TÉCNICO LISBOA

PROBING DISORDER EFFECTS IN TOPOLOGICAL MATERIALS VIA NON-LINEAR HALL RESPONSE

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BERRY PHASE, BERRY CURVATURE & ANOMALOUS VELOCITY

Berry Potential

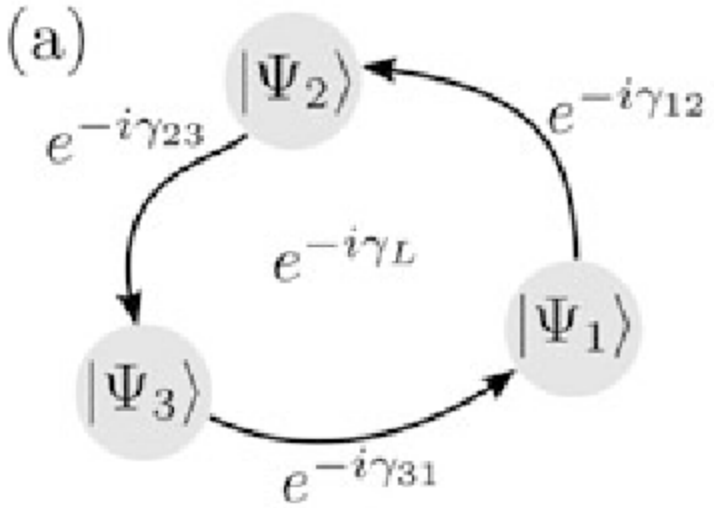
$$\mathcal{A}_n(\boldsymbol{R}) = i\langle n(\boldsymbol{R})|\frac{\partial}{\partial \boldsymbol{R}}|n(\boldsymbol{R})\rangle.$$

Berry Curvature

$$\Omega^n_{\mu\nu}(\boldsymbol{R}) = \frac{\partial}{\partial R^\mu}\mathcal{A}^n_\nu(\boldsymbol{R}) - \frac{\partial}{\partial R_\nu}\mathcal{A}^n_\mu(\boldsymbol{R})$$

Anomalous Velocity

$$v_n(q) = \frac{\partial \varepsilon_n(q)}{\hbar \partial q} - \Omega^n_{qt}.$$



Berry phase in discrete quantum system - Asbóth et al., 'A Short Course on Topological Insulators

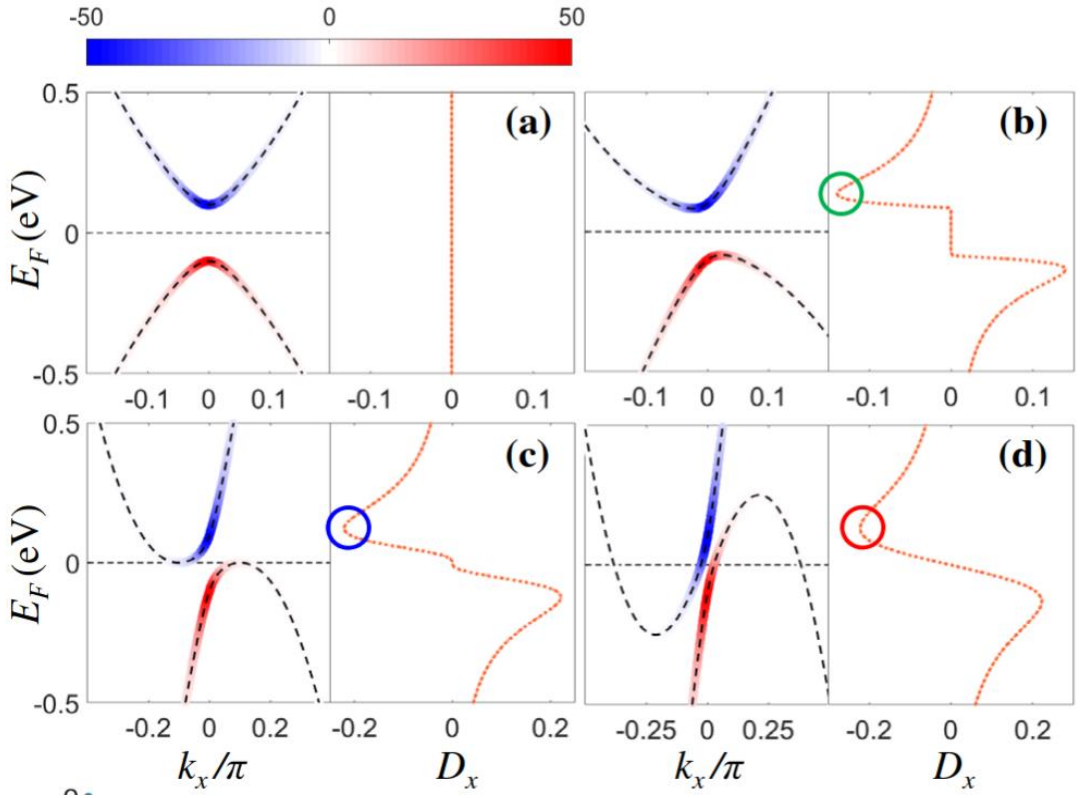
BERRY CURVATURE DIPOLE AS SOURCE OF INTRINSIC NLHE

Berry Curvature Dipole

$$D_{ab} = \int_k f_0(\partial_a \Omega_b).$$

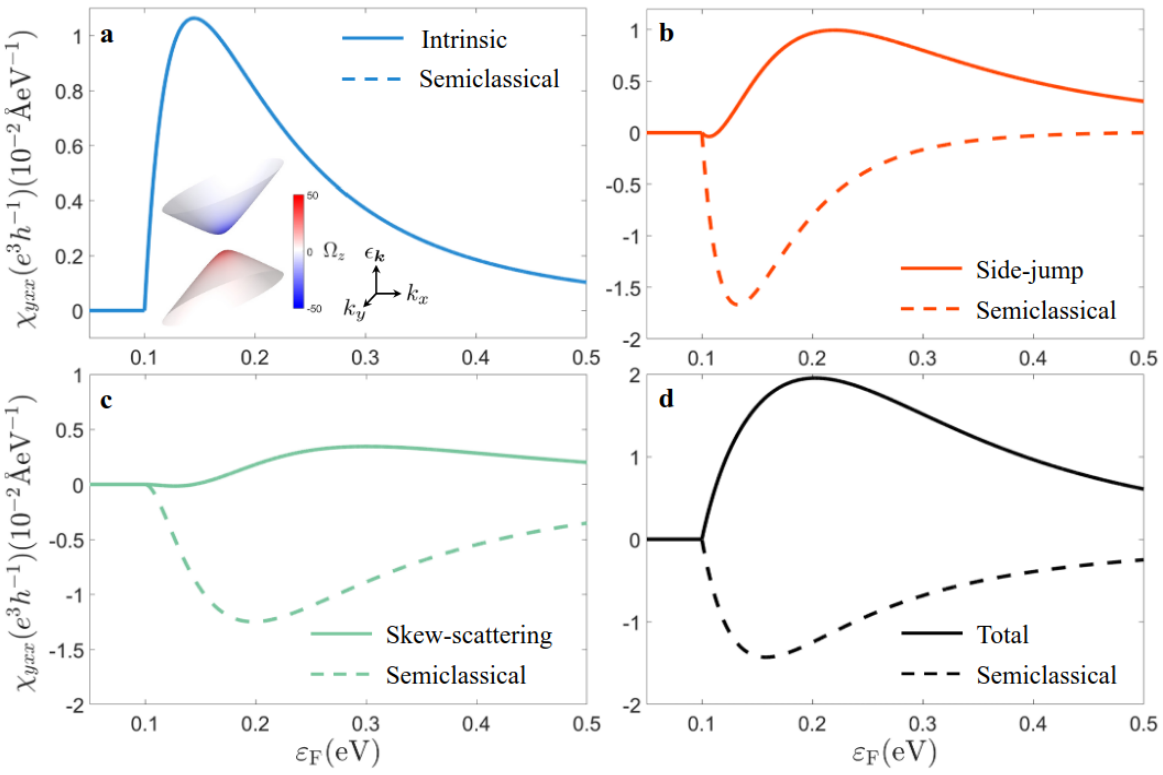
Non-linear Condutivicty Tensor

$$\chi_{\mathrm{abc}} = -\varepsilon_{adc} \frac{e^3 \tau}{2(1 + i\omega\tau)} \int_k f_0(\partial_b \Omega_d).$$



*Plot by Du et al. 'Band Signatures for Strong Nonlinear Hall Effect in Bilayer WTe2'

DISORDER-DRIVEN CONTRIBUTIONS TO NLHE



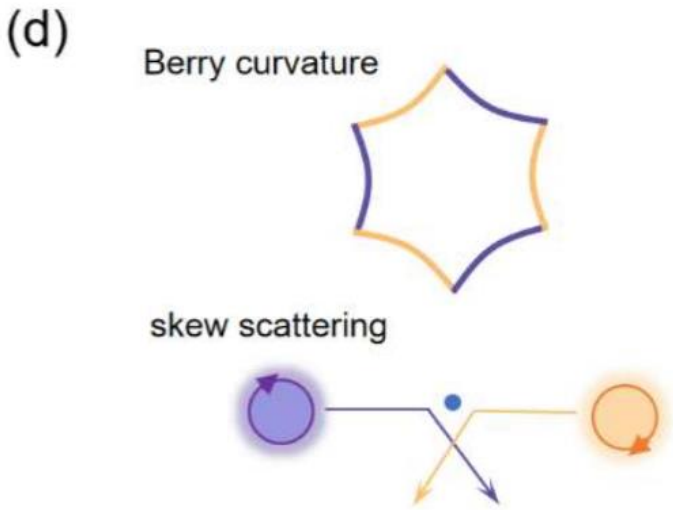
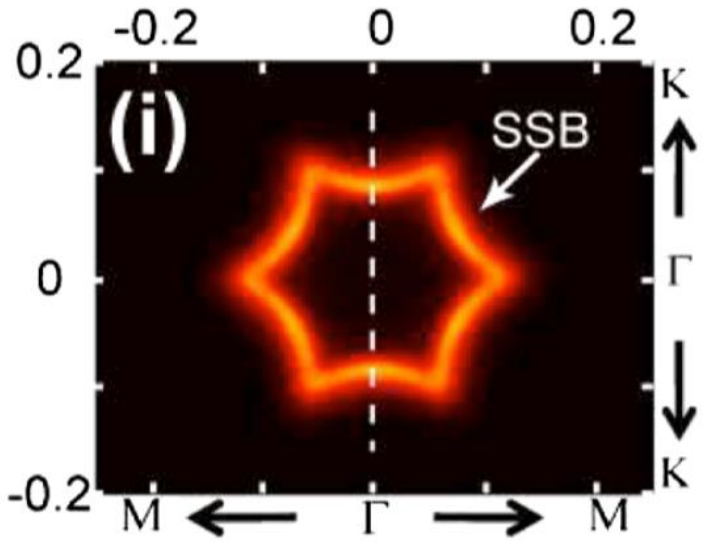


*Illustration of skew-scattering contribution to the NLHE by Shen et al., 'Topological surface state dominated nonlinear transverse response and microwave rectification at room temperature' and plot by Du et al. 'Quantum theory of the nonlinear Hall effect'

BI2TE3 SURFACE STATES, HEXAGONAL WARPING & INVERSION SYMMETRY

$$H(\vec{k}) = E_0(k) + \upsilon_k(k_x\sigma_y - k_y\sigma_x) + \frac{\lambda}{2}(k_+^3 + k_-^3)\sigma_z,$$

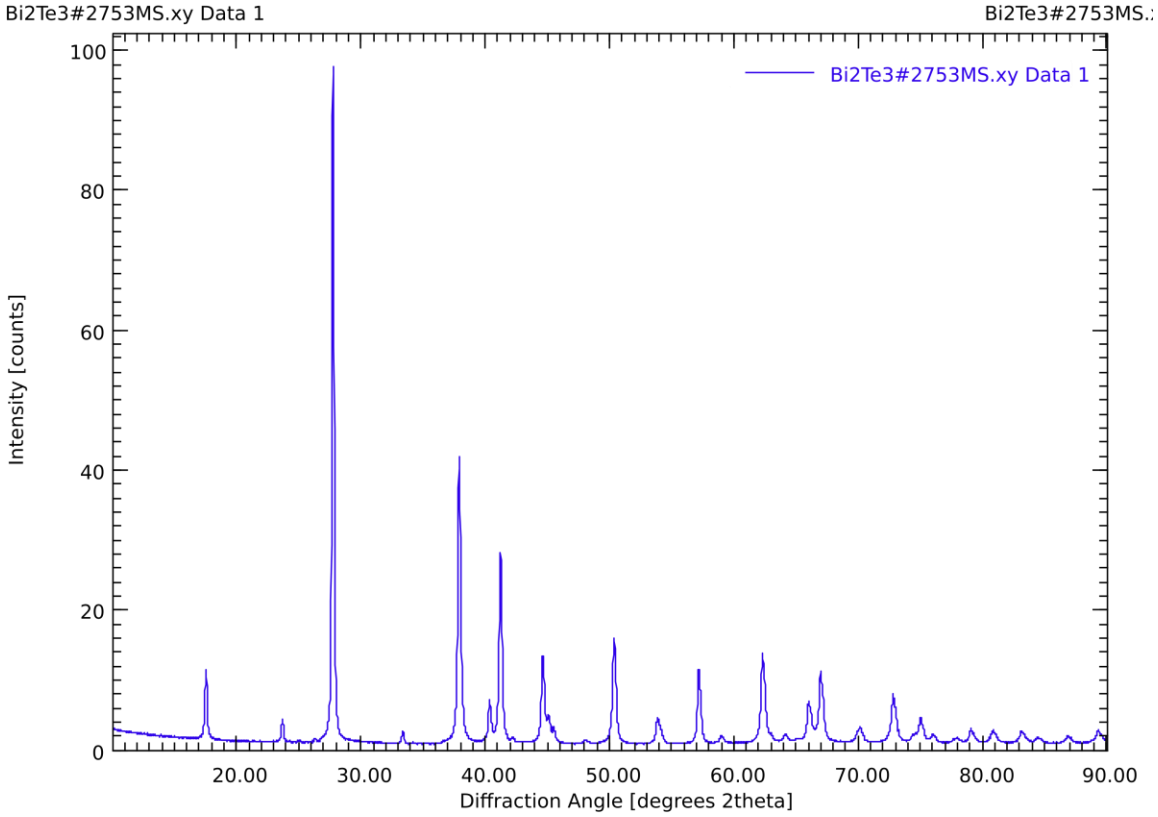
Plot of Fermi surface of Bi2Te3 surface states by Chen et al., 'Experimental Realization of a Three-Dimensional Topological Insulator, Bi2Te3'



PRELIMINAR EXPERIMENTAL WORK

Bi2Te3 Clean Samples

Melt-spinning setup



XRD of melt-spun samples

REFERENCES

• Asbóth et al. 'A Short Course on Topological Insulators';

• Xiao et al. 'Berry phase effects on electronic properties';

• Sodemann et al. 'Quantum Nonlinear Hall Effect Induced by Berry Curvature Dipole in Time-Reversal Invariant Materials';

• Du et al. 'Band Signatures for Strong Nonlinear Hall Effect in Bilayer WTe2';

• Du et al. 'Quantum theory of the nonlinear Hall effect';

• Shen et al. 'Topological surface state dominated nonlinear transverse response and microwave rectification at room temperature';

• Fu, Liang 'Hexagonal Warping Effects in the Surface States of the Topological Insulator Bi 2Te3';

• Chen et al. 'Experimental Realization of a Three-Dimensional Topological Insulator, Bi2Te3'.