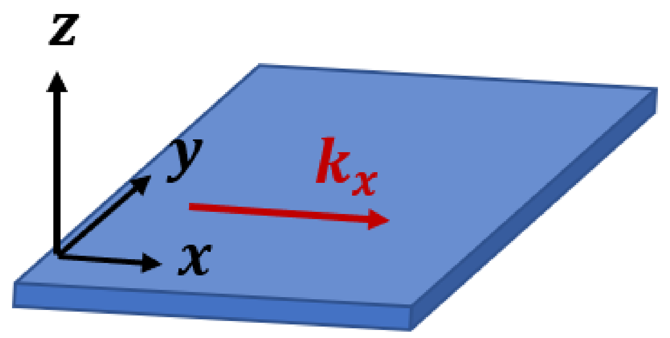
Introduction

Metasurfaces have been studied extensively in recent years as important platforms for controlling and guiding electromagnetic waves. In this poster, we introduce different metasurface designs that allow for controlling and steering different polarizations (spins) of surface waves. We also study a new type of surface waves that is supported by our L-shape design called chiral surface waves which are circularly polarized waves that possess two transverse spins. Controlling the spin-orbit interactions of electromagnetic waves is of great importance for applications in spintronics and valleytronics.

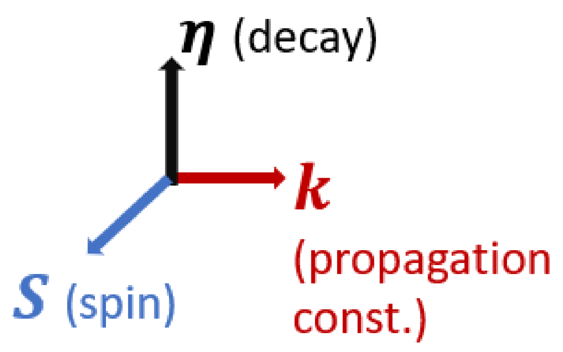
Spin-momentum Locking of Surface Waves

Quantum spin-hall effect of light was recently introduced in surface waves (SWs) which carry transverse spins and evanescent tails. Consider a metasurface with the surface wave propagating along the x$-axis$ and the normal to the surface is along z$-axis$.

This surface wave will have two possible spins (**in-plane transverse** and **longitudinal**) for any TE, TM or hybrid TE-TM mode, its spin is defined using this equation:



$$\mathbf{S} = \mathrm{Im}\left\{\frac{\mathbf{E}^{*}\mathrm{x}\mathbf{E} + \mathbf{H}^{*}\mathrm{x}\mathbf{H}}{W}\right\}$$



$$\mathbf{S} = \left(\frac{\kappa}{k_z}, \frac{2\mathrm{Im}(m)}{1+|m|^2}\frac{k_0}{k_z}, 0\right), \quad m = \frac{\frac{2\pi}{c}\sigma_{yz}}{1 - i\frac{2\pi k_0}{\kappa c}\sigma_{yy}}$$

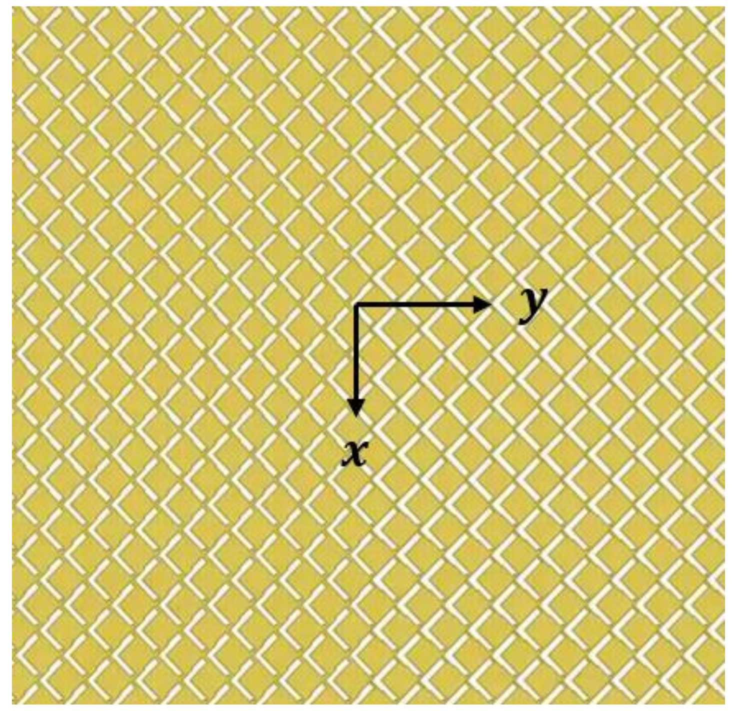
Spin-momentum locking law here is the **right-hand triplet** formed by momentum, k_x, decay, η_z, and spin, S_y. Hence, the only transverse spin that a surface wave has is the in-plane S_y.

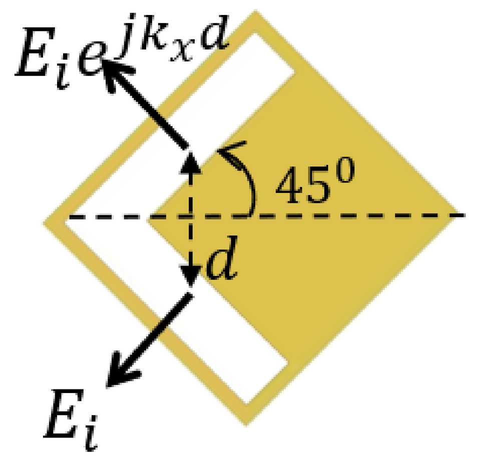
S_z is always zero.

L-shape Metasurface Design for Supporting Chiral Surface Waves

We introduce a metasurface design which supports the **two transverse spins** ($\boldsymbol{S_z \neq 0}$).

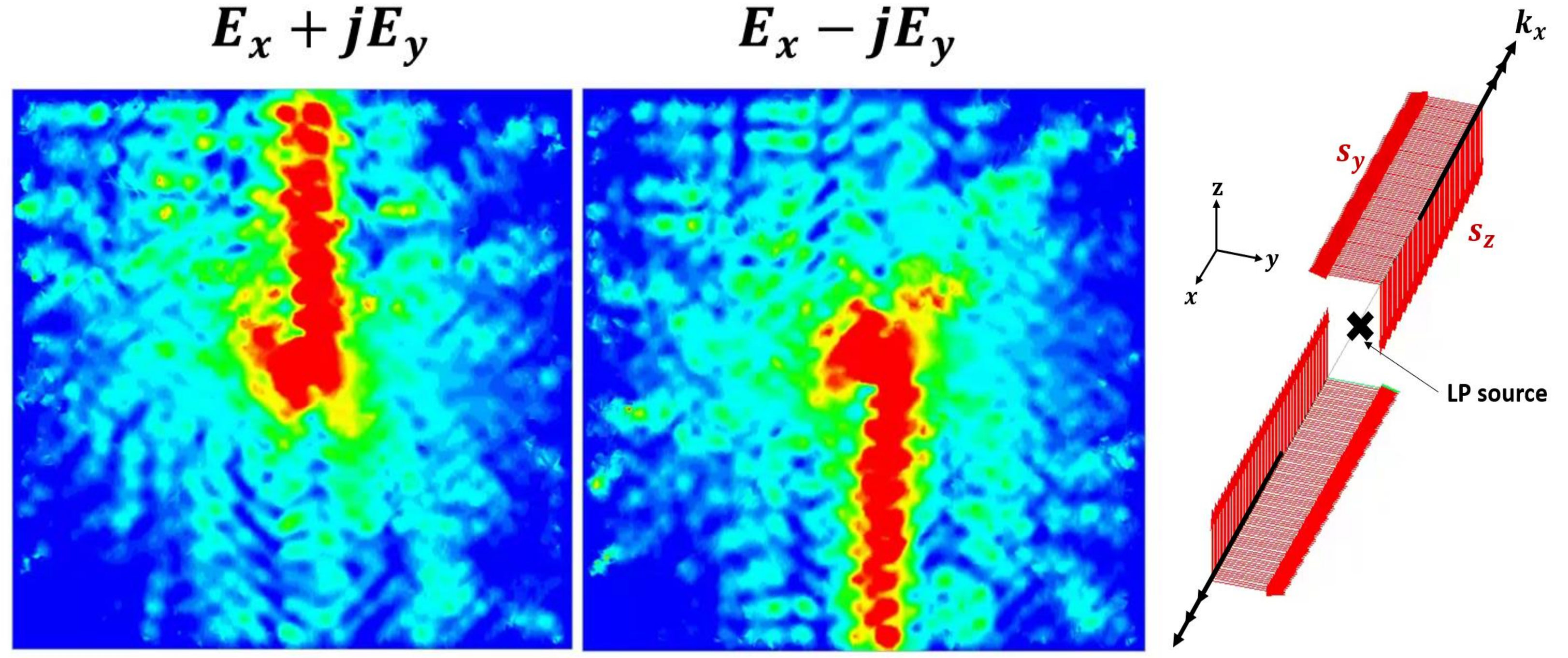
The design consists of rotated L-shape which induces E-fields normal to the two rectangular apertures and can be decomposed into x and y components at phase shift $k_x d$.





d is adjusted such that it forms a 90^0 phase shift when propagating forward. This results in an **in-plane field rotation**. Therefore, produces S_z component.

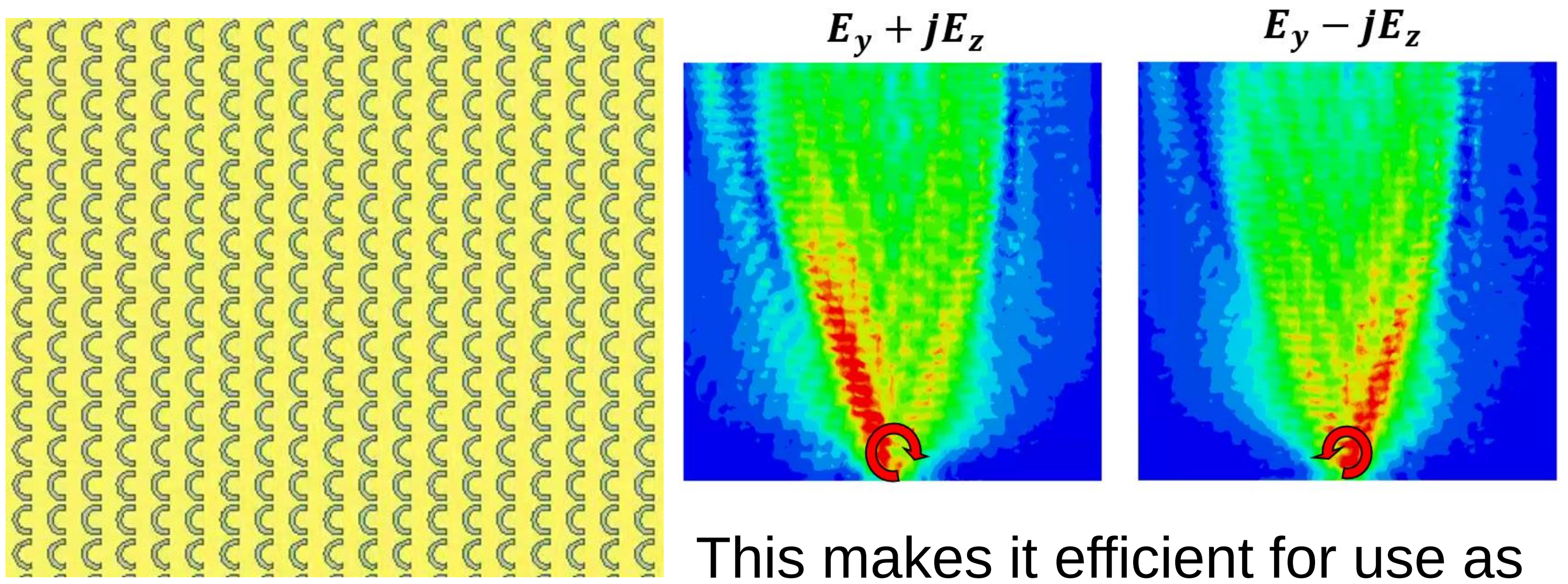
The chiral SW unlike other SWs possesses two transverse spins, one spin (S_y) inherent to any surface wave and the other new spin (S_z) is enforced by the design due to **in-plane field rotation.**



The two transverse spins of the chiral surface wave follow the ***spin-momentum locking*** resulting in a ***unidirectional wave propagation*** when excited at the center.

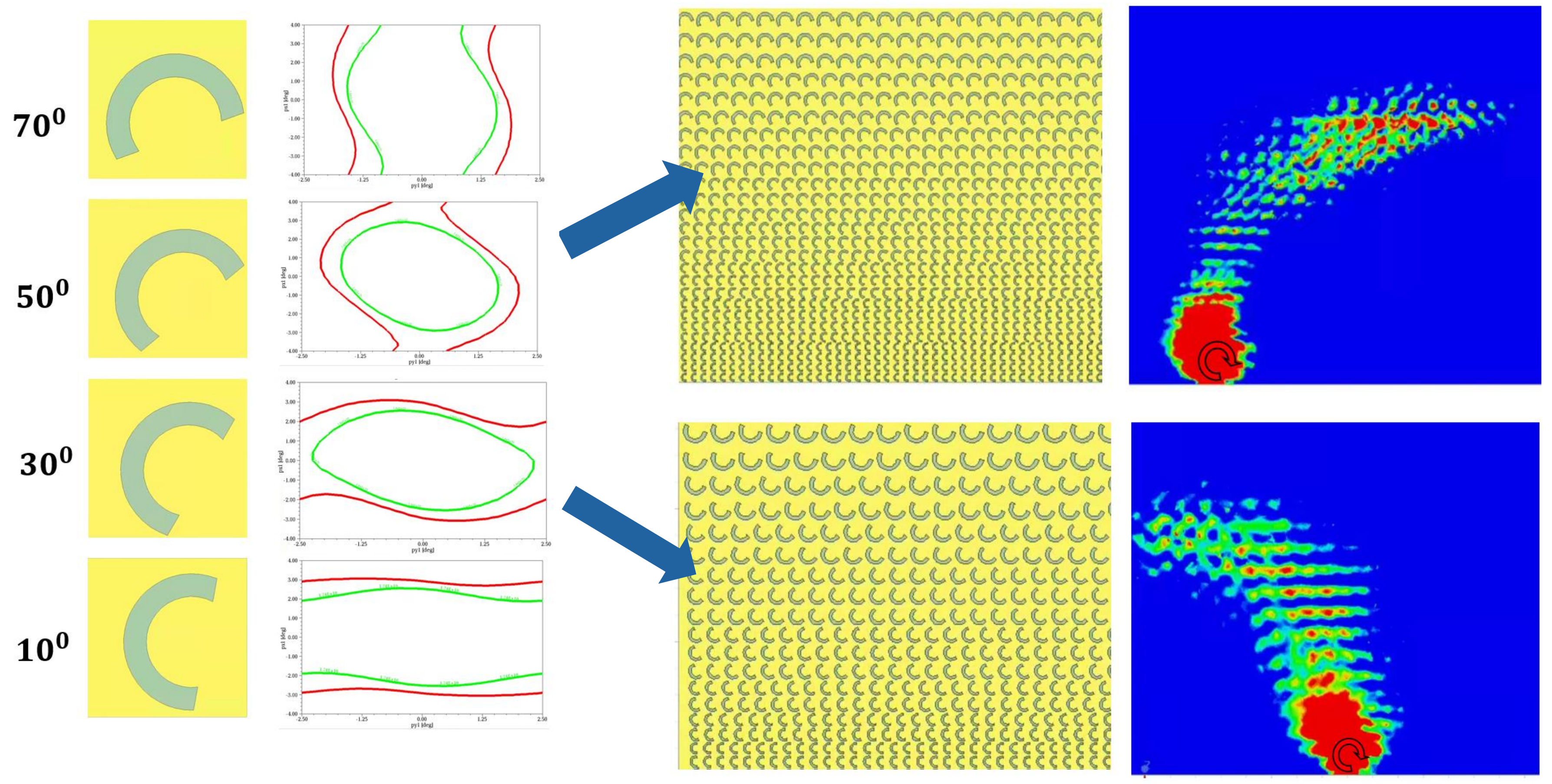
C-shape Metasurface Design for Steering Circularly Polarized Waves

By carefully choosing the c-shape dimensions, one can engineer its equifrequency contour (EFC) to split the linearly polarized wave into two circularly polarized waves of different helicities propagating with different k-vectors along the surface. The spin component we control here is the **longitudinal spin ($\boldsymbol{S_x}$).**



This makes it efficient for use as polarization-based beam splitter.

Engineering the EFCs of the c-shape by rotating and scaling the unit cell can allow for routing surface waves with certain polarization handedness.



The design can be optimized to smoothly route the wave propagation of one helicity along a specified curved path.