reference 2 but evaluated more accurately. There are two unknown parameters in the theory: a multiplicative constant which is determined by the requirement that T_1 be continuous at the critical temperature, and a parameter $r = \epsilon_0(0)/\Delta$, where $\epsilon_0(0)$ is the half gap width of BCS at 0°K ($3.5kT_c$) and Δ can be regarded as the half-width of the electronic energy levels. In reference 2, Δ is introduced into the theory by smearing or folding the BCS density of states function with a square function of width 2Δ and height $(2\Delta)^{-1}$. Δ can be interpreted either as an uncertainty width due to electron scattering mechanisms not accounted for in the BCS theory, or as a smearing of the BCS density of states due to anisotropy of the energy gap.[7]

The "uncorrected" curve in Fig. 1 is that calculated by Hebel directly from the BCS theory for $r = 15$; for other values of r the curve is nearly parallel to this one for $T_c/T > 1.5$. The "corrected" curves are calculated using the energy gap found experimentally by Biondi and Garfunkel from microwave measurements[8] [i.e., $\epsilon_0(T)$ proportional to, but 7.5 % smaller than, the BCS prediction]. According to Hebel,[6] the calculation of T_{1S} can be corrected for an energy gap different from the BCS prediction if the form of the BCS wave functions is correct, and only their energies are assumed to be incorrect. In that case $T_{1S}T$ is a function of $\epsilon_0(T)/kT$ alone.

Agreement with theory is excellent assuming $r = 15$ [$\Delta = \epsilon_0(0)/15$]. This agreement is in contrast with the Knight-shift observations of Reif and of Androes and Knight.[9] Our measurements are made on particles large compared to the coherence length (10^{-3} cm). The parameter Δ is nearly temperature independent, consistent with the idea that it represents either the inverse electronic lifetime against boundary scattering, or more likely anisotropy of the energy gap.[7] It is probable that if Δ represented phonon scattering, it would be strongly temperature dependent, contrary to observation.

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OPTICAL MASER DESIGN

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Schawlow and Townes[1] have discussed the possibility of operating a maser in the infrared or visible wavelength region. They point out that the difficulty of maintaining an adequate population excess in the upper of the two levels between which maser action takes place increases rapidly with the operating frequency because of the large rate of spontaneous emission. They envisage only the use of photon excitation for populating the appropriate level in the working medium.

In observing the resonance absorption of a spectral line, there exists the well-known difficulty of obtaining a large amount of light from a source without broadening the line to the point where only a fraction of the total is absorbed. In view of this, it appears difficult to employ efficiently optical excitation of a maser working in the visible region. The use of electron impact excitation of the working medium would reduce the practical difficulty of obtaining a sufficient density of excited atoms, and the use of a discharge in the medium itself is suggested. In a medium containing a single gas or vapor, the possibility of obtaining the required excess population in the upper of two levels exists in cases where there is a favorable lifetime ratio, i.e., a long-lived upper state and a short-lived lower state. As an example of this, the 6678A line in helium I is due to a transition between the $3\,^1D_2$ state, mean life 1.5×10^{-8} sec, and the $2\,^1P_1$ state, mean life 4.3×10^{-10} sec. Many processes exist in a discharge which may disturb the relative population of such levels from the value implied by these lifetime values, and it may be possible to choose conditions which maintain a high population in the upper state.

Detection of the onset of continuous oscillation in the optical maser working in the visible region would be particularly simple. The Fabry-Perot étalon, used as the "cavity" of the maser, gives a concentric fringe system at infinity when the light source is placed between the plates, similar to the conventional case when the étalon is used by transmission. Using highly reflecting plates, of which only one need transmit a small percentage of the light, and a spacing of several centimeters, the width of the observed rings would normally be larger than the instrumental width. If maser oscillation were taking place, due to the presence of an adequate excess population in an upper level in the medium between the plates, the light due to this process would have an extremely small frequency width, and lines of the instrumental width would appear superimposed on the broader lines due to spontaneous emission. To confine oscillation to only one order, or mode, the aperture of the étalon could be restricted to reduce the number of effective beams in those orders in which the light is not normal to the plates. The order in which maser oscillation would be most likely to occur would then be the central, or normal, order.

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POSSIBILITY OF PRODUCTION OF NEGATIVE TEMPERATURE IN GAS DISCHARGES

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In a recent paper[1] Schawlow and Townes have discussed a possibility for obtaining maser action in the optical region. In their proposed scheme, negative temperature is obtained by optical pumping. One may expect also that under favorable conditions the excitation of atomic levels by electrons in a discharge can lead, in principle, to a state of negative temperature. However, severe restrictions exist if densities of the excited atoms as large as those needed for maser action are required. The present Letter considers briefly these limitations and certain types of systems which appear to be most favorable for practical application of this proposal. Pure gases behave quite differently than certain kinds of gas mixtures. First let us consider the former case.

For the purposes of rough estimates of various discharge conditions as described below, let us make a simplifying assumption that the main source of population of an excited state is due to collisions of the first kind between the electrons and atoms in the ground state leading directly to the excited level under consideration. It can be shown that, at least in cases discussed below, other details such as cascade processes and collision of electrons with other excited atoms do not appreciably effect our order-of-magnitude estimates.

In the following, the indices 0, 1, and 2 refer to the ground, the lower, and the upper states of the maser levels, respectively. If $1/\theta_{0i}$ is the rate of excitation of the ith excited state by electron impact with the atoms in the ground state and $1/\theta_{i0}$ is the rate for the reverse process, for a Maxwellian distribution of electrons at a temperature T_e, the relationship

$$\theta_{0i}/\theta_{i0} = \exp(E_i/kT_e)$$