Semiconductor Two-Photon Emission Sources

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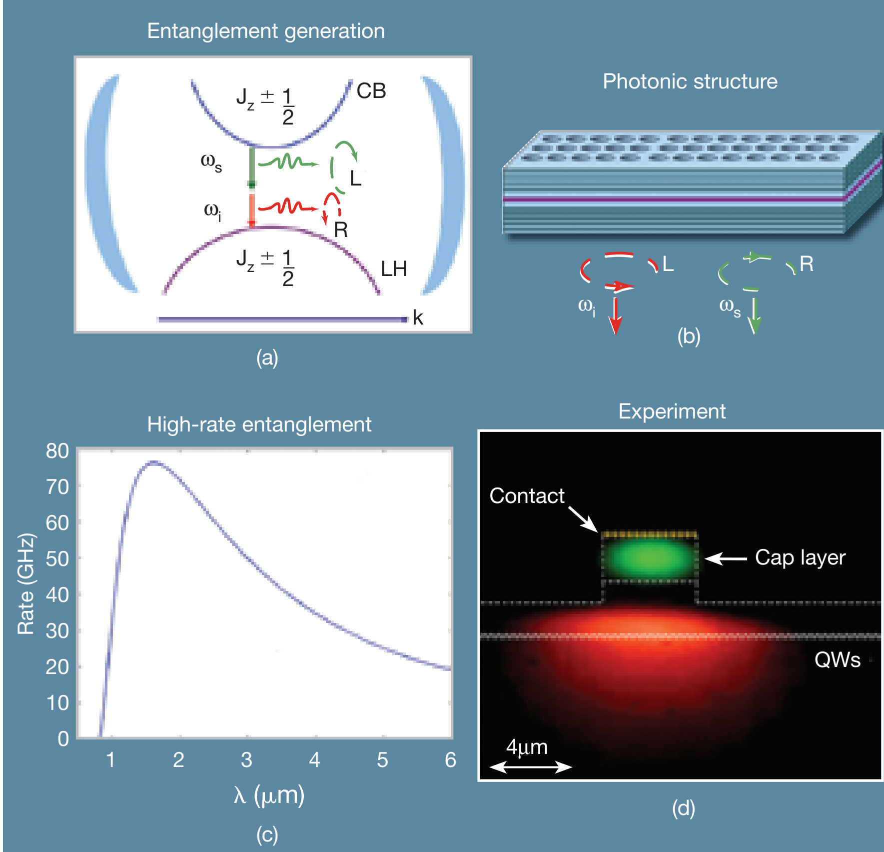
In the process of two-photon emission (TPE), the transition between quantum levels occurs via virtual states, resulting in the simultaneous emission of two photons. These transitions are described by a second-order process in the time-depended perturbation theory; hence, they are much weaker than the first-order one-photon transitions.

For this reason, observation of multi-photon spontaneous decay has so far been restricted to a few atomic transition cases, where the lowest-order process is forbidden. Semiconductors have high carrier densities, making even these relatively weak transitions measurable. Two-photon absorption in semiconductors has been substantially investigated. However, semiconductor TPE has been neither observed nor theoretically analyzed before.

We have proposed semiconductor TPE as a compact high-rate source of entangled photons operated at room-temperature.[1] Entangled-photon states are essential in various applications of optical quantum information, including quantum computation, imaging[2] and quantum cryptography. In specially designed semiconductor quantum wells (QWs), the TPE transitions must have zero angular momentum change, and photon pairs emitted collinearly will have opposite polarizations to be separated by a polarization beam-splitter. The energy conservation for this process does not specify the energy of each individual photon, and the emitted two-photon state is therefore energy-entangled with pair generation rates as high as tens of GHz.



(a) Entanglement generation principle. (b) The proposed photonic micro-cavity structure. (c) The calculated emission rate vs. one of the TPE wavelengths in a cavity-controlled QW TPE entanglement source. (d) Experimental false color IR emission imaging of the facet of the QW-based waveguide. The upper lobe (green) is a parasitic 890 nm one-photon emission from the GaAs cap layer and the lower lobe (red) is the wide-band TPE from the QWs.

Recently, we have also reported the experimental observation of TPE from semiconductors with a typical wide-spectrum with relatively high efficiencies—near 20 nW output power. In our experiments, semiconductor structures were electrically pumped below the one photon lasing threshold, which was increased to above 200 mA by anti-reflection coatings.[3]

We have also shown nonlinear two-photon gain in semiconductors, which can provide the possibility for intrinsic mode-locked laser operation, allowing the generation of ultra-short optical pulses in compact practical semiconductor devices.[3,4] ▲

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References

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