Studies of Two-Level Atoms Identically Prepared by a Phase- and Amplitude-Controlled Excitation Field

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While the response of two-level atoms to nearly resonant driving fields is in principle well known, experimental studies of such responses are generally limited to statistical systems where signals from atoms in widely different states relative to the driving field are observed. We have performed a series of experiments in a collimated beam of atomic ^{174}Yb (which constitutes a nearly-ideal two-level system), designed to probe the response of a small sample of nearly-identically prepared two-level atoms to resonant excitation.

Of special interest in our experiment was the study of stationary atom-field states. In the vector model [1], these states correspond to the alignment of the pseudo-spin vector, $\vec{\rho}$, parallel or anti-parallel to the driving field vector $\vec{\omega}$ [2]. In these states, the atom's energy is unchanged by the laser field. We point out that these stationary states are the dressed states familiar from resonance fluorescence theory [3]. In our experiment, we generate these states by first exciting ground-state atoms with a resonant excitation pulse of area $\pi/2$, and then exposing the atoms to a field-shifted in *phase* by 90° (see Fig. 1).

We observe the atomic response to the excitation field by monitoring fluorescence at right angles to both the atomic and laser beams (see Fig. 2).

In the absence of a phase-shift, the atomic fluorescence displays nutations. After the phase-shift, nutations disappear (see Fig. 3).

The capability of studying atoms prepared identically by a nearly resonant excitation field should make it possible to study many basic aspects of the atomic response which have hitherto been taken for granted but gone untested. Interesting new effects may also be observed. For example, atoms excited to specific dressed states as described above should display a novel transient *two*-peak resonance fluorescence spectrum. Of course, this spectrum should eventually evolve back to the usual three-peaked spectrum characteristic of steady-state measurements. Measurements of these effects are underway.

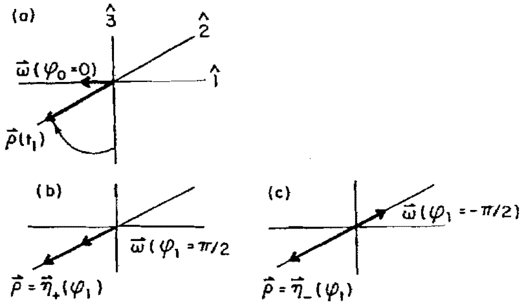

Figure 1: Generation of stationary (i.e. dressed) atom-field states. a) Response of atoms to a resonant pulse of phase $\varphi_0=0$ and area $\pi/2$. $\vec{\rho}$ and $\vec{\omega}(\varphi_0)$ are, respectively, the atomic pseudo-spin vector and effective field vector. b) Configuration of $\vec{\rho}$ and $\vec{\omega}$ after the phase of the driving field is shifted by $\pi/2$ radians. c) Same as b after a phase-shift of $-\pi/2$ radians. In both b and c, the pseudo-spin remains stationary despite the presence of the driving field, since $\dot{\vec{\rho}}=\vec{\omega}\times\vec{\rho}=0$.

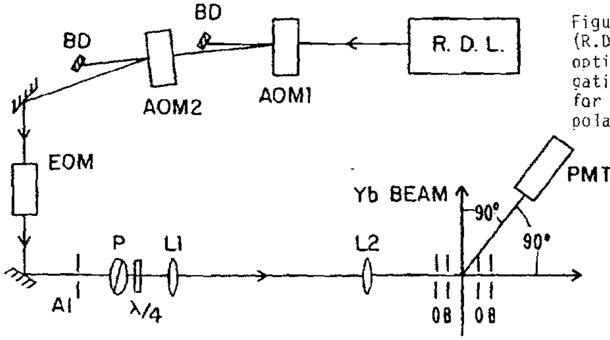

Figure 2: Experimental Schematic. (R.D.L.) ring dye laser, (AOM) acousto-optic modulator for laser amplitude gating, (EOM) electro-optic modulator for phase control, (P,λ/4) circular polarizer, (OB) optical baffles.

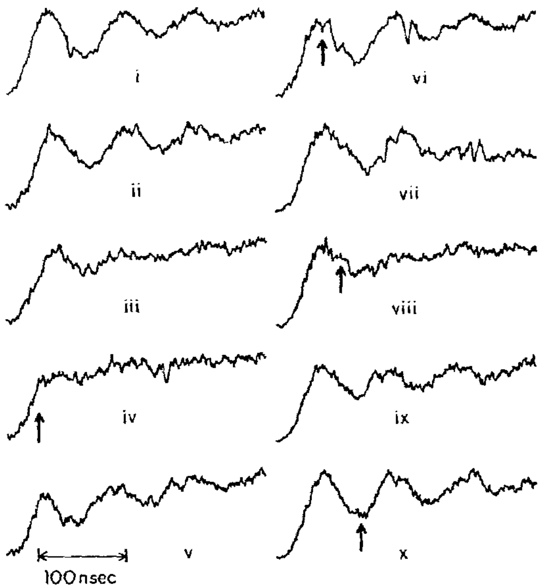

Figure 3: ^{174}Yb Fluorescence (556 nm) versus time. i) No phase-shift, ii) - x) 90° phase-shift applied at successively later times into the step-function laser pulse. The arrows in some traces show the location of the phase-shifts. In traces (iv) and (viii), the atoms experience excitation areas of $\pi/2$ and $3\pi/2$, respectively, before the 90° phase-shift is applied. Consequently, they are excited into the stationary (i.e. dressed) states shown in Figs. 1b and 1c. (Note that the fluorescence lifetime of the ^{174}Yb upper state employed here is about 875 nsec.)

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