

QWF18 Fig. 2. Same parameters as Fig. 1 with a addition of a crossed optical dipole beam (power 10 W) with a waist of 20 μm .

gion. Trapped atoms have a mean energy, $k_B T \sim U_0/10$.

We have performed classical Monte Carlo simulations of the collision process that show that for optimized laser cooling and launching parameters, and $f = 0.5$, $\sim 6\%$ of the launched atoms are loaded. For a magnetic trap lifetime of 200 s, one can expect a steady-state number of $\sim 10^{10}$ atoms.

1. M.H. Anderson *et al.*, Science **269**, 198 (1995); C.C. Bradley *et al.*, Phys. Rev. Lett. **75**, 1687 (1995); K.B. Davis *et al.*, Phys. Rev. Lett. **75**, 3969 (1995).
2. J.M. Doyle *et al.* Phys. Rev. A **52**, R2515 (1995).
3. M. Kasevich *et al.*, Phys. Rev. Lett. **63**, 612 (1989).
4. C.S. Adams *et al.*, Phys. Rev. Lett. **74**, 3577 (1995).

QWF19

Motion of cold atoms in far-off-resonant standing wave donut beams

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A donut beam, on the condition of $z \ll z_R$ and $w(z) \approx w_0$, can be expressed as

$$E(r) = e_x c \left(\frac{r\sqrt{2}}{w_0} \right)^l \exp(-r^2/w_0^2) \times \exp[i(l\phi)] \exp(ikz), \quad (1)$$

where $z_R = \pi w_0^2/\lambda$, $w^2(z) = \pi(z^2 + z_R^2)/\lambda R$, $r = \sqrt{x^2 + y^2}$, and $\phi = \arctan(y/x)$. It has a singularity of phase and the intensity on the axis is zero. For a single donut beam, the scattering force of atoms is related to the phase ϕ , which results in azimuthal motion of atoms. In the standing wave donut beams, the scattering force of atoms disappears and the dipole force will be more complicated and related to phase ϕ .

The motion equations of cold atom in far-off-resonant standing wave donut beams are expressed as dimensionless parameters (R , Φ , Z , τ),

$$\ddot{R} - R\dot{\Phi}^2 = -\frac{2(l - R^2)}{l!} \times R^{2l-1} e^{R^2} \cos^2(Z + l\Phi), \quad (2)$$

$$\ddot{R}\Phi + 2\dot{R}\dot{\Phi} = \frac{2}{(l-1)!} \times R^{2l-1} e^{R^2} \sin(Z + l\Phi) \cos(Z + l\Phi), \quad (3)$$

$$\ddot{Z} = \frac{1}{l} (kw_0)^2 R^{2l-1} e^{R^2} \sin(Z + l\Phi) \cos(Z + l\Phi),$$

where $R = \sqrt{2r/w_0}$, $Z = kz$, $\Phi = \phi$, $\tau = tv$, $v = \sqrt{4\hbar/M\Delta w_0^2} \sqrt{W/2\pi I_s w_0^2}$, Γ , W is the laser power, and I_s is the saturation intensity.

When $\cos(Z + l\Phi) = 0$, the dipole forces of R , Φ , and Z directions are all equal to zero and the optical potential is the minimum in space. It forms a spatial spiral surface. This novel equilibrium structure of atoms caused by change of ϕ in space is very different from that of TEM_{00} mode standing wave.

The motion of the atom in standing wave donut beams is studied theoretically, and the experiment to probe the spatial spiral structure is under investigation.

QWF20

Two-pulse conical yoked superfluorescence in Rb vapor

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We have observed yoked superfluorescence (YSF)¹ on the 5D-6P-5S channel in atomic rubidium after two-photon excitation of the 5D-5S transition by a short (3 ps), 778-nm pulse from a Ti:sapphire laser system. The excitation pulse is formed by a pair of spatially overlapping pulses of wave vectors \mathbf{k}_1 and \mathbf{k}_2 where $|\mathbf{k}_1| = |\mathbf{k}_2| = 2\pi/\lambda$ and λ is the wavelength of the 5D-5S transition.

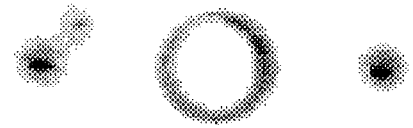
When the atoms are excited by taking one photon from along \mathbf{k}_1 and one from along \mathbf{k}_2 , then phase matching requires that the yoked transition consists of photon pairs along \mathbf{k}_{DP} and \mathbf{k}_{PS} where

$$\mathbf{k}_1 + \mathbf{k}_2 = \mathbf{k}_{DP} + \mathbf{k}_{PS} \quad (1)$$

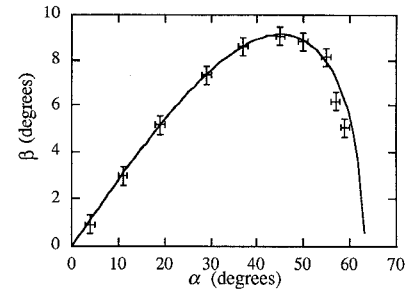
and \mathbf{k}_{DP} and \mathbf{k}_{PS} are the wave vectors of, respectively, the upper (5D-6P) and the lower (6P-5S) transition components of the YSF. The YSF pulses are emitted in a cone determined by Brownell *et al.*¹

This conical emission of YSF was observed on the 420 nm lower transition (see Figs. 1 and 2). The measured behavior of the conical apex angle β as a function of the angle between the excitation pulses α is given in Fig. 2 as a series of points and shows good agreement with the solid line based on Brownell *et al.*¹

At $\alpha = 0$ we find $\beta = 0$ so that $\mathbf{k}_{DP} = \mathbf{k}_{PS}$ as expected since the atomic densities we work are not high. At large values of α , the angle β of the conical emission decreases and eventually drops to zero. This limit corresponds to the condition when the upper (presumably inhibited) transition component of the YSF is emit-



QWF20 Fig. 1. A photograph of conical YSF obtained with a CCD camera with an objective lens tuned to infinity. Conical YSF shows as a ring; also visible are the spots correspondent to the two YSF pulses generated by each laser beam alone.



QWF20 Fig. 2. Apex angle β of emission cone associated with the yoked 6P-5S transition as a function of the angle α between the two components \mathbf{k}_1 and \mathbf{k}_2 of the two-photon resonant excitation pulse.

ted in the backward ($\mathbf{k}_{DP} = -\mathbf{k}_{PS}$) direction. This is a unique feature of our experimental setup, where the coherence in the 5S-5D transition is prepared such that, unlike previous reports,²⁻⁴ the two components of the yoked emission do not propagate along the same direction $\mathbf{k}_{DP} = \mathbf{k}_{PS}$.

Another unique feature of our experiment is that the dependence of the conical superfluorescence intensity on the delay between the two excitation pulses corresponds to the auto-correlation of the resonant component of the pulse.

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1. H. Brownell, X. Lu, S.R. Hartmann, Phys. Rev. Lett. **75**, 3265 (1995).
2. W.R. Garrett, Phys. Rev. Lett. **70**, 4059 (1993).
3. H. Brownell, B. Gross, X. Lu, S.R. Hartmann, J.T. Manassah, Laser Phys. **3**, 509 (1993).
4. K. Ikeda, J. Okada, M. Matsuoka, J. Phys. Soc. Jpn. **48**, 1636 and 1646 (1980).

QWF21

Gain without inversion in three-level V-type system: a dressed-state analysis

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A three-level atom in the V-configuration is treated under two coherent laser fields at resonance with the two allowed transitions. The master equation for the system and full quantum mechanical Hamiltonian are derived, and equations of motion for the elements of the density matrix are obtained by projecting into