SUPERRADIANCE AT A WAVELENGTH OF 535 nm 
IN A MIXTURE OF CALCIUM AND THALLIUM VAPORS

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Abstract

The results of the first experiments in which the superradiance in Tl vapors on the transition with green wavelength 5350 Å (a resonance transition 3D2 - 4F5 in calcium) are presented. The dependence of pulse peak intensity on thallium vapor density is investigated. A computer simulation is performed showing the possibility of a substantial decrease in duration of superradiance pulses in a mixture of thallium and calcium vapors.

1. Introduction

Superradiance (SR) is the process of cooperative spontaneous decay of multiatomic systems. This phenomenon is extensively studied both theoretically and experimentally [1, 2]. Experiments on superradiance were performed for alkali metal vapors (Na, Cs, Tl, etc.), color centers in KCl crystals, and vibrational and rotational transitions of molecules. A typical duration of SR pulses ranges from units to tens of nanoseconds for metal vapors and molecular transitions and from tens to hundreds of picoseconds for crystals and high-density gases. In the majority of experiments, SR transitions were pumped with laser radiation. One of the main factors impeding further advance in the domain of picosecond and subpicosecond pulses is the finite pump pulse duration. The SR pulse duration decreases with increasing pump intensity, but when it approaches the pump pulse duration, shortening of the SR decay signal ceases and its duration is determined by the pump pulse duration. As shown in [3, 4], the effect of pump duration on the SR pulse duration can be obviated by using two-component media representing a mixture of two species of atoms with identical or close transition frequencies and different transition dipole moments.

In this paper, we consider a scheme for the experimental realization of two-component SR in a mixture of thallium and calcium atoms and analyze the possibilities of its optimization from the viewpoint of obtaining pulses of the shortest duration and the highest intensity. Moreover, we discuss the results of the first experiments in which the SR in Tl vapors on the transition with wavelength 5350 Å, which is in resonance with the calcium transition, was observed. A computer simulation of SR on this transition is performed, and its results are in qualitative agreement with the experimental results.

2. Two-Component SR in a Mixture of Tl and Ca Vapors

Two-component SR is the process of cooperative decay of a polyatomic system containing atoms of two kinds with identical frequencies \( \omega_a = \omega_b \) and different transition dipole moments \( d_a < d_b \) for these resonance transitions. The component with a smaller transition dipole moment will be referred to as the "slow" component, and the other will be termed the "fast" component.
Fig. 1. Energy level diagram for calcium and thallium atoms.

Fig. 2. Schematic diagram of the experimental setup: 1a, 1b) Al₂O₃: Ti³⁺ lasers; 2) dichroic mirror; 3) lens; 4) cell with Ca and Tl vapors; 5) oven; 6) monochromator; 7) photomultiplier; 8) photodetector; 9) oscillograph; 10) C2280 Hamamatsu time analyzer.

We propose to observe two-component SR in a mixture of Ca and Tl vapors which have transitions with practically identical wavelengths $\lambda = 5350$ Å. The energy level diagram is presented in Fig. 1. In this system, Ca represents the fast component (with the transition oscillation strength $f = 0.97$) and Tl is the slow component ($f = 0.151$). Both atomic transitions are self-limited. The concentrations of atoms on the levels under consideration can be varied by changing the pump energy.

These elements were chosen because they have close temperature dependences of the vapor pressure.