VALLEY AND SPIN CURRENTS OF ELECTRONS AND CHARGED EXCITONS IN 2D TRANSITION METAL DICHALCOGENIDES

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The recent emergence of two-dimensional transition metal dichalcogenides (TMDs) provides a new laboratory for exploring the internal quantum degrees of freedom of electrons for new electronics [1]. These include the real electron spin and the valley pseudospin that labels the degenerate band extrema in momentum space. The generation and control of spin and valley pseudospin currents are at the heart of spin and valley based electronics. We will discuss two mechanisms for generating spin and valley currents of electrons in 2D transition metal dichalcogenides: (I) the valley and spin Hall current arising from the Berry curvatures [2, 3]; and (II) the nonlinear valley and spin currents arising from Fermi pocket anisotropy [4]. The two effects have distinct scaling with the field and different dependence of the current direction on the field direction and crystalline axis. We discuss the possibility to observe and distinguish the two effects as distinct patterns of polarized electroluminescence at pn junction in monolayer TMDs. We show that the nonlinear current response from the Fermi pocket anisotropy allow two unprecedented possibilities to generate pure spin and valley flows without net charge current, either by an AC bias or by an inhomogeneous temperature distribution. This points to a new route towards electrical and thermal generations of spin and valley currents for spintronic and valleytronic applications. We will also discuss the valley Hall effect of charged excitons in monolayer TMDs, where the excitons can acquire valley dependent Berry curvature from two origins [5]. The first is the inheritance of the Berry curvature from the Bloch band [3]. The second is from the exchange interaction between the electron and hole constituents of the exciton which give rises to an effective coupling of the excitonic valley pseudospin to its center of mass motion [5]. The two mechanisms can dominate respectively for positively and negatively charge excitons. The valley Hall effect of charge excitons can be detected from the light emission with contrasted circular polarization on the opposite edges, which leave behind valley and spin polarised electrons or holes.

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