FIG. 1

Dispersion relations of magnetized cold plasmas. (**a**) Dispersion relation surfaces of an overdense plasma. Only the $k_\perp > 0$ and $k_z > 0$ part of positive-frequency branches are shown. Different colors represent different branches. (**b**) The dispersion curves $\omega(k_z)$ at fixed $k_\perp$ of an overdense plasma. The colors represent different values of $k_\perp$. Only the crossing of the curves with the same color indicates the crossing of different branches. $\omega_{1,2}/|\Omega| = (\sqrt{4r^2+1} \pm 1)/2$, where $r = \omega_{\rm p}/|\Omega|$. $k^\pm$ are given by equation (4) assuming $\Omega > 0$. (**c**), (**d**) Same as (a),(b) but for an underdense plasma.

FIG. 2

Topological phase diagrams of magnetized cold plasma. (**a**) 3D phase diagram of a cold plasma in the $(\omega_{\rm p}, \Omega, k_z)$ space. There are 10 topological phases. (**b, c**) 2D cross sections of (a) at $\omega_{\rm p} = 1$ and $\Omega = 1$. Only the $k_z > 0$ and $\Omega > 0$ part is shown. Dashed lines indicates $\Omega = \omega_{\rm p}$. Dotted lines indicates $k_z = k^*$. The Roman numerals I-III indicate three different topological phases in each cross section. The band structures and Chern numbers at three black dots in (b) are shown in Fig.3.

FIG. 3

Chern numbers. Chern numbers of each positive frequency bands of the three phases of the phase diagram. Since the dispersion relation is isotropic in (k_x, k_y) plane, only the $k_\perp > 0$ part is shown. The parameters used are $\Omega = 1$ and $(\omega_{\rm p}, ck_z) = (0.4, 1.2)$, $(1.5, 1.2)$, and $(1.5, 0.5)$, which are shown as colored dots in Fig. 2(b).

FIG. 4

The band structures of nonuniform plasmas at $ck_z/|\Omega| = 0.7$. (**a**) Schematic diagram of the density profile in x direction, where $cl/|\Omega| = 40$ and $c\delta/|\Omega| = 4$. (**b**), (**c**) The non-zero components of electric fields of edge modes in (e) at $ck_y/|\Omega| = 0.05$. (**d**)-(**f**) The band structure $\omega(k_y)$ with various inner and outer densities. The plasma frequencies $(\omega_{\rm p,1}, \omega_{\rm p,2})/|\Omega|$ are $(0.8, 0.6), (0.6, 0.4)$, and $(0.4, 0)$ in (d), (e), and (f), respectively. The

topological edge modes on left and right side are shown by blue and red lines, respectively. The rest modes are shown by gray lines. Notice that the critical plasma frequency given by equation (5) is $\omega_{\mathrm{p,c}}/|\Omega| \approx 0.5$.

FIG. 5

Four possible types of Fermi-arc-like structures. (**a-d**) Band structure $\omega(k_z)$ at $k_y = 0$ with different parameters, where Fermi-arc-like structures of edge mode connecting Weyl points. The topological edge modes are highlighted by the red curves. The bulk modes of the inner and outer plasmas when $k_\perp = 0$ are highlighted by orange and blue curves, respectively. The other bulk modes are indicated by gray curves. $k_1^- = k^-(\omega_{\mathrm{p},1})$ and $k_2^- = k^-(\omega_{\mathrm{p},2})$. The plasma frequencies $(\omega_{\mathrm{p},1}, \omega_{\mathrm{p},2})/|\Omega|$ in (a)-(d) are $(0.75, 0), (1.1, 0), (0.75, 0.3)$, and $(1.1, 0.3)$.

FIG. 6

Band structure when two different gaps overlap. In this case, $ck_z/|\Omega| = 1.4$ and the inner and outer plasma frequency are $(\omega_{\mathrm{p},1}, \omega_{\mathrm{p},2})/|\Omega| = (1.4, 0.1)$. The bulk modes of the inner and outer plasma when $k_\perp = 0$ are highlighted by orange and blue curves, respectively. The other bulk modes are indicated by gray curves. The gap between bands 1 and 2 of the inner plasma overlaps with gap between bands 2 and 3 of the outer plasma. However, this band gap is filled with local upper hybrid modes due to continuous density profile.