Extremely bright astrophysical objects excited by THz radiation: do they operate in a maser regime?

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Abstract - **The general conditions of brightness and radiation temperature increasing are discussed. It is shown that such an increase is possible in non-inverted medium, and perhaps actually takes place for some extremely bright astrophysical sources excited by THz radiation.**

I. Introduction And Background

A lot of astrophysical THz sources with anomalously high brightness have been discovered in space and considered as masers. However, the maser model of these sources faces certain unsolved questions. The most difficult for explanation feature is a rather rarely mentioned correlation of line width and brightness temperature, which is typical for almost all laboratory lasers and is absent for non-laser sources**.** To ascertain whether the stimulated emission of radiation takes place or not, the critical importance pertains character of correlation between linewidth and the radiation power density or the brightness. Such correlation is not observed mostly for the astrophysical masers. Besides, the large quantity of the maser-type sources in space is amazing for whereas its reception in laboratory demands essential efforts of an experimenter.

It is shown here that the effect of stimulated emission is not the only optical process providing the extremely high brightness and temperature of the millimeter and centimeter radiation at least for some of the non-thermal astrophysical objects. The general conditions of increase of brightness of radiation in absence of inverse density of population are given also.

II. Results

In the absence of inverted population, the necessary conditions for the brightness increase are the irreversibility of the optical process and the impossibility to describe it in the framework of the ray approximation[1]. An increase in the brightness and the temperature of radiation without the stimulated emission is possible for instance due to luminescence under the excitation by radiation, because this kind of inelastic scattering is irreversible, and the ray approximation is invalid for its description since the propagation direction of the output radiation is not related to the propagation direction of the incident radiation.

To take into account the complicated way in which the output radiation is excited and its finite frequency band, we obtain the expression for the estimation of the brightness of the radiation at the exit of an extended gas medium:

$$B_{out} = \frac{\sum B_i \Delta n_i \eta_i \lambda_i^3 A_i}{\Delta n_{out} \lambda_{out}^3 A_{out}} .$$

Here B_i is the brightness of the incident radiation at the wavelength λ_i, A_i and A_{out} are the Einstein spontaneous transition coefficients, Δn_i and Δn_{out} are the population differences for the corresponding bands. In the Rayleigh-Jeans limit for output radiation, the radiation temperature to be expressed in a simple way through the brightness:

$$T_{out} = \frac{c^2}{2\nu_{out}^2 k} B_{out} .$$

The last equations enable to estimate how much are the maximum brightness and the maximum brightness temperature which can take place without stimulated emission for local sources in interstellar gas nebulae[1]. As for example this can be done for bright hydroxyl sources in nebulae W3(OH), W51, W49 (the transition $^2\Pi_{3/2} J = \frac{3}{2} 2^+ \rightarrow {}^2\Pi_{3/2} J = \frac{3}{2} 2^-$).

Einstein A-coefficients for the hydroxyl molecule are well-known, also the values of incident radiation brightness B_{in} $\approx 3 \cdot 10^{-14}$ $W \cdot m^{-2} \cdot Hz^{-1} \cdot sr^{-1}$ in the THz range are measured for these nebulae[2-4], and substitution of the numerical values to the last equation reveals that the T_{out} is of order of $6 \cdot 10^{10}$K at the maximum of the luminescence line – practically, this coincides with the results of direct observation.

Conditions of the THz excitation influence on the features of extremely bright astrophysical objects emission are discussed.

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