Cavity ring-down spectroscopy of semiconductor quantum dots

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Abstract: We employ cavity ring-down to perform absorption experiments of InGaAs/GaAs QDs. Integrating an AlAs/GaAs DBR incorporating InGaAs QD's into a Fabry-Perot cavity, we demonstrate this approach and its potential for sensitive measurements on semiconductor nanostructures.

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Ring-down spectroscopy provides an extremely sensitive direct measurement of absorption [1,2]. Here we report an experimental effort to develop this technique as a method for making high precision measurements of fundamental properties of quantum dots (QDs). The ring-down cavity for the measurements is composed of an AlAs/GaAs distributed Bragg reflector on top of which InGaAs quantum dots are integrated and a curved conventional, dielectric-coated, low-loss mirror attached to a piezo-electric transducer (PZT). The spectral profile of the quantum dots absorption is determined by measuring the decay dynamics of the intracavity field as a function of the wavelength of the probe laser, which is a cw frequency-stabilized Ti:sapphire laser. The cavity transmission peak is locked to the laser frequency using the PZT. A trigger pulse is then applied to an acousto-optic modulator in front of the cavity to switch off the input light with a well-characterized response time. The change in the cavity decay measured in transmission as a function of wavelength is shown in Figure 1 and displays a clear trend of enhanced absorption (and hence shorter ring-down time) when the laser wavelength is tuned near the center of quantum dot absorption. To relate the ring-down measurement to the QD absorption, we examine the photoluminescence signal of the quantum dots to obtain a qualitative measurement of the QD density variations, carefully characterizing the dielectric mirror and performing low precision photo-spectrometer measurements of the DBR mirror reflectivity to determine its stop band. By incorporating a QD density variation into the QD/DBR structure the cavity loss as a function of wafer position allows the loss contribution due to the QD absorption to be observed as shown in Figure 2.

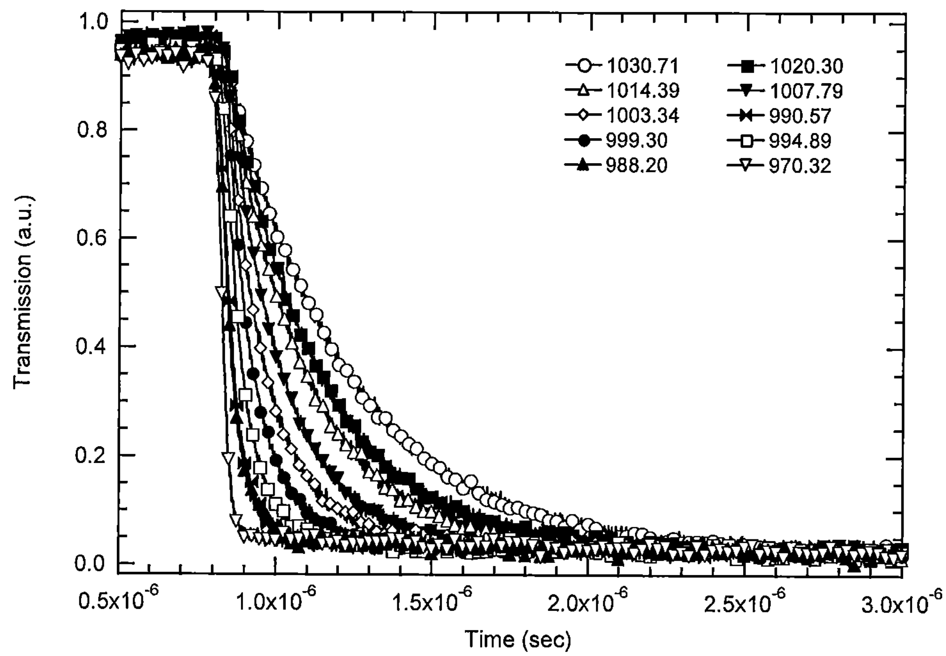

Fig. 1 Ring-down dynamics at selected wavelengths in a high-density region of quantum dots on the DBR mirror

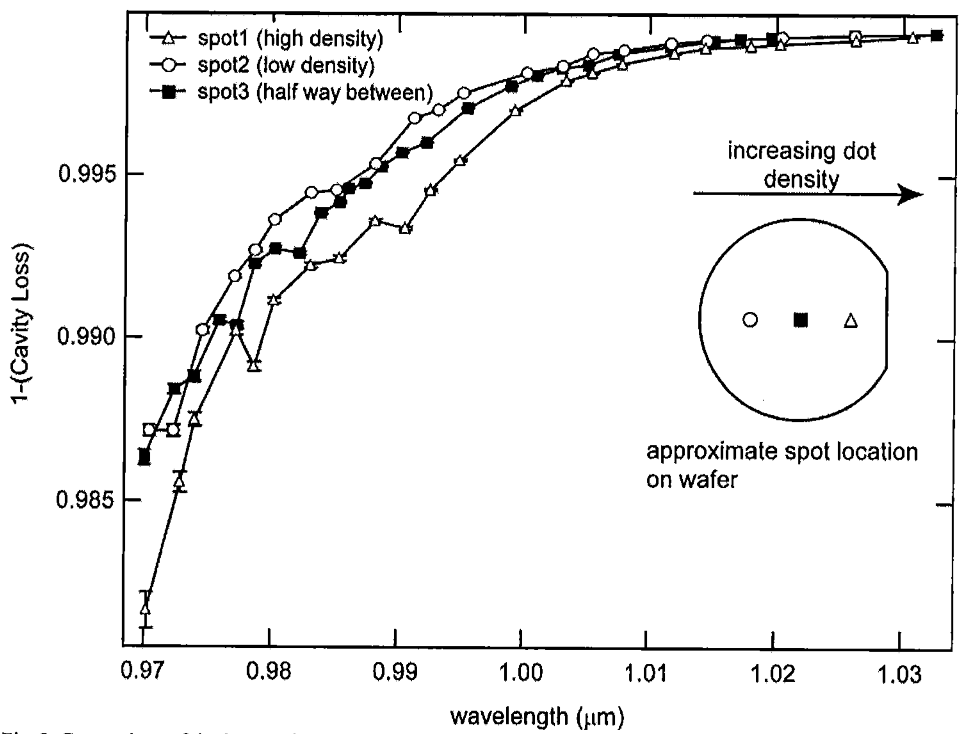

Fig. 2. Comparison of the intracavity absorption between low and high-density regions of quantum dots on the DBR mirror. The wavelength dependent quantum dot absorption is clearly shown, along with a clear distinction between low and high-density regions.

[1] D. Romanini et al. *Chem. Phys. Lett*, **264**, 316-322 (1997)

[2] J. Ye and J L. Hall, *Phys. Rev. A* **61**, 061802(R) (2000)