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High magnetic field imaging and spectroscopy of bound excitons in individual carbon nanotubes

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We report low temperature (4.2K) micro-photoluminescence (μPL) studies of high-purity semiconducting individual single walled carbon nanotubes (CNTs) in magnetic fields up to 30T. We observe ultra-narrow emission linewidths with a FWHM<80μeV. Using these narrow linewidths we study in detail the effects of high magnetic fields on the exciton fine structure. In pristine CNTs the dark exciton is clearly resolved at B<1T with a consistent zero-field splitting of Δ_x=2meV between the dark and bright spin-singlet exciton for (8,6) tubes (Fig.1a). Upon high intensity laser irradiation the optical properties of the CNTs are dramatically transformed. An additional dark-bright pair of exciton states is created (Fig.1b). We attribute these new states to bound spin-singlet excitons with an increased zero-field splitting of Δ_x^{bound}=6meV. This may explain the apparent variability of Δ_x observed within single chiralities in early individual CNT magnetospecroscopy [1,2].

In addition, the magnetic field alters the spatial distribution of the emission, causing emission from previously dark regions with a different spectral response. We observe strong magnetic brightening accompanied by significant shifts in the spatial distribution along the tube (Fig. 1d,e). The spatial dependence of the emission spectrum suggests that the presence of defect states at different points along the nanotube can be detected due to magnetic field induced localisation.

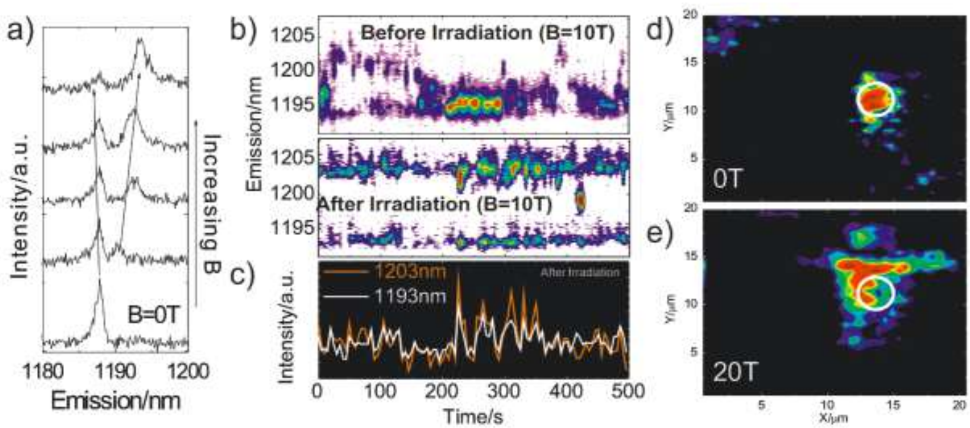

Figure 1. a) Bright-dark transition in a pristine (8,6) CNT. b) Emission time-series before and after high intensity irradiation at 10T, a new dark-like exciton is observed. c) Time-series showing the correlation between the two emission states after irradiation. Spatial mapping of single CNT emission at (d) 0T and (e) 20T.

References

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