion and electron masses are equal. Here 8192 ions and 8192 electrons are released on a doubly-periodic system. The initial velocity distributions are Maxwellian with zero relative drift. The electric field is quite strong, accelerating an electron by $0.14V_{te}$ in the plasma time $1/\omega_{pe}$. Figure 1(a) shows the evolution of system electrostatic energy and also the breakdown of this energy into the two most