Schematic diagram of the coupled-quantum well structure studied, the potential energy diagram used to model it, and the location of the particle-in-a-box states for that potential.  (b) Far-infrared emission by coupled quantum wells.  The peak at 17 meV is attributed to the E4-E3 transition.  The dashed line is the calculated radiation from Al0.27Ga0.73As the 100 K.  We attribute to emission by hot phonons in the AlGaAs layers.  The dashed curve on the lower figure is the computed spectral density emitted by a 100-µm-thick slab of Al0.27Ga0.73As at 100 K (TO phonon energy 33.3 meV).  This is a reasonable assumption for the lattice temperature, as discussed below.  As expected, no peak at 17 meV was observed when the pump wavelength was changed to 10.6 µm (117 meV photon energy), corresponding to the E2-E3 transition, but the higher energy component of the spectrum remained.

Our n-type GaAs/AlGaAs sample consists of 30 CQWs grown by molecular beam epitaxy on a semi-insulating GaAs substrate.  The dimensions shown on the upper figure have been confirmed by transmission electron microscopy.  The aluminum mole fraction of all barriers is about 27%.  To supply the electrons for the intersubband transitions, a sheet of Si was inserted in each confining barrier 3.0 nm from the interface with the quantum well.  Hall measurements at 77 K show an electron sheet density of $1.1 \times 10^{10} \text{cm}^{-2}$ in each coupled well and a mobility of $2.7 \times 10^4 \text{cm}^2/\text{V-s}$.  The subband energies have been computed in a calculation that includes in a self-consistent manner the electrostatic potential arising from the distribution of charge in the coupled quantum well.

The far-infrared emission measurements were made with the sample attached to a copper cold finger by indium solder.  The cold finger was cooled to 20 K by a closed-cycle helium refrigerator, but simple calculations show that under the 6-W optical excitation the temperature of the illuminated region may be as high as 100 K.  We pumped electrons from the E3 subband into the E4 subband with a CW CO2 laser polarized parallel to the direction of confinement and focused to a 150-µm-diameter spot on one cleaved face at a corner of the sample.  The far-infrared radiation emitted from the other cleaved face of that corner of the sample was collected and analyzed with a Fourier-transform spectrometer.  The radiation was detected with a gallium-doped germanium photoconductor cooled to 4.2 K.  The spectral wavelength range of the system is 50 to 120 µm (photon energy 10 to 25 meV).  The pump laser was chopped at approximately 200 Hz and the signal was measured with a lock-in amplifier.

REFERENCES


Strain-induced lateral confinement of excitons in semiconductor quantum wells

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There is a worldwide effort to achieve efficient and controlled confinement of carriers to "quantum wires" and "quantum dots".  Use of these structures, of
dimensionality lower than the by-now-familiar quantum wells, is expected to improve the performance of lasers and nonlinear optical devices. With varying degrees of success, teams of researchers have made quantum wires and dots in various ways—for example, by etching freestanding structures, by defining buried structures by ion implantation, and by growing them directly on patterned or unpatterned substrates.

We have developed and demonstrated a new technique for lateral confinement of excitons near semiconductor surfaces, that uses patterns of inhomogeneous strain. This confinement technique is unique in that it is universally applicable to almost all semiconductors, without regard to their fabrication characteristics, growth properties, or crystal structure.

Strain confinement works by locally altering the energy level structure of carriers by patterned strain that is generated by patterning etching wire or dot stressors from a uniformly strained overlayer. Relaxation of the compression in those structures is accompanied by dilation of the underlying semiconductor in the region near the center of the stressor. As pictured in the figure inset, this dilation results in a reduction of the bandgap and creates a potential well for excitons.

Evidence for stable trapping of excitons in an array of strain-induced wires within a continuous semiconductor quantum well is shown in the figure. The upper spectrum, with a peak at ~795 nm, is that of an unpatterned GaAs quantum well with AlGaAs barrier layers. The lower curve is that of a nearby region of the same sample that has been patterned with an array of linear stressors 350 nm wide. These stressors were etched from a 160 nm thick layer of amorphous, highly compressed carbon that was deposited directly onto the upper barrier of the GaAs quantum well. Excitons trapped in the wires recombine at 811 nm. This luminescence red shift is the measure of the lateral potential well, here 31 meV. Excitons recombining in the well regions between the wires are the source of the emission peak at ~794 nm. Lateral potential wells for excitons of up to 50 meV have been achieved in dots patterned on a GaAs epitaxial layer.

REFERENCES

Quantum-confined Franz-Keldysh effect in CdTe quantum dots in glass

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There has been considerable interest in the electric-field dependence of optical properties of semiconductor quantum-well structures. We have extended these electric-field studies to quantum dots, i.e., to structures confined in all three dimensions. The new CdTe quantum-dot glass first reported here is especially suited for electric-field effects because of the large Bohr radius, \( a_B \approx 73 \) Å; it has as many as six quantum-confinement peaks in the absorption spectrum with dot radii, \( r_o \approx 36 \) Å. The observed changes in the absorption spectrum (see top figure) are interpreted to arise mainly from a red shift of the lowest transition and the redistribution of the oscillator strength as forbidden transitions are opened up by the symmetry-breaking action of the external field. This interpretation is made plausible by a spherical-coordinate-system calculation (upper figure), that neglects the Coulomb interaction; it is similar to that for cuboidal structures by Miller,