Magnetic brightening of “dark” excitons in carbon nanotubes

S. ZARIC, J. KONO, Dept. of Elec. & Comp. Engineering, Rice Univ., X. WEI, NHMFL, Florida State Univ., R. H. HAUGE, R. E. SMALLEY, Chemistry Dept., Rice Univ. — We have measured polarized-excitation photoluminescence (PL) on micelle-suspended single-walled carbon nanotubes (SWNTs) in aqueous solution in external magnetic fields ($B$) up to 45 T at room temperature. Each PL peak, corresponding to a specific chirality, splits into two in a $B$ and the amount of splitting increases with $B$. The magnetic field dependence of the relative intensities of the two peaks reveals that the lower-energy peak increases in intensity (or “brightens”) with increasing $B$. These results can be understood in terms of “magnetic brightening” of an excitonic state that is “dark” at 0 T. Namely, recent calculations taking into account intervalley Coulomb mixing in semiconducting SWNTs predict the existence of a dark excitonic state at an energy $\Delta_X$ below the lowest optically active (bright) excitonic state. On the other hand, magnetic flux $\phi$ threading a nanotube removes the intervalley degeneracy which is seen in absorption measurements as peak splittings by an amount $\Delta_{AB}$ proportional to $\phi$ (when $\phi/\phi_0 \leq 1/6$, $\phi_0$: magnetic flux quantum). While two equally-bright excitonic peaks are predicted and observed at high fields ($\Delta_{AB} \gg \Delta_X$), magnetic brightening is expected at lower fields ($\Delta_{AB} \sim \Delta_X$), which is consistent with our observations. 1 S. Zaric et al, Phys. Rev. Lett., to appear (see also cond-mat/0509429)