One way traffic of wave propagations

Waves in waveguides can usually travel in both ways. When the conditions for coherent perfect channeling (CPC) are met, waves travel only in one way. The schematics of the three-waveguide system CPC are shown in Figure 1(a). Three waveguides are joined at the junction where a scatterer is placed. The scatterer for CPC is mounted on the entrance of waveguide-3, and consists of a rubber sheet (purple) tightly mounted on a rigid frame, and decorated by a rigid platelet (golden color). Usually, when an incoming wave (towards the junction) reaches the junction, the scatterer (blue sphere) would send outgoing waves (away from the junction) in all three waveguides. So all waveguides are like two-way streets. As illustrated in Figure 1(b) for CPC, however, when two identical incoming waves (red arrows) in waveguide-1 and waveguide-2 meet at the junction, the scatterer is highly excited if the wave frequency matches its resonant frequency, and it 'sucks' in the incoming waves and channels them to waveguide-3. The incoming wave in waveguide-1 can only turn left to waveguide-3. Moving downwards along waveguide-2 or upwards in waveguide-1 is forbidden. Similarly, the incoming wave in waveguide-2 can only turn right to waveguide-3. This happens only when both incoming waves are present, and they must be 'coherent', i. e., identical, and the channeling is 'perfect', i. e., all incoming waves are channeled to waveguide-3 without loss. So in CPC, waveguide-1 and waveguide-2 are like one-way streets.

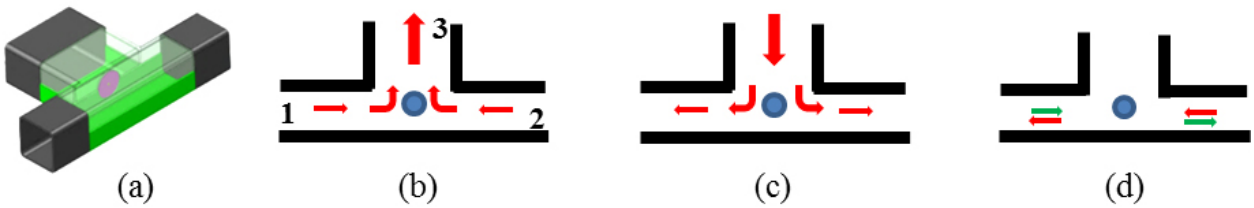

Fig. 1.

The reverse CPC is depicted in Figure 1(c). In this case, the incoming wave in waveguide-3 is split into two identical outgoing waves traveling along waveguide-1 and waveguide-2, respectively. Waveguide-3 is like a one-way street in reverse CPC.

If the incoming waves are of opposite phase to one another, as marked by the red and the green arrows in Figure 1(d), the wave intensity will be exactly zero at the scatterer. The scatterer then acts like a hard wall and no waves in the main waveguides can enter waveguide-3, which becomes a one-way street in the opposite direction as in Figure 1(c). CPC is turned off.

Electromagnetic waves (light) and quantum wavefunctions of electrons (and other microscopic particles) share the same mathematical equation as acoustic waves in waveguides. Our acoustic CPC sets an example and lays down the *necessary* conditions for the scatterers to realize CPC for

these waves. For an incoming wave in either waveguide-1 or waveguide-2, the scatterer must split it in such a way that 25% of the total energy (or intensity) of the incoming wave is in each of the outgoing waves in waveguide-1 and waveguide-2, while 50% of the energy is in waveguide-3. For acoustic waves we used a monopole scatterer, but for other waves one could use different scatterers that split the incoming wave in such ratio.

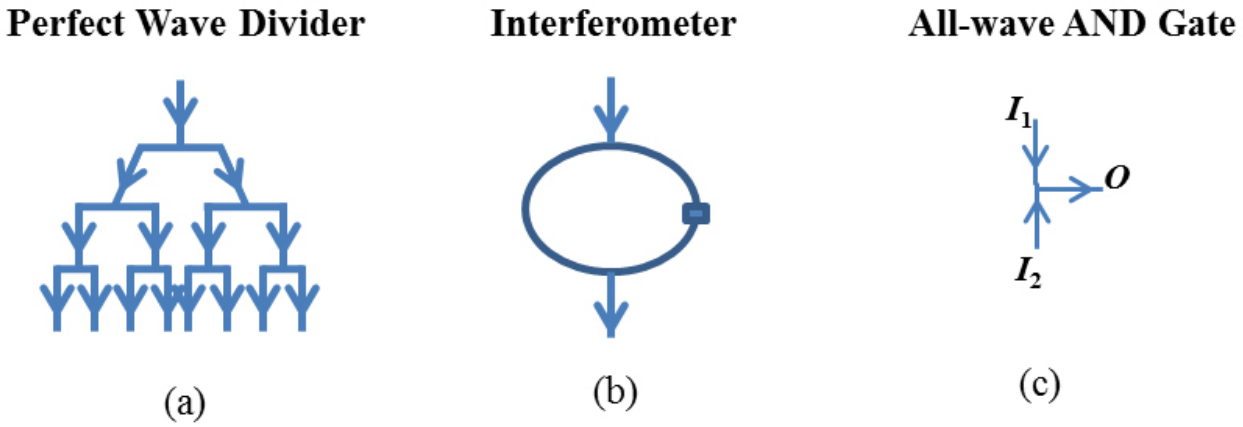

Fig. 2.

Figure 2 depicts three possible application schemes. In Figure 2(a) a perfect wave divider is depicted that splits one input wave into 8 identical waves. In Figure 2(b) a high sensitivity interferometer is depicted. The input wave is first divided into two identical ones at the top junction, which then meet again at the bottom junction. Any change of the wave in the right channel due to imperfection (the blue block) would break the CPC conditions and lead to residue waves in the otherwise one-way streets, which can be detected with high sensitivity. Figure 2(c) shows an all-wave logic AND gate, in that the output 'O' is '1' only when both inputs 'I_1' and 'I_2' are '1'. All input energy is turned into output with zero loss.

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