Topological Insulator - Bi$_2$Se$_3$

Topological insulators (TIs) realize a novel quantum phase, in which an insulating bulk band gap is host to metallic spin-polarized topological surface states (TSS) protected by time-reversal-symmetry. The TSS supports almost lossless spin polarized currents on the surface due to the chiral spin texture, which suppresses backscattering. Insight into the dynamics of TSS is an essential first step to generating and controlling these currents (Fig. 2a). Injection of currents in TIs has been observed using a two-color coherent control scheme, where the phase between two laser pulses (freq. $\omega$ and $2\omega$) is used to tune the population of the state. (Fig. 2b) As a surface sensitive direct probe of electronic band structure, TR-ARPES is a technique ideally suited to observing the injection of currents in Bi$_2$Se$_3$. 

**fsEC XUV source**

Typical time-resolved ARPES sources are limited in photon energy (~6 eV), and can access only a small region of the Brillouin Zone (BZ), with an energy resolution of ~70 meV-150 meV. In contrast, the system developed at UBC uses high harmonic generation (HHG) in a femto-second enhancement cavity (fsEC) to produce up to a photon energy of 40eV. (Set up shown in Fig. 1).

With the 21st harmonic (25 eV), we have established an energy resolution of ~25 meV and a time resolution of < 350 fs. This unique 60 MHz source allows for characterization of the time evolution of electronic states across the full BZ for novel quantum materials.

**Figure 1**

- Hemispherical Electron Analyzer (Sciante R4000)
- IR or Visible Pump 1045 nm (1.19 eV)
- 523 nm (2.37 eV)
- XUV Probe >10$^6$ photons/s <10$^5$ photons/pulse with Krypton
- 0.4 x 0.2 mm FWHM UHV Chamber
- 2D Detector
- GM, Xe, Kr, Ar
- 1045 nm (1.19 eV) fundamental 120 fs pulses, 30-170 $\mu$J pulse energy up to 10 kW average power
- Future Upgrade Mid-Infrared OPO & DFG
- Pump for tr-ARPES
- SHG Delay Stage
- Yb-doped fiber laser with power amplifier

**Figure 2**

a) Population Depletion

b) 2nd TSS Conduction Band TSS Bulk Valence Bands