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Towards realization of two-dimensional electroabsorption modulators

Electrical modulation of optical signals can be achieved by modulation of either the refractive index or the absorbance of a material by an electric field. Contemporary electroabsorption modulators (EAMs) employ the quantum confined Stark effect (QCSE) [1-3] which is the field-induced red-shift and broadening of the strong excitonic absorption resonances characteristic of low-dimensional semiconductor structures. Here we show an unprecedentedly strong transverse electroabsorption (EA) signal in a monolayer MoS_2 by modulating the gate voltage in a transparent field effect transistor configuration (Figure 1a). The EA spectrum is dominated by an apparent linewidth broadening of around 15 % at a modulated voltage of only V_{pp} = 0.5 V. Contrary to the conventional QCSE, where the red-shift is quadratic with the electric field, the signal increases linearly (Figure 1b) with the applied field strength and arises from a linear shift of the overlapping exciton and trion resonances in opposite directions [4]. We considered two possible mechanisms to explain the spectral shifts: field induced changes in the exciton and trion binding energies by different amounts, and a transverse permanent dipole induced by device asymmetry. Further, we show that WSe_2 embedded in a micro-capacitor structure exhibits EA signals dominated by an inhomogeneous linewidth broadening of the exciton resonance for electric fields exceeding 400 kV/cm (Figure1c). The linewidth broadening shows a quadratic dependence with the electric field. This might be due to a nonhomogeneous distribution of the electric field or charge density over the sample, or randomly-orientated permanent dipole moments induced by surface roughness. The large modulation depths greater than 0.1 $dBnm^{-1}$ bear the scope for extremely compact, ultrafast, energy-efficient EAMs for integrated photonics, including on-chip optical communication.

References

[1] Miller, D. A. B., Chemla, D. S., Damen, T. C., Gossard, A. C., Wiegmann, W., Wood, T. H. and Burrus, C. A., Phys. Rev. Let., 53 (1984) 2173-2176.
[2] Miller, D. A. B., Chemla, D. S., Damen, T. C., Gossard, A. C., Wiegmann, W., Wood, T. H. and Burrus, C. A., Phys. Rev. B., 32 (1985) 1043-1060.
[3] Reed, G. T., Mashanovich, G., Gardes, F. Yand and Thomson, D. J. Nat. Photon., 4 (2010) 518-526.
[4] Vella, D., Ovchinnikov, D., Martino, N., Vega-Mayoral, V., Dumcenco, D., Kung, Y.-C., Antognazza, M.-R., Kis, A., Lanzani, G., Mihailovic, D. and Gadermaier, C., 2D Mater., 4 (2017) 1-9.

Figures

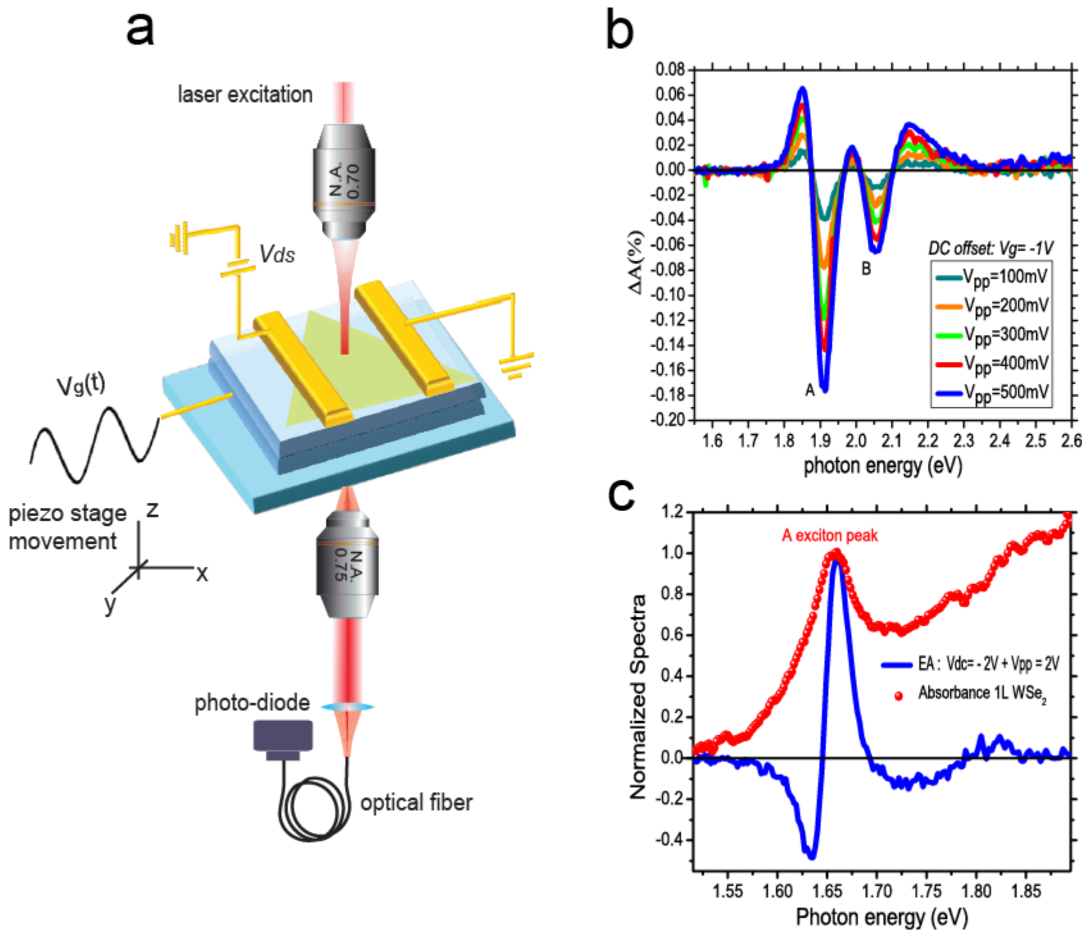

Figure 1: a) Schematics of the extinction and electroabsorption measurements using a tuneable laser in a confocal microscope. b) Electroabsorption spectra of 1L MoS_2 for different peak-to-peak voltage modulation amplitude Vpp. c) Normalized Absorbance and Electroabsorption signal of 1L WSe_2.