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Configurable topological beam splitting via antichiral gyromagnetic photonic crystal

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Section 1: Beam splitter based on various physical mechanisms

First, the beam splitter composed of trivial PC waveguide is not topologically protected, intrinsically suffering from great backscattering loss, as seen in Fig. S1(a).

Second, topological photonic valley-Hall states generally exist at the interface between regions with opposite valley-Chern number, thus resulting in selective coupling of valley-dependent edge states. For example, as shown in Fig. S1(b), when left-circularly polarized waves are incident into the upper port, the propagating waves can couple into the lower channel and will couple into the left and right ports because of the phase vortex matching. However, the coupling to upper port is suppressed because the upward channel possesses the opposite phase vortex. Thence, for the topological beam splitters based on topological photonic valley-Hall insulator, they only support the transport of the left-circularly polarized or right-circularly polarized waves, and require more bulk PCs and are difficult to realize configurable energy splitting.

Third, for the topological beam splitters based on topological photonic spin-Hall insulator, they only support the transport of the pseudo spin-down and spin-up waves. Besides, they are similar to the valley-Hall beam splitters that also require more bulk PCs and are difficult to tune the rate of energy splitting. For example, as shown in Fig. S1(c), the shrunken and expanded PCs are trivial and nontrivial PCs possessing the zero and nonzero topological invariants respectively, and the trivial-nontrivial interface supports the pseudo spin-down and spin-up states with opposite propagation directions respectively. When the pseudo spin-down waves are incident into the lower port, the propagating waves can couple into the left and right ports but not couple into the upper port. Because the direction of pseudo spin state in the upper channel is opposite to that in the lower, right, and left channels, indicating that the pseudo spin-down state along the interface is only downward propagation, so the upper channel is closed.

Fourth, in popular chiral GPC structures, the one-way edge state is topologically protected but only flows along one direction, rendering beam splitter not possible, as plotted in Fig. S1(d). Furthermore, for a compound chiral GPC consisting of two rectangular GPCs magnetized oppositely, the same edge of these two GPCs might support oppositely propagating one-way edge states. However, attributed to the existence of chirality, the two parallel edge states of each GPC propagate in opposite directions, so that two parallel zigzag edges support the edge states transporting outwards

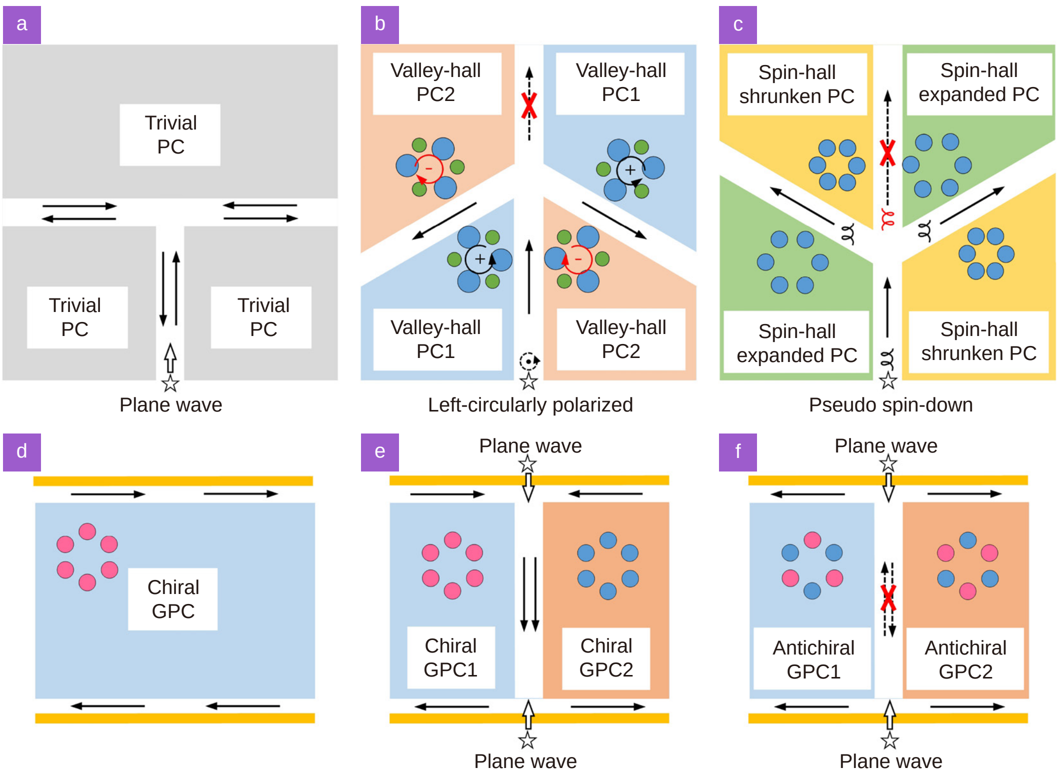

Fig. S1 | Beam splitter based on various physical mechanisms.

and inwards respectively, thereby making dual-edge four-channel topological beam splitter impossible. Besides, due to the existence of one-way edge state at armchair interface, the two zigzag edges will be connected with each other, inducing inevitable crosstalk, as illustrated in Fig. S1(e). Therefore, only the beam splitter based on antichiral GPC holds all the excellent characteristics, owing to the fact that the antichiral GPC only supports the antichiral one-way edge state at the zigzag edge while does not support any edge state at the armchair edge, as seen in Fig. S1(f). These comparisons clearly indicate the uniqueness of current antichiral GPC in constructing this novel topological beam splitter for allocating energy into two and more one-way edge state channels with topological robustness and arbitrarily configurable energy allocation ratio via simple excitation condition change.

To make a clear comparison, Table S1 shows the characteristics of beam splitters based on various physical mechanisms, including trivial PC, topological valley-Hall PC, topological spin-Hall PC, chiral GPC, and antichiral GPC. Obviously, only the beam splitter based on compound antichiral GPC holds all the excellent characteristics, owing to the antichiral GPC only supports the antichiral one-way edge state at the zigzag edge while does not support any edge state at the armchair edge.

Table S1 | Characteristics of beam splitters based on various physical mechanisms.

System	Multi-channel	Crosstalk-proof	Compact	Configurable	Topologically-protected
Trivial PC	Yes	Yes	No	No	No
Valley-Hall PC	Yes	Yes	No	No	Yes
Spin-Hall PC	Yes	Yes	No	No	Yes
Chiral GPC	No	No	Yes	Yes	Yes
Antichiral GPC	Yes	Yes	Yes	Yes	Yes