Symmetry of packing geometry of doped cavities and its influence on entangled states of excitations

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Recently, a great attention it is devoted to the quantum systems composed from coupled cavities. For example, in the Ref. [1] it is proposed a chain of atom-microcavity systems coupled by a common fiber optic. The authors have analyzed the possibility to form the super-modes and they study the dependence of this effect on the chain geometry and the number of atoms-cavity subsystems. The cooperative states between the radiators placed in two and three cavities is proposed in the Ref.[2]. According to recent studies of quantum entanglement between the subsystems it is necessary to reduce the number of subsystems in order to avoid the complication definition of the discord in the case when the their number is larger than two [3]. For example, the authors of Ref. **??**, generalizing quantum discord for three-qubit, have introduced the conception of *quantum dissension.* In this communication, following the conception of ref. [2], we propose to revise the collective states of atoms and cavity modes in order to reduce them to simple situation of two quantum subsystem in interaction. Here we propose to construct the higher symmetrical atomic and field states using the packing method the coupled cavities. In this situation the doped atoms in each cavity and cavity modes may be described as a two quantum subsystem in interaction.

For example, due to the symmetry between two coupled cavity we can introduce the collective modes and atomic states like in in the Ref. [2], so that it is possible to calculate the quantum mutual information between the atomic ρ_A and field (ρ_F) states : $I(\rho) = H(\rho_A) + H(\rho_F) - H(\rho_{AB})$. As is observed from the Fig. , for three doped cavities, we have two packing possibilities to arrange them on line or on the plan(a). In the line arrangement the middle cavity interacts with the first and third cavity, and it is absent the direct interaction between first and third cavity. Taking into account the rotation symmetry with the angle π, leaves the system in the same states after the exchange between first and third cavity, we define the following collective states: $|\psi_1\rangle = \frac{1}{\sqrt{2}}(|egg\rangle + |gge\rangle)\,|000\rangle$, $|\psi_2\rangle = |geg\rangle\,|000\rangle$, $|\psi_3\rangle = \frac{1}{\sqrt{2}}\,|ggg\rangle\,(|100\rangle + |001\rangle)$, $|\psi_4\rangle = |ggg\rangle\,|010\rangle$.

Here we used the following notation $|geg\rangle$ and $|001\rangle$ are the states of atoms and field respectively. The position in state corresponds to the cavity number. In this case the states of the field and atoms in the first and third cavity defer from the state of second cavity.

The number of functions decreases when the cavities are placed in equidistant triangle. In this situation the interaction between the first and third cavity is established [2]. We observe that the collective atomic and field states in the Hilbert space may be regarded as independent subspaces for atoms and field. The calculation of discord and quantum mutual information is possible.

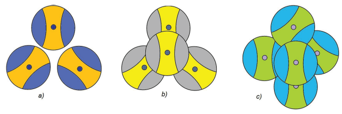

FIG. 1. Doped coupled cavities

Beginning with four cavities, we have the possibility to package them in line, in plan and space (Fig 1(b)). In the line arrangement, the first and fourth atom doesn't interact directly and create the new two subgroups of the Hilbert space.

The circle connection of four doped cavities gives us the possibility to couple first and fourth cavity in a plan. But in this system, the direct connection between the first and third, second and fourth cavity is absent so that it is impossible to construct the common collective states for all atoms and field modes. The number of degrees of freedom can be reduced substantially and the direct interaction of all four cavities is possible if we arrange them in the space, in the vertices of a regular tetrahedron (Fig. 1b): $|\psi_1\rangle = \frac{1}{2}(|eggg\rangle + |gegg\rangle + |ggeg\rangle + |ggge\rangle)\,|0000\rangle$, $|\psi_2\rangle = \frac{1}{2}\,|gggg\rangle\,(|1000\rangle + |0100\rangle + |0010\rangle + |0001\rangle)$. All the symmetry rotations leaves the wave functions unchanged. In this case, the collective atomic states and collective mode states may be introduced. In such situation we can build two quantum subsystem in interaction.

For five cavities the direct interaction between them are not so simple to organize. The maximal symmetry is obtained for the packing in the vertices of a regular bi-pyramid (Fig. 1c). We observe that the direct interaction between the upper and down cavity is absent.

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