Thus when the mass is included in the equations, it is found to have gravitational properties, from considerations of special relativity (energy considerations).

We note that one of the cross sections here obtained (that for photon scattering) was previously obtained by Pijr,[3] who clearly showed the analogy of this effect to the corresponding classical effect. Since, as we have seen, the scattering cross section of a particle with zero rest mass by a Schwarzschild field is

$$d\sigma_0 = (k^4 M^2 / 8\pi) \, | d\theta / \theta^3 | ,$$

then, inserting the angle $\theta = k^2M/4\pi R$ (the angle through which light rays are bent according to the classical theory), we have $d\sigma_0 = 2\pi R dR$, which is the classical expression for the cross section for scattering by a sphere of radius R.

In conclusion I thank D. D. Ivanenko and M. M. Mirianashvili for their interest in the work.

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Translated by E. J. Saletan
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MOLECULAR AMPLIFIER AND GENERATOR FOR SUBMILLIMETER WAVES

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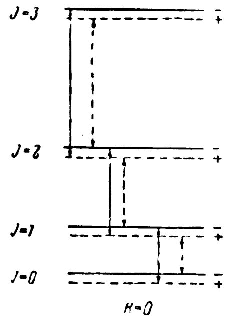
Submitted to JETP editor April 1, 1958

J. Exptl. Theoret. Phys. (U.S.S.R.) **34**, 1658-1659 (June, 1958)

IN the present paper we consider the possibility of constructing a molecular amplifier and generator (MAG), for waves shorter than 1 mm, using ammonia molecules. The rotational transitions of the NH_3 molecules lie in the wavelength region below 1 mm. These transitions can be used to



The rotational spectrum of NH_3 for J = 3, 2, 1, and 0, and for K = 0.

construct the MAG. The rotational transitions are sorted out at the same time as the inversion levels, viz.: molecules in the lower inversion level are sorted out by passing the molecular beam through a quadrupole condenser. The system of rotational-inversion levels after sorting is given in the figure for J = 3, 2, 1, and 0 and for K = 0. Levels which are not occupied by molecules are shown by dotted lines. The solid arrows show transitions increasing the energy of the incident radiation; dotted arrows show those absorbing energy.

An amplifier can be constructed using a device in which the radiation coming from one horn crosses a number of molecular beams and falls on a second horn. If the average density of the number of active molecules is equal to N, the coefficient of negative absorption is determined by the equation

$$\alpha = 8\pi^2\nu \, | \mu_{mn} |^2 N / hc\Delta\nu, \qquad (1)$$

where ν is the frequency of the transition, μ_{mn} the dipole-moment matrix element, $\Delta\nu$ the line width, h Planck's constant, and c the velocity of light.

If the power of the radiation leaving horn 1 is equal to P_0, the power after passing a path l and entering horn 2 rises to $P_k = P_0 e^{\alpha l}$. Let $\nu = 6 \times 10^{11}$ cps ($\lambda = 0.5$ mm), $|\mu_{mn}|^2 = 2 \times 10^{-36}$, $\Delta\nu = 5 \times 10^3$ cps, and $N = 10^{10} \text{cm}^{-3}$. Then $\alpha = 1 \text{ cm}^{-1}$. If $l = 10$ cm, $P_k/P_0 = 2.2 \times 10^4$. The maximum power which such a beam can produce is about one microwatt. To construct a molecular generator one can use two plane-parallel mirrors as the resonator. If the distance between the mirrors is l, the reflection coefficient of the mirrors is k, and we assume that energy losses of the plane waves occur only upon reflection from the mirrors, the Q-factor of such a system is equal to

$$Q = (2\pi l / \lambda) / (1 - k). \qquad (2)$$

If $l = 1$ cm, $\lambda = 0.05$ cm, k = 0.95, then Q = 2400. However, energy losses occur also because the wave is not plane but has an angular spread $2\theta \approx \lambda/D$, where D is the linear dimension of the mirror. Because of this effect, the energy P_n after n reflections will be

$$P_n = P_0/(1 + nl\lambda/D^2)^2. \quad (3)$$

The quantity nl is the path traversed by the wave during the n reflections. This time is equal to $\tau = nl/c$.

If we know the Q-factor of the system, the time in which the power decreases by a factor e is equal to $\tau = Q/2\pi\nu$. During this time the wave traverses a path $nl = c\tau$; if $Q = 2400$, and $\nu = 6 \times 10^{11}$ cps, $nl = 21$ cm.

If D = 3 cm, we get from (3) $P_n = 0.8P_0$, i.e., in our case the losses during reflection play the dominant part.

The condition for self-excitation can be written in the form

$$ke^{\alpha l} > 1. \quad (4)$$

If $\alpha = 1\ \mathrm{cm}^{-1}$, $l = 1$ cm, k = 0.95, condition (4) is satisfied by a wide margin. If $e^{\alpha l} \gg 1$, self-excitation occurs for small k.

Translated by D. ter Haar
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A CHROMIUM CORUNDUM PARAMAGNETIC AMPLIFIER AND GENERATOR

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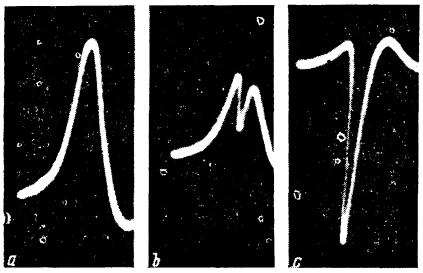
Submitted to JETP editor April 1, 1958

J. Exptl. Theoret. Phys. (U.S.S.R.) **34**, 1660-1661 (June, 1958)

In reference 1 it was proposed to use a molecular system possessing three energy levels for the construction of molecular amplifiers and generators. Later this problem was considered in more detail as applied to paramagnetic crystals.[2] There are reports about the construction of three-level paramagnetic amplifiers using a single crystal of gadolinium ethylsulphate[3] and a single crystal of chromium cyanide.[4,5] We have investigated the possibility of constructing a paramagnetic amplifier and generator using a single crystal of chromium corundum ($Al_2O_3 \cdot Cr_2O_3$). The spectrum of Cr^{3+} in corundum was investigated in a number of papers.[6-9] The Cr^{3+} ion in corundum is in an axial electrical field which splits the spin quadruplet of the lower orbital singlet level into two doublets, the distance between which is equal to $2D = -0.3824\ \mathrm{cm}^{-1}$. The spin-lattice relaxation time of Cr^{3+}, even at liquid nitrogen temperatures, is sufficiently long,[10] $\sim 10^{-4}$ sec.



Photograph of the $M = 3/2 \rightarrow 1/2$ absorption line at 3000 Mcs for different power levels of the auxiliary radiation P_{aux}. Fig. 1a corresponds to $P_{aux} = 0$. Fig. 1c corresponds to a value of P_{aux} for which saturation is reached. Fig. 1b corresponds to an intermediate case.

For a paramagnetic amplifier, we have used the levels that are characterized by the quantum numbers $M = 3/2, \pm 1/2$ when the crystalline axis is oriented parallel to the constant external magnetic field. If the axis of the crystal is turned, the states mix and transitions between all three levels become allowed. The levels $M = -1/2, 1/2$ were used for amplification, and the auxiliary radiation excited transitions between the levels $M = 1/2, -3/2$. The frequency at which emission (or generation) occurred was ~ 3000 Mcs and the frequency of the auxiliary radiation ~ 15000 Mcs.

In the figure we show photographs of the line corresponding to the $-1/2 \longleftrightarrow +1/2$ transition at a frequency of 3000 Mcs, as a function of the power level of the auxiliary radiation. It is clear from the photographs how the absorption line (1a) goes over into an emission line (1c) when the power of the auxiliary radiation is increased. At $T \sim 2°$K, the system became self-excited and acted as a generator.

Detailed data on the operation of the constructed amplifier will be published later.

The authors express their gratitude to Professor A. I. Shal'nikov for his assistance with the performance of the experiments at low temperatures.

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