trons in the immediate vicinity of the Fermi surface.

The appearance of superconductivity in GaN can hardly be due only to the electron density extremum; in this case additional data should perhaps be used. Thus Samsonov and Neshpor[8,9] noted a correlation between the superconducting transition points and the nature of the electron-density distribution in the crystal lattices of metal-like compounds of transition metals with non-metals such as boron, carbon, nitrogen, and silicon. This correlation appears as an increase of the transition temperatures of metal-like compounds having approximately the same crystal structure with increase of the asymmetry of the electron-density distribution in the lattice. This correlation is also supported by a reduction of the transition temperatures on increase of the relative content of the transition metal, i.e., in those cases where the role of the Me–Me bonds increases and the role of the Me–X bonds decreases (here Me is a metal and X is a metalloid).

Using these data for compounds of non-transition metals with non-metals we may postulate that these compounds can have high values of T_c due to the weaker Me–Me bonds compared with the transition metals. However, this is possible only when the proportion of covalent X-X bonds, which lower the conduction electron density, is not too high.

The superconductivity of the compound GaN is apparently the first case to be reported of superconductivity in nitrides of non-transition metals. As mentioned above, in contrast to transition-metal nitrides wihich have broad regions of homogeneity and consequently composition-dependent T_c, gallium nitride has no region of homogeneity and consequently its transition to superconductivity is sharp and there is one T_c for different samples of stoichiometric composition.

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THE GENERATION OF MILLIMETER WAVES IN RUBY BY OPTICAL PUMPING

G. M. ZVEREV, A. M. PROKHOROV, and A. K. SHEVCHENKO

Nuclear Physics Institute, Moscow State University

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USUALLY the frequency of the auxiliary radiation for a quantum paramagnetic amplifier and generator (Q.P.A. and Q.P.G.) must be higher than the amplified or generated frequency. For making a Q.P.A. and Q.P.G. in the submillimeter range, the most realistic prospect in practice is to use auxiliary radiation in the optical range.

Recently, Devor et al.[1] used the radiation from a pulsed ruby laser to excite a Q.P.A. that worked at a temperature of 4.2°K and a wavelength of 1.34 cm, with ruby as the working substance.

We have carried out experiments on the generation of millimeter wavelength radiation, in the range $(35-50) \times 10^9$ cps, by ruby cooled to liquid nitrogen temperature. A ruby laser, also operated at T = 77°K, served as the pump. In Fig. 1b is shown the energy level scheme for a ruby crystal in an external magnetic field in the orientation we used—the c-axis perpendicular to **H** ($\theta = 90°$). Figure 1a shows the energy level scheme for ruby in zero magnetic field (laser). The laser radiation component associated with the transition $\bar{E} \rightarrow {}^4A_2(\pm 1/2)$ induces transitions of ions from level 3 to levels 5 and 6 (Fig. 1c). It should be borne in mind that the line width of the optical transition $\bar{E} \rightarrow {}^4A_2$ at liquid nitrogen temperature is 0.3—1 cm^{-1}, depending on the quality of the crystals used, and accurate matching of the transition frequencies is not required of the pump.

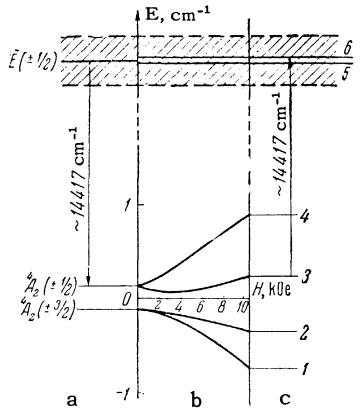

FIG. 1. The energy level scheme of the Cr^{3+} ion in ruby: a – zero magnetic field; b – magnetic field increases from left to right; c – energy levels for a magnetic field strength of 10,500 Oe. The shaded band corresponds approximately to the width of optical transition lines.

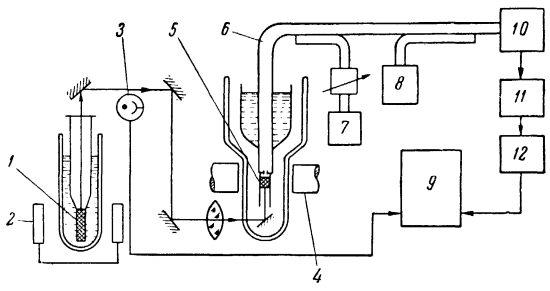

FIG. 2. Schematic diagram of the experimental arrangement: 1 – ruby crystal in laser; 2 – flash tube; 3 – photomultiplier; 4 – magnet; 5 – ruby crystal – Q.P.G. resonator; 6 – wave guide system; 7, 8 – klystrons; 9 – pulse oscilloscope; 10 – mixer; 11 – intermediate frequency amplifier; 12 – detector.

The experimental arrangement is schematically shown in Fig. 2. The radiation from a ruby crystal immersed in liquid nitrogen passed through a system of mirrors and a lens, and fell on another ruby crystal (cross section 2 × 2 mm). This crystal situated in a cutoff waveguide served as a resonator in the millimeter region. The crystal was cooled by liquid nitrogen through a thermal conductor. The laser radiation fell on the crystal through the open end of the cutoff waveguide. The high-frequency section of the apparatus consisted of a superheterodyne radio-spectrometer of the reflection type, with the aid of which the required value of magnetic field was set and the Q.P.G. radiation recorded. The pulse of laser radiation and the pulse of generated microwave power were observed simultaneously on the screen of a pulse oscilloscope. In Fig. 3 is shown one of the oscilloscope traces obtained with a laser radiation energy of ~ 0.1 joule. The microwave radiation appears in "spikes," as is frequently observed for a paramagnetic generator with normal radio-frequency pumping. The frequency of the spikes increased when the energy of the laser pulse was increased. The power of the radiation in the millimeter range was $\sim 10^{-5}$ W.

The principal features of the operation of a Q.P.A. with optical pumping can be obtained from an analysis of the kinetic equations for a system of three energy levels, taking into account the large energy interval between the two lower levels (E_1 and E_2) and the third upper level.

Let N_1, N_2, N_3 be the populations of the three levels, W be the transition probability under the influence of the laser radiation field, w_{31} and w_{32} be the probabilities of spontaneous transitions into the lower level, w_{12} and w_{21} be the probabilities of relaxation transitions between the lower levels. Then

$$\begin{aligned} dN_1/dt &= (-N_1 + N_3)W - N_1 w_{12} + N_2 w_{21} + N_3 w_{31}, \\ dN_2/dt &= N_1 w_{12} - N_2 w_{21} + N_3 w_{32}, \\ dN_3/dt &= (N_1 - N_3)W - N_3 (w_{31} + w_{32}). \end{aligned} \qquad (1)$$

From these equations we can find the difference between the populations under steady state conditions. Putting

$$w_{32} = w_{31} = w_3, \qquad h\nu/kT \ll 1, \qquad w_{21} = w_{12}(1 + h\nu/kT),$$

we have

$$\Delta N = N_2 - N_1 = \frac{w_3/w_{12} - h\nu/kT - 2w_3 h\nu/WkT}{3 + 4w_3/W + w_3/w_{12}} N, \qquad (2)$$

where N is the total number of particles. By substituting in (2) the known probabilities of relaxation

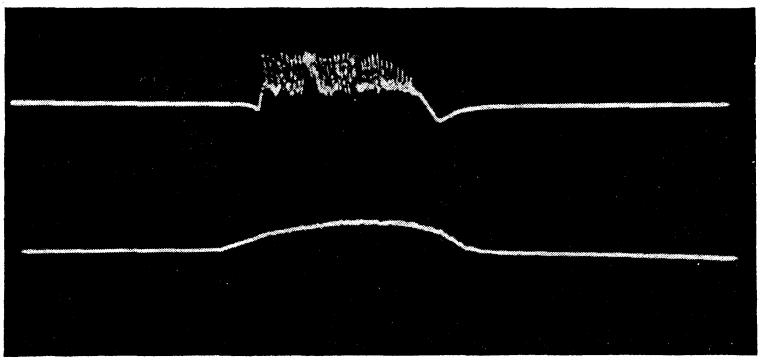

FIG. 3. Pulse of millimeter wave radiation (above), and of laser radiation (below). Sweep duration 500 μsec.

transitions in ruby at T = 77°K (the spin-lattice relaxation time τ_1 = 50 μsec, the lifetime of the level $\bar{E}$ is ~ 5 msec), we can show that it is impossible to obtain a steady-state negative temperature between the levels E_1 and E_2. The negative temperature observed in our experiments, and the generation associated with it, are caused by nonstationary processes. Calculations show that generation cannot proceed for longer than 2—3 τ_1.

In the ideal case, if the spin-lattice relaxation process is neglected, it is possible to find the maximum energy that our three level system is able to radiate: it is $Nh\nu/6$. For our specimen with a chromium ion concentration of ~ 0.05%, this energy is ~ 2.5 erg. Since generation lasts ~ 150 μsec, the maximum radiation power should not exceed 1.7 mW. The generated power observed in the experiment indicates the large role of relaxation processes.

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COEXISTENCE OF ANTIFERROMAGNETIC AND SPECIAL DIELECTRIC PROPERTIES IN THE $BiFeO_3$—$LaFeO_3$ SYSTEM

Yu. E. ROGINSKAYA, Yu. N. VENEVTSEV, and G. S. ZHDANOV

L. Ya. Karpov Physico-chemical Institute

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THE compound $BiFeO_3$ is ferroelectric with a Curie temperature T_C ~ 850°C and antiferromagnetic with type G magnetic structure and Neel point T_N ~ 380°C.[1-4] The attention of a number of investigators[5,6] has been turned recently toward a new class of substances combining ferroelectric and special magnetic properties and thereby having great scientific and practical interest. Complex investigations (x-ray, dielectric, and magnetic) of binary systems of compounds which to some degree or other combine special dielectric and magnetic properties are of great value for a thorough study of these phenomena.

The present paper describes results of such an investigation of the system $BiFeO_3$—$LaFeO_3$, in which $BiFeO_3$ is a ferroelectric antiferromagnet, and $LaFeO_3$ is antiferromagnetic with weak ferromagnetism.[7] The usual ceramic techniques were used to synthesize the samples. X-ray analysis of the samples at room temperature showed that a complete series of solid solutions with the perovskite structure is formed over the entire concentration range. These solid solutions exist in four modifications, depending on the $LaFeO_3$ content (in mole percent): up to 18.8—rhombohedral; from 18.8 to 55—pseudomonoclinic I (PMI); from 55 to 73—pseudomonoclinic II (PMII); above 73—pseudomonoclinic III (PMIII).

The magnetic measurements were carried out by the Faraday method from room temperature to 500°C in fields up to 8 kOe. The samples of all compositions demonstrated unusual magnetic properties.

Figure 1 shows the temperature dependence of the magnetization σ(t) for different samples of the system in a field of 7600 Oe. Similar results for the magnetic susceptibility of $BiFeO_3$ as a function of temperature have been obtained by Smolenskiĭ et al.[8]

In Fig. 2, besides the lines of the phase transition in this system (of which more will be said below), is presented the dependence of the room-temperature spontaneous magnetization σ_0 on the composition of the samples.

The presence of spontaneous magnetization in the compositions with 12.5, 15, and 17.5% $LaFeO_3$, as well as in all investigated samples in the three pseudomonoclinic regions and the similarity between the magnetization vs. temperature curves for these compositions and the like curves for the weak ferromagnet $LaFeO_3$, is evidence that all these samples are also antiferromagnets with weak ferromagnetism.

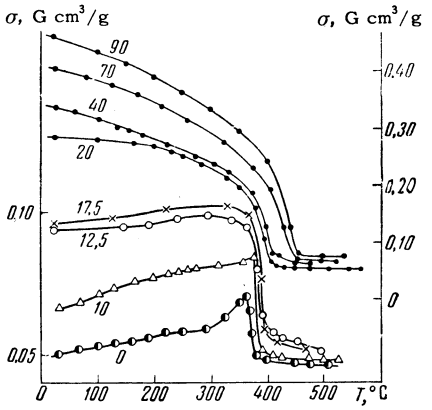

FIG. 1. Temperature dependence of the specific magnetization of samples of the system $BiFeO_3$-$LaFeO_3$ in a field of 7600 Oe. The numbers on the curves indicate the $LaFeO_3$ content in mole %. The scale on the right is for compositions containing 20, 40, 70, and 90 mole % $LaFeO_3$.