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Magnetic and electric field-controlled coupling in quantum ring molecules — •Luis G. Dias da Silva, Jose M. Villas-Boas, and Sergio E. Ulloa — Department of Physics and Astronomy, Nanoscale and Quantum Phenomena Institute, Ohio University, Athens, Ohio 45701-2979

Semiconductor artificial molecules have been proposed as a scalable implementation of a controllable 2-qubit unit, with broad applications in quantum information [1]. Recent experiments report direct manifestation of this coupling in the optical emission of quantum dot molecules [2]. Charge tunneling provides a truly quantum coupling between Stark-shifted exciton states, which reflects in anticrossings between direct and indirect exciton photoluminescence lines as the applied electric field is varied [2]. Nevertheless, the strength of the tunneling coupling is not easily controllable in quantum dots as it is defined by the overlap of the carrier wavefunctions frozen in the structure.

In work, we show that vertically coupled quantum *ring* molecules (QRMs) offer the interesting possibility for controlling the electron tunneling between the ring states by tuning an external magnetic field B. This control arises from orbital selection rules in the excitonic ground-state (GS) transitions: as opposed to quantum dots, the GS total angular momentum L in polarized quantum rings changes from $L = 0$ to $L \neq 0$ (at a B value that depends on the ring radius)[3]. We show that, in QRMs, these properties lead to an effective tuning of the direct-indirect exciton coupling.

In the proposed set-up, direct and indirect excitonic states can also be Stark-shifted in and out of resonance by an electric field along the ring axis. For two concentric rings with different radii, we show there's a magnetic field B^* for which a change in L occurs in the (direct) exciton state in one ring but not on the other. For $B < B*$, electronic tunneling is permitted and the coupling between direct and indirect excitons leads to anticrossings as a function of the electric field. For $B > B^*$, tunneling is suppressed due to angular momentum selection rules and the anticrossing becomes a crossing between direct and indirect exciton states. We show that the parameters in which this "tunneling blocking" occurs can be attained in current ring samples [4], making these experiments within reach.

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[1] J.M. Villas-Boas et al., PRB **69** 125342, (2004).
[2] H.J. Krenner et al., PRL **94** 057402, (2005); G. Ortner et al PRL **94** 157401, (2005); B.D. Gerardot PRL **96** 137403, (2005);E.A. Stinaff et al Science **311**, 636 (2006).
[3] Luis G.V. Dias da Silva et al., PRB **72**, 125327 (2005).
[4] D. Granados et al. APL **86** 071918, (2005).

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