Photonic Engineering of Spin-Orbit Synthetic Hamiltonians in Liquid Crystal Cavities

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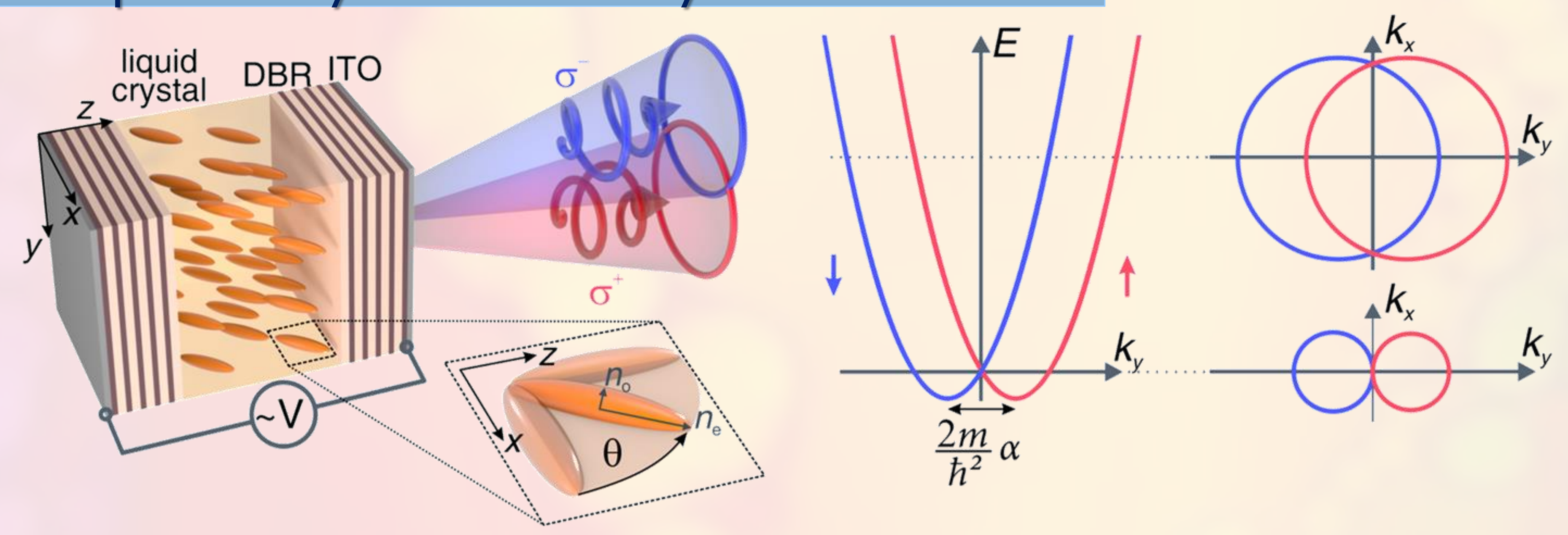
Liquid crystal cavity for SOI



Rashba – Dresselhaus Hamiltonian

Energy E of the cavity modes in a waveguide approximation are solutions of an eigenvalue problem. When the modes of opposite parity are close to degenerate, the equation reads:

$$\left(\frac{\hbar^2k_x^2}{2m_x}+\frac{\hbar^2k_y^2}{2m_y}\right)\mathbf{F}'+(\delta_xk_x^2+\delta_yk_y^2)\hat{\sigma}_z\mathbf{F}'-2\alpha k_y\hat{\sigma}_y\mathbf{F}'+\frac{1}{2}(E_X-E_Y)\hat{\sigma}_z\mathbf{F}'=E\mathbf{F}',$$

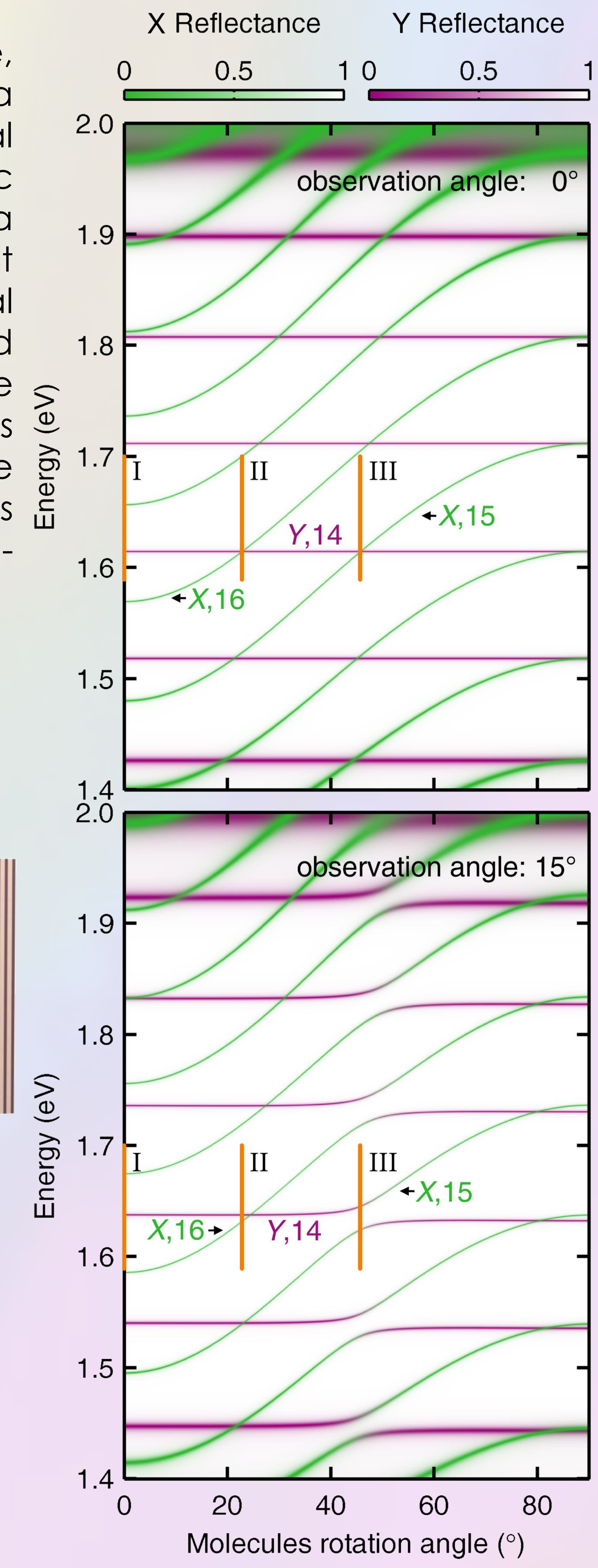
When the modes of the same parity are degenerate, the equation leads to optical spin Hall effect Hamiltonian:

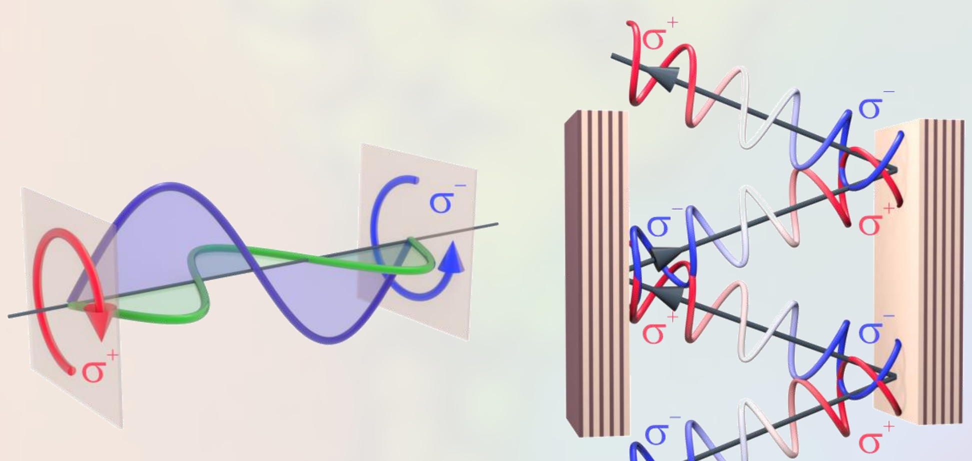
$$\left(\frac{\hbar^2k_x^2}{2m_x}+\frac{\hbar^2k_y^2}{2m_y}\right)\mathbf{F}'+\frac{\hbar^2}{4m_0'}\left(\frac{\varepsilon_{xx}-\varepsilon_{yy}}{\varepsilon_{zz}\varepsilon_{xx}}\right)\left((k_x^2-k_y^2)\hat{\sigma}_z+2k_xk_y\hat{\sigma}_x\right)\mathbf{F}'=E\mathbf{F}'$$

Parity of the photonic modes

In this work we present a tunable, multimode microcavity consisting of a nematic liquid crystalline (LC) optical medium enclosed between two dielectric mirrors. Structure is surrounded by a transparent ITO electrodes to controll the tilt angle of the LC molecules with external voltage, thus energy of the X-polarised cavity mode (E_X). We show that for the energies of the X- and Y- polarised modes with the opposite parity mode number are close to degenerate a coupling term arises between them, which is equal to Rashba-Dresselhaus spin-orbit interaction:

$$\hat{H}_{R\text{–}D}=-2\alpha\hat{\sigma}_zk_y,$$

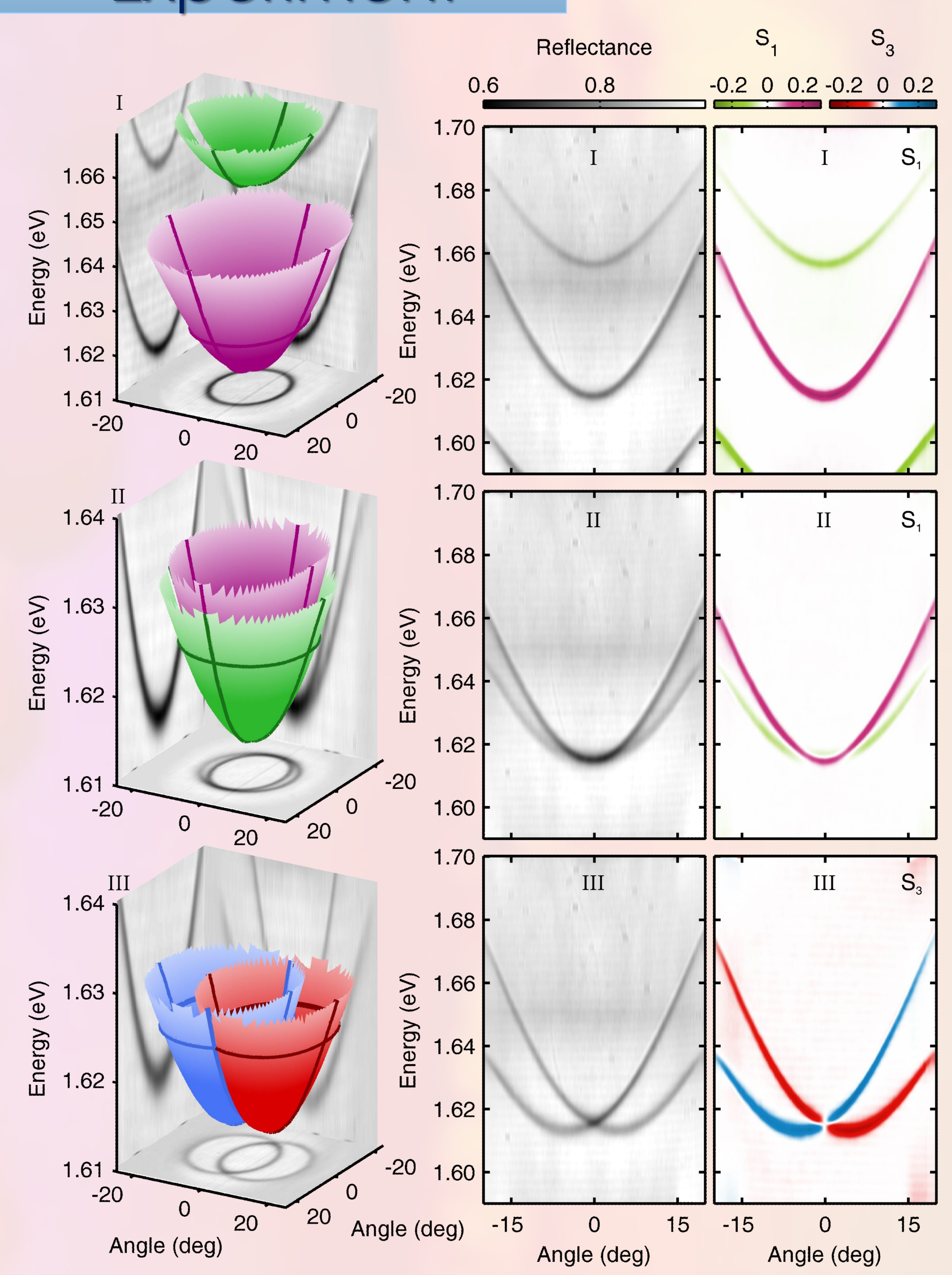




Experiment

Hamiltonian describing experiment:

$$\hat{H}_{exp}=\frac{\hbar^2k_x^2}{2m_x}+\frac{\hbar^2k_y^2}{2m_y}-2\alpha\hat{\sigma}_zk_y+\frac{1}{2}(E_{X,l}-E_{Y,l'})\hat{\sigma}_x$$

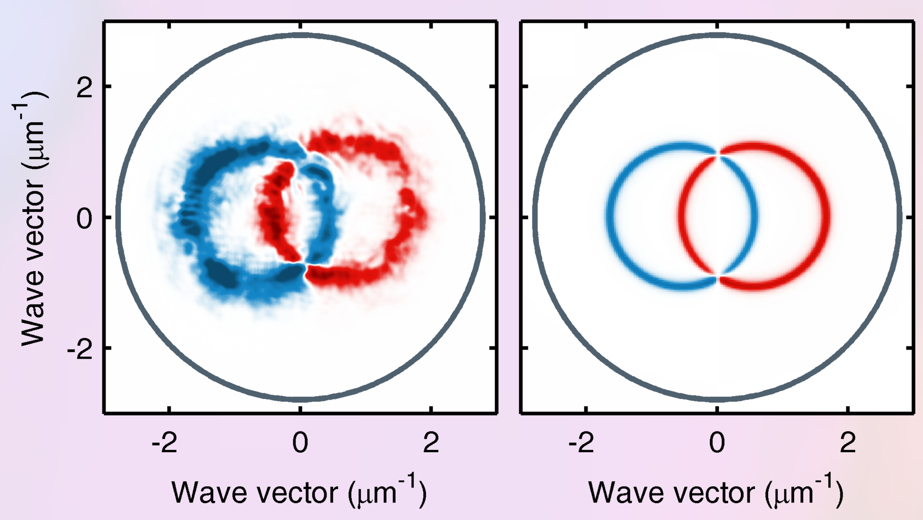


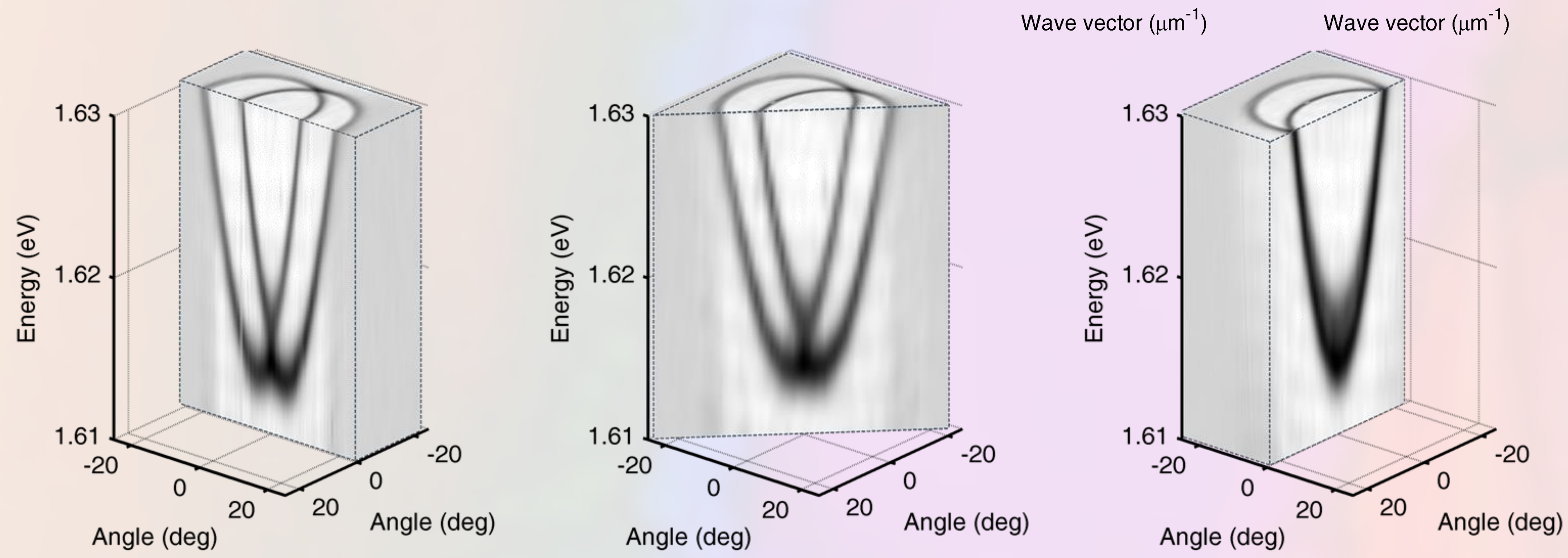
k-space tomography in reflectance configuration at three specific voltages:

I. 0.00 V: Cavity modes are parabolic, polarised linearly in the main axis of the LC molecules.

II. 1.38 V: Parabolic cavity modes of the same parity (14 and 16) are degenerate at k = 0, but retain their initial linear polarizations .

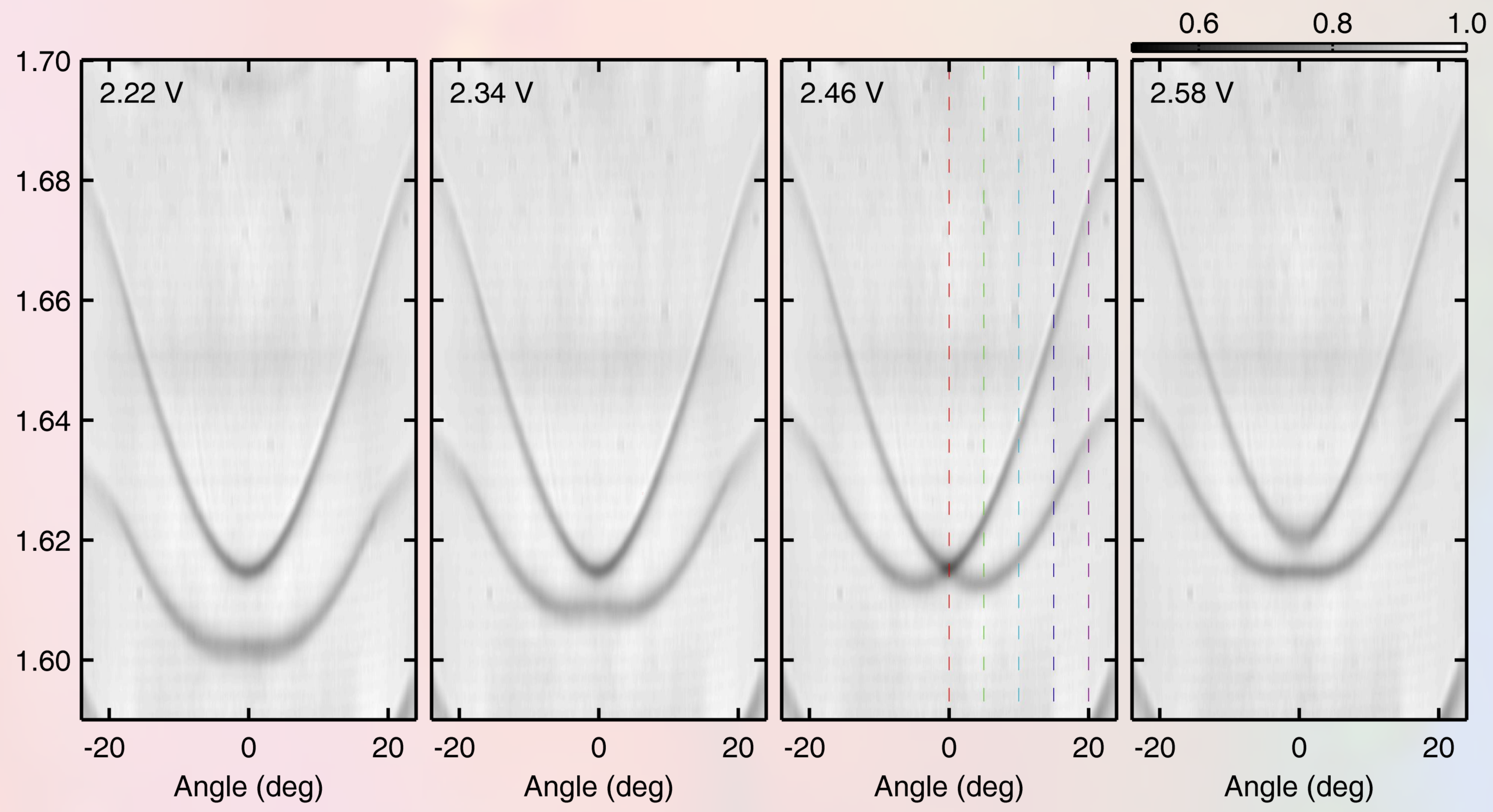
III. 2.48 V: Degenerate at k = 0 cavity modes of opposite parity (14 and 15) reveal Rashba-Dresselhaus coupling between them. Dispersion relation consists of two, circularly polarised parabolas shifted in the reciprocal space.

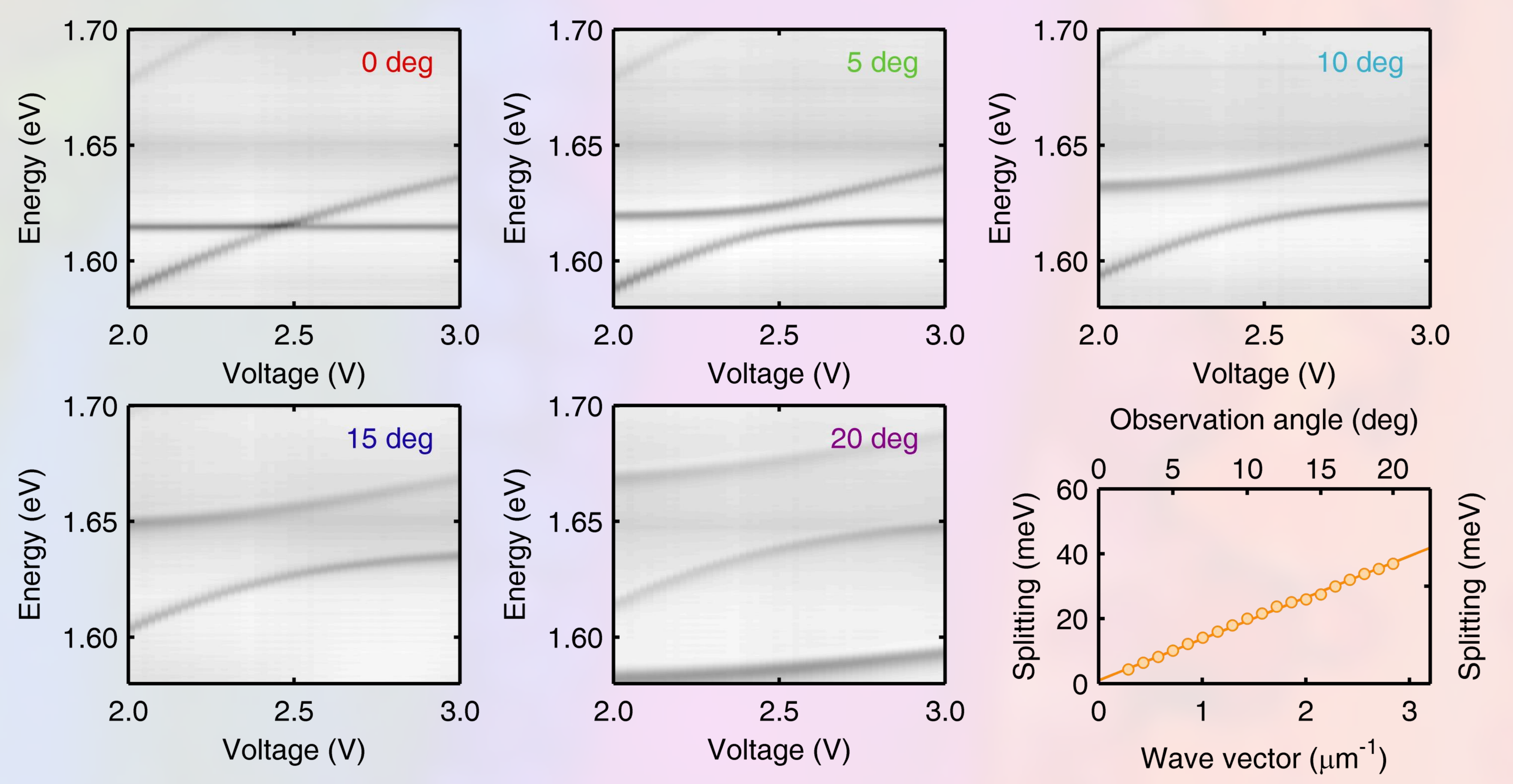




Spin-orbit synthetic Hamiltonians engineering

Coupling strength between the cavity modes of different parity increases linearly with the wavevector.





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