Abstract

Recently, the public has become aware of keywords like "Quantum computer" or "Quantum cryptography". Regarding their potential application in solid state based quantum information processing and their overall benefit in fundamental research quantum dots have gained more and more public interest. In this context, quantum dots are often referred to as "artificial atoms", a term subsuming their physical properties quite nicely and emphasizing the huge potential for further investigations.

The basic mechanism to be considered is the theoretical model of a two-level system. A quantum dot itself represents this kind of system quite nicely, provided that only the presence or absence of a single exciton in the ground state of that structure is regarded. This concept can also be expanded to the presence of two excitons (bi-exciton).

Transitions between the relevant levels can be induced by optical stimulation. When integrating quantum dots in diode like structures measurements of this phenomena can be accomplished regarding photo currents. This means of detection is highly sensitive and allows for tuning of the energy levels with respect to the energy of an exciting laser utilizing the Stark effect (via an external electric field). The photo current then shows narrow resonances representing those transitions. By this, the system can be used as a highly sensitive nano-spectrometer.

The examination of coherent interactions between quantum dots and an electromagnetic field uses laser pulses that are much shorter than the dephasing time of the system (2 ps). The basic study to be done on two level systems is the measurement of Rabi oscillations allowing for the selection of an arbitrary superposition of states. In this work, the existing setup was improved regarding the possibility to control the temperature of the sample. Up to now, only investigations at 4,2 K have been possible. Even at 70 K Rabi oscillations could be shown. Moreover, the influence of temperature on other properties of the system could be investigated. Resonances show noticeable broadening which results in decreased lifetime of the levels participated.

In the same way it was shown that the temperature can influence the main channel of recombination of the predominate level. Varying

the external voltage at the sample even at 4,2 K can set the exciton to decay radiatively (bias voltage smaller than 0,4 V) or through tunneling processes—and thus measureable through photo currents—due to an increased bending of bands (more than 0,4 V). This border can be changed for the benefit of the tunneling processes by thermal activation at higher temperatures.

Investigations on quantum interference were another major part of the work. They are of special interest when it comes to quantum computing. For this, the sample is irradiated with two delayed laser pulses. The first pulse defines then a possible superposition of both possible states and gives the system a phase information. The following second pulse will sample this information with high sensitivity with respect to possible variations of the the quantum dot energy. The latter one may be influenced via the Stark effect. This procedure results in so called Ramsey interferences. Their periodicity shrinks with decreasing pulse delay. This gap was widened to nearly 1 ns for both exciton and biexciton. For the first time, Ramsey interferences of the biexciton were studied as well. This state consists of two single excitons and is excited with a resonant and coherent two-photon process. It was shown that the resolution of these interferences is increased by a factor of two with respect to the exciton case as expected.

The coherent two-pulse experiments offer many possibilities: frequency stabilisation of quantum dots below the homogenous linewidth, a voltage controlled preparation of states and the implementation of C-not-gates with weakly coupled qubits.