RESONANCE ABSORPTION OF THE V^{3+} ION IN CORUNDUM AT 1.21 mm WAVELENGTH

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We report here an experimental investigation of resonance absorption of the V^{3+} ion in corundum at wavelength $\lambda \sim 1.21$ mm and at liquid-helium temperature in magnetic fields from 0 to 5 kOe. The observed absorption corresponded to transitions from the lower level corresponding to the singlet state $S_{z'} = 0$ to the levels of the higher doublet ($S_{z'} = \pm 1$). The presently available data on the splitting D between the singlet and the doublet in zero magnetic field were obtained from indirect experiments aimed at investigating magnetic susceptibility, electron paramagnetic resonance, and optical fluorescence spectra [1,3-6].

It is indicated in [2] and [3] that an initial splitting 2E of the $S_{z'} = \pm 1$ doublet may exist, in view of the appreciable intensity of the transition with $\Delta M = 2$ in parallel orientation in an external magnetic field. This effect is obviously connected with the presence of an electric field component of low symmetry in the corundum crystal with V^{3+}. A quantitative estimate of 2E was given in [3], $|E| < 10^{-2}$ cm^{-1} [1], but no direct measurements were made so far. To investigate the resonance absorption of V^{3+} in corundum ($\lambda \sim 1.21$ mm) we used a quasioptical feed-through spectroscope without cavity, which was constructed by us. The radiation source was a backward-wave tube [7] generating an average of ~3 mW in the range from 0.83 to 1.35 mm. The microwave power was fed quasi-optically to a sample placed in a helium cryostat via teflon windows in the cover. The sample in the form of a rod ~15 mm in diameter and 150 mm long had a V^{3+} concentration ~0.1%. The optic axis of the crystal was in a plane perpendicular to the radiation propagation direction. Two InSb receiving crystals were installed in the cryostat in front of and behind the sample. The radiation striking the second InSb crystal was focused with a teflon lens. The helium cryostat could be placed between the poles of an electromagnet.

Two series of measurements were made. In the first, the absorption line was investigated in different constant magnetic fields, including zero field, with the microwave-oscillator frequency continuously variable. In a zero field, two closely-spaced absorption lines were observed, corresponding to transitions from the lower singlet level of the V^{3+} ion to the levels of the doublet $S_{z'} = \pm 1$. Figure 1 shows the transmission T of the investigated sample vs. frequency in zero magnetic field, calculated from the data obtained from both receiving crystals. The total error was of the order of 30%.

We determined the frequencies of the transitions from the lower level to each of the doublet levels, $D_1 = (247.3 \pm 0.3)$ and $D_2 = (248.9 \pm 0.3)$ GHz, and also the initial splitting of the doublet, $2E = (1.6 \pm 0.6)$ GHz. In addition, we calculated the coefficient of resonance absorption of V^{3+} in corundum, $\alpha \geq 0.3$ cm^{-1}.

The second series of measurements was made at a number of fixed frequencies with the magnetic field varied from 0 to 5 kOe.

The absorption line observed in this case consisted of eight hfs components (nuclear spin I = 7/2). The frequency dependence of the first and last of these components on the

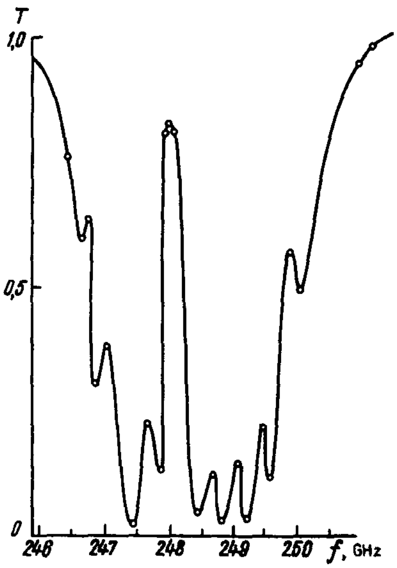

Fig. 1. Resonance absorption line of V^{3+} in corundum in a zero magnetic field.

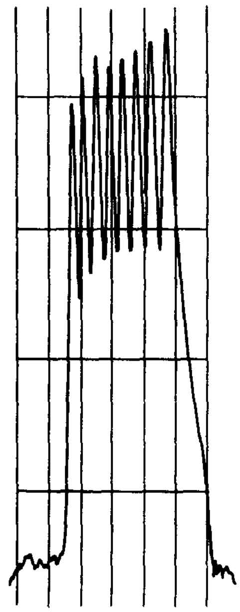

Fig. 2. Absorption line of V^{3+} in corundum in an external magnetic field.

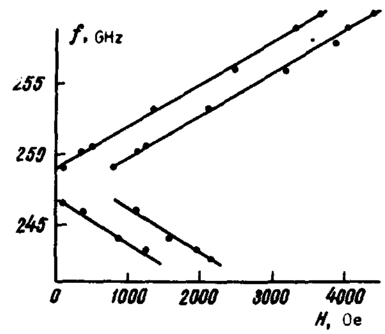

Fig. 3. Frequency of the two outermost hfs components of the absorption line vs. magnetic field.

external magnetic field is shown in Fig. 3. The splitting between the singlet and the doublet, determined from Fig. 3 and equal to 247.8 GHz, coincides within the limits of experimental error with $D = (D_1 + D_2)/2$, determined in the first measurement series, and with the results of [6], where $D = 8.29 \pm 0.02$ cm^{-1}. When the external magnetic field tends to zero, the distance between the outermost components yields the upper limit of the initial doublet splitting, $2E \leq 2.1$ GHz.

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