Comment on a controlling method of spins of atoms with optical near fields

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If two evanescent waves respectively propagating in the direction of the x-axis and of the y-axis are built on top of a dielectric surface, a pattern of circle polarization whose polarization axis is in the z-axis will be made on a straight line on the surface [1]. This is a special circle polarization whose polarization axis is orthogonal with the propagating direction. If an alkali-atom beam runs along with the straight line of this circle polarization pattern, the z-component of angular momentum of the atom increases by 1 due to the induced absorption. If the initial state of the atom is $S_{1/2}$, the valence electron is either in the up-spin state $(J, M) = (1/2, 1/2)$ or in the down-spin state $(J, M) = (1/2, -1/2)$. Atoms in the up-spin state and the down-spin state change to a state $P_{1/2}$ and to a state $P_{3/2}$, respectively. However, if we inhibit the transition to the state $P_{3/2}$ by selecting frequency of the evanescent wave, we can make atoms of the up-spin state $(J, M) = (1/2, 1/2)$ stable. Finally, atoms in the state $P_{1/2}$ relax to the state $S_{1/2}$ of the up or down-spin state. Thus, by repeating the pumping and relaxing processes we can make all the atoms in the up-spin state (see Fig.1). This is a procedure proposed by Kitahara and Hori [2] to arrange the spins of atoms in the same direction.

The probability of the spontaneous emission of atoms near an interface is different from the one in vacuum because the probability depends on the direction of the emitted photon. Moreover, since the atoms are very close to the dielectric surface, the difference cannot be negligible. In order to take account of the surface effect, we expand the electromagnetic waves in terms of the Carniglia-Mandel mode [3], which is a normal mode of the electromagnetic waves with the boundary condition of an infinite plane surface to form a complete orthonormal set. Then we calculate the transition probability from the $P_{1/2}$ state to the up-spin state (w_{up}) or to the down-spin state (w_{down}), perturbatively. The greater the ratio $R(n, z) = w_{up}/w_{down}$ becomes, the faster the up-spin atoms are collected. The ratio $R(n, z)$ depends on the distance from surface to the atoms (z) as well as the refraction index (n) of the dielectric surface. A result on the transition from the state $6P_{1/2}$ to $6S_{1/2}$ of ^{133}Ce atoms is shown in Fig. 2. It follows from the figure that the ratio $R(n, z)$ takes its maximum value at n =1.5 and then monotonically decreases with z. We find that the ratio $R(n, z)$ is enhanced due to the surface effect by 30% than the value estimated in Ref. [2].

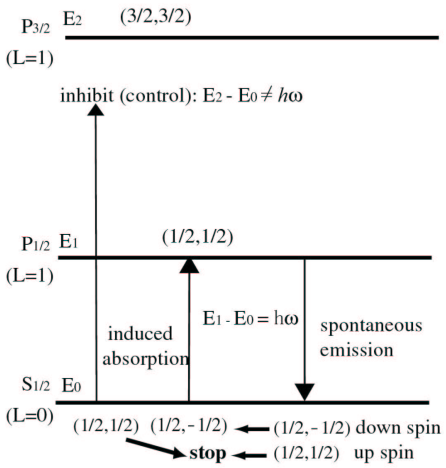

Fig.1: processes of transition

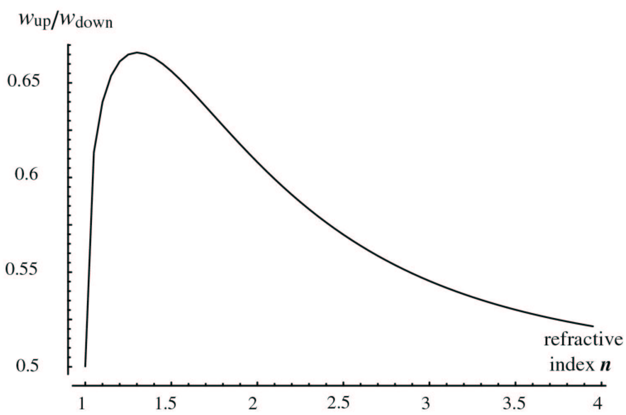

Fig.2: rate of transion probabilities

References

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