When the Rydberg atoms are prepared in the upper level of a transition resonant with the cavity mode, they amplify the blackbody radiation at the corresponding frequency, and, above a given threshold, emit a transient maser pulse. We have conted the number n of atoms transferred by this process at time t following the laser pumping pulse in the lower level of the maser transition. We experimentally determine the probability $P(n, t)$ of finding n atoms transferred at time t, n being of course equal to the number of photons in the field at that time. For t short enough, the $P(n, t)$ law is found to be an exponentially decaying function of n, a distribution typical of an amplified blackbody radiation field. At longer times t, the distribution changes its shape and becomes a bell-shaped function centered around a $n \neq 0$ value, which is characteristic of a coherent emission. The observed probability laws are in very fair agreement with the theoretical ones [2]. We are thus able to investigate in a very simple situation the change of the statistical property of the radiation field at the onset of a superradiant emission. This experiment is reminiscent of the classical observation made on lasers by Arecchi and co-workers [3] about fifteen years ago. The big differences lie in the fact that the photon statistics is here directly determined on extremely small systems (a few thousand radiators only) at very long wavelengths ($\lambda = 1$ mm).

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Dynamical Nonlinear Optics and Bistability

Low Threshold Optical Bistability with Optical Pumping

F. T. Arecchi, G. Giusfredi, E. Petriella, and P. Salieri
Istituto Nazionale di Ottica, I-50125 Firenze, Italy

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By use of circularly polarized light we have exploited optical pumping within the Zeeman sublevels of the ground state to obtain optical bistability (OB) in sodium vapours with low threshold power (around 1 mW) and wide tuning range (> 12 GHz). Experimental results are presented for different conditions of operation and compared to computer calculations, that include propagation effects and inhomogeneous broadening, based on a three level atomic model that accounts for optical pumping.

We remind that OB implies a large modification of the linear susceptibility, hence the local field must reach saturation values, that is, for two level atoms,

$$E_s = (\gamma_\perp \gamma_s)^{\frac{1}{2}} \hbar / \mu \qquad (1)$$

with μ the electric dipole of the optical transition, $\gamma_\perp$ the dipole decay rate and γ_s the spontaneous decay rate.

By application of a weak magnetic field we have aligned the ground state Na spins along the direction of propagation of a circularly polarized laser beam tuned around the D_1 line. Circular polarization is propagated within a carefully designed cell with internal mirrors to avoid Brewster windows.

Optical pumping yields a depletion of the levels coupled to the upper optical state by the selected circular polarization, thus modifying the polarizability. The saturation requirement becomes

$$E_s = (\Gamma \gamma_s)^{\frac{1}{2}} \hbar / \mu \qquad (2)$$

with Γ of the order of the relaxation rate between the uncoupled $m_F = +2$ (with left polarization, $m_F = -2$ with the right one) and the manifold of the other m_F uncoupled levels of the ground state.

Comparison of (1) and (2) implies a power reduction of Γ/γ_s with respect to the two-level case. Relaxation times for Zeeman pumping are known to be very long. In our case the basic limitation lies in the atomic collisions with the walls of the sodium cell, so that

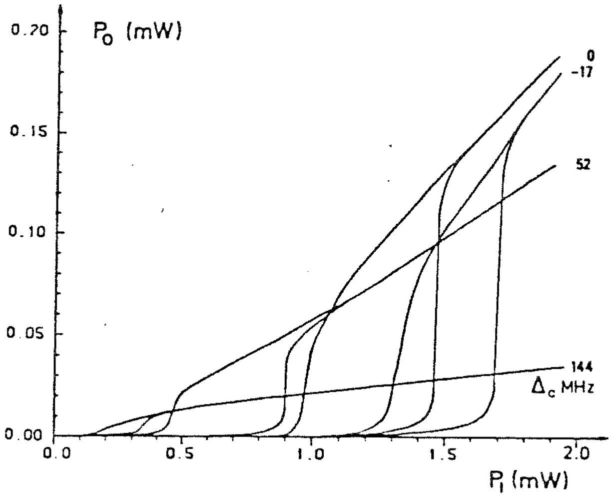

Fig. 1. Power out (P_0) vs. power in (P_i) measured at constant detuning $\Delta\nu = +1.5$ GHz from the center of the D_1 doublet for different cavity mistuning Δ_c values. Temperature 180 °C. Argon pressure 26.5 Torr. Beam diameter 2 mm

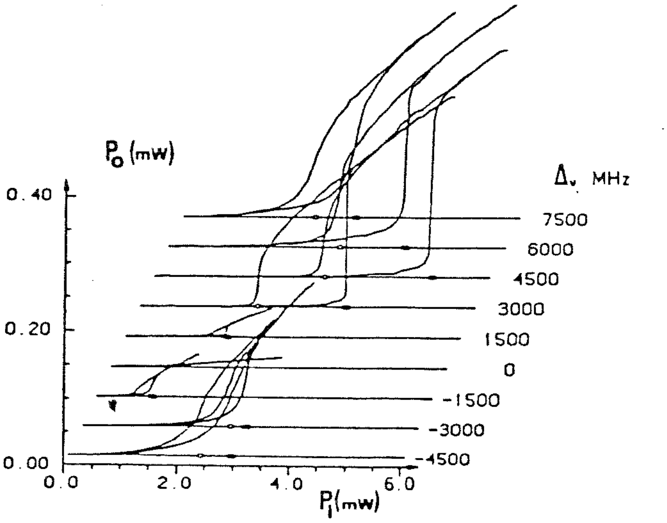

Fig. 2. Power out (P_0) vs. power in (P_i) observed at different detuning values measured from the peak of the peak of the $F=2$ hyperfine transition. Temperature 180 °C, Argon pressure 16.5 Torr. Beam diameter 2 mm

we used Ar as a buffer gas to slow diffusion and collisionally broaden the optical line without destroying the spin state.

Figure 1 shows a series of experimental hysteresis curves for a fixed detuning $\Delta\nu$ between field and atomic resonance and for different frequency mistuning Δ_c values between field and cavity. In Fig. 2 OB is shown for different detunings Δ_ν with Δ_c adjusted to maximize the upper branch transmission at each Δ_ν. Ar pressure is 26.5 and 16.5 Torr respectively, corresponding to $\gamma \sim 1.66 \times 10^9$ and 1.04×10^9 respectively. All curves are in close agreement with computer plots based on our three level theory.