L.4: Development and application of a magneto-SPV and magneto-PL setup

Ultra-low disorder (10 ppb) in III-V semiconductor hetero-junction and quantum structures are important for making numerous devices including laser diodes and photodetectors. In order to enhance the device efficiency at the extreme operating conditions, quantitative estimation of disorder embedded in the system and its impact on the optoelectronic processes are essential [1,2]. However, accurate measurement of the density of radiative defects in such ultra-low disordered system is a big challenge for most of the presently available techniques. Recently, we have estimated the density of disorders and effective mass of excitons for such ultra-low disordered systems using magneto-photoluminescence (Magneto-PL) technique [3,4]. These measurements are performed at liquid helium temperature (4.2 K) where the charge carriers are mostly occupied in the ground state of semiconductor quantum well (QW) structures. However, the excited states of a QW, are difficult to be probed via low temperature magneto-PL measurements. Under high intensity excitation conditions, one may see the signature of excited state but it is not desired due to several complications which might arise due to the sample heating and many body effects. Under such condition, surface photo-voltage (SPV) being a complementary technique can be highly beneficial for obtaining complete information of the excitonic processes in quantum structures. Generally, PL signal decreases with rise in temperature and can be considerably feeble at room temperature, which is not a problem in SPV measurements. Thus, the impact of temperature and magnetic field on the radiative and non-radiative processes in such quantum structures can be understood via the simultaneous measurement of SPV and PL spectra on QW samples. In view of this, a compact experimental assembly was designed and fabricated for the quasi-simultaneous measurement of Magneto-SPV and PL as shown in Figure L.4.1(a). In this experimental configuration, sample is kept inside a Dewar of thermostat surrounded by liquid helium chamber with helical shaped NbTi superconducting magnet, which can produce magnetic field up to 8 T. An indium tin oxide coated semi-transparent conducting glass plate faces the sample under soft contact mode as shown in the inset of Figure L.4.1(b). Laser light for PL measurements is coupled to an optical fiber, which transports the excitation light to the surface of the sample. PL signal that comes out from the sample which is then collected by the same optical fiber, and dispersed by a spectrometer (IHR-320). In case of SPV measurements, the same spectrometer is used to disperse the broad spectra from a quartz tungsten halogen lamp, and coupled to the optical fiber. The surface photo-voltage generated in the sample is then collected by the ITO coated top electrode. The new experimental assembly is found to be beneficial for gaining a complete information on the dynamics of thermally excited charge carriers and the effect of magnetic field driven confinement on the radiative recombination efficiency of quantum structures.

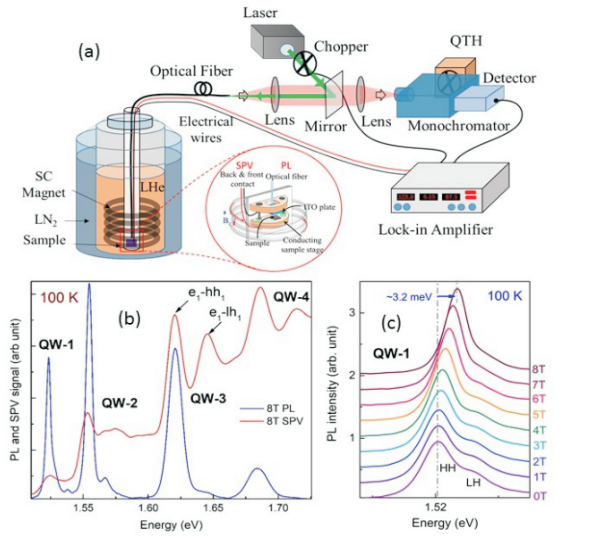

Fig. L.4.1: (a) The schematic of sample mount for the quasi-simultaneous measurement of PL and SPV (b) Magneto-SPV & PL spectra (c) Field dependent Magneto-PL spectra.

Representative magneto-PL and magneto-SPV spectra of a GaAs/AlGaAs multi QW sample are shown in Figure L.4.1(b). The spectra are recorded at 100 K under 8 T magnetic field. It is obvious that the information related to the ground and excited states of four QWs can only be obtained by performing quasi-simultaneous magneto-PL and magneto-SPV measurements. Magnetic field dependent spectra is shown in the Figure L.4.1(c). Analysis of these results can give clear information of the oscillator strength for various electronic states of quantum structures under high magnetic field. This kind of experiments would also be beneficial for the simultaneous detection/measurement of bright and dark excitons in semiconductor quantum structures. The setup is specifically being used to investigate the properties of QWs which are used for the development of laser diode arrays and detectors.

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