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Large Enhancement of Spontaneous Emission Rates of InAs Quantum Dots in GaAs Microdisks

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positron-antiproton capture in traps when high-density clouds of accumulated antiprotons and positrons are brought and kept together by means of specially chosen electromagnetic field and strong cooling (was not demonstrated up to now). However, the cross-section of the spontaneous recombination during collisions remains very small even at extremely low temperatures. The theory predicts that the recombination rate may be increased in an external resonance laser field. Experimental proof of the induced recombination was obtained in electron and proton beams under the action of a CO_2 laser at 10.6 μ and a dye laser at 450 nm. The increase of the recombination rate by up to two orders of magnitude was achieved at laser power values of 15 W and 1–3 MW, respectively. The transition probability depends in general on the mutual orientation of the electric field vector and the velocity of the positron. Note that in real traps in which large magnetic field and constant or pulsed electric field are used, the velocity distribution can have more or less pronounced anisotropy.

A different mechanism recently proposed for the recombination of free electrons with free ions implies a pulsed electric field.[3] If an ion is situated in a static electric field, the Coulomb potential is modified so that a saddle point is created. The electron that passes the saddle point in the modified Coulomb potential requires some time to return back and escape from the ion. If the static field is turned off during this time, the electron remains trapped in a highly excited bound state $n \approx 200$.

In the present report we propose a combination of pulsed electric field and laser pulse field at wavelength near 800 nm to stimulate the formation of antihydrogen atoms in lower states ($n \approx 3$) in positron-antiproton plasma under the conditions of Penning and Paul traps at low temperatures. The laser intensity estimated is about dozens of W/cm^2. In crossed constant magnetic field and circularly polarized alternating electric fields a new kind of stationary rotating wave packet states were shown to arise in hydrogen-like systems under special conditions. These packets, knows as Trojan states, remain strongly localized and thus differ significantly from common Rydberg states. Using numerical modeling of wave packet dynamics we analyse the stability of these states with respect to field perturbations and estimate the possibility to use them as intermediate states for antihydrogen production. We discuss the polarization dependencies of the laser-induced recombination rate for the case of the anisotropic velocity distribution. The work was supported by CRDF grant REC006.

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QTuC 8:00 am–9:45 am
Room: 203

Enhanced Spontaneous Emission

Hailin Wang, Univ. of Oregon, USA, Presider

QTuC1 8:00 am

Large Enhancement of Spontaneous Emission Rates of InAs Quantum Dots in GaAs Microdisks

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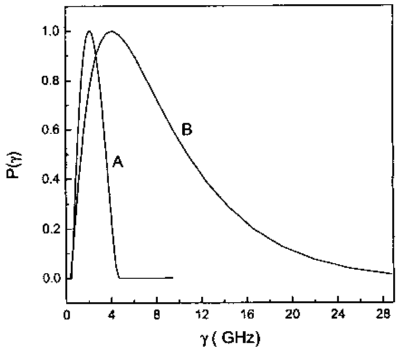
Control of spontaneous emission in a microcavity has many important applications, e.g. improvement of the efficiency of light emitting devices. InAs quantum dots (QDs) embedded in microdisks are ideal systems for spontaneous emission control.[1] The whispering gallery (WG) modes of microdisks have low volume and high quality factor.[2] The homogeneous linewidth of InAs quantum dots is smaller than the spectral width of WG modes. Thus, a large enhancement of the spontaneous emission rates should be expected for QDs coupled to WG modes. However, large inhomogeneous broadening of the QD energy levels and random spatial distribution of the QDs in a microdisk lead to a broad distribution of the spontaneous emission rates. Using an efficient regularized method based on the truncated singular value decomposition and the non-negative constraints, we extract the distribution of spontaneous emission rates from the temporal decay of emission intensity. The maximum spontaneous emission enhancement factor exceeds 10.

InAs QDs are grown on GaAs by molecular-beam-epitaxy. The microdisks are fabricated by electron beam lithography and two-steps of wet etching. The diameter of the disks is ~3 μm. Each disk is supported by a 500-nm long $Al_{0.7}Ga_{0.3}As$ pedestal. The microdisk is optically excited by 200 fs pulses from a mode-locked Ti:Sapphire laser. The emission from the side of the microdisk is dispersed by a monochromater, and then goes into a streak camera for lifetime measurement. For wavelengths both shorter and longer than the cavity resonances, the photoluminescence (PL) curves exhibit monoexponential decay. The decay time, obtained from monoexponential curve fitting, is ~570 ps. The PL at the wavelength of a WG mode consists of a resonant part and a nonresonant part. The resonant part represents the emission of QDs into the WG mode, while the nonresonant part comes from the emission of the uncoupled QDs which have little spatial overlap with the WG mode. We curve fit the temporal decay of PL with a double-exponential function $I(t) = I_1 \exp[-t/t_1] + I_2 \exp[-t/t_2]$. t_1 represents the decay time averaged over all coupled QDs. t_2 is the off-resonant spontaneous emission decay



QTuC1 Fig. 1. $P(\gamma)$ extracted from the off-resonance (A) and on-resonance (B) PL curves.

time. From the value of t_1, we find the average enhancement factor for spontaneous emission rates of the QDs coupled to the WG mode $TE_{13,2}$ is 3.8.

Compared to the average enhancement factor, a more accurate way of describing the spontaneous emission enhancement is to introduce a distribution function $P(\gamma)$ for the spontaneous emission rates γ. The temporal evolution of emission intensity at the frequency of a WG mode $I(t) = \int_0^\infty P(\gamma)\exp(-\gamma t)\,dt$. We numerically solve this integral equation to retrieve $P(\gamma)$ from the measured $I(t)$. Figure 1 shows the distributions of the spontaneous emission rates $P(\gamma)$. At the off-resonance wavelength, $P(\gamma)$ has a narrow peak centered at ~2 GHz. At the wavelength of $TE_{13,2}$ mode, $P(\gamma)$ has a long tail at the higher decay rate. For some QDs, the spontaneous emission rates exceed 20 GHz. The corresponding decay time is less than 50 ps. Therefore, the spontaneous emission enhancement factor for some QDs exceed 10.

References

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QTuC2 8:15 am

Silicon Microcavity Based on 1-D Photonic Bandgap Structure

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1. Fabrication

Recently, we have observed the enhancement of the room temperature visible photoluminescence (PL) from a hydrogenated amorphous silicon nitride (a-SiN_x:H) microcavity.[1] The microcavity is realized by sandwiching a λ/2 active a-SiN_x:H layer between two distributed Bragg reflectors (DBR's). The microcavity resonance wavelength was designed to be at the maximum of the bulk a-SiN_x:H luminescence spectrum. First, the bottom DBR was deposited by PECVD on the silicon substrate using 14 pairs of λ/4 alternating layers of a-SiN_x:H and a-SiO_x:H. For the nitrogen rich a-SiN_x:H deposition, ammonia (NH_3) with a flow rate of 10 sccm, and 2% silane (SiH_4) in ni-