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Ultra-Compact 90° Twist Based on a Pair of Two Closely Placed Flat Chiral Irises

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Abstract—A new ultra-compact device for rotating the polarization plane of planar electromagnetic wave in a square waveguide by 90° whose dimension is almost ten times less than wavelength is suggested. It is based on strong interaction of near-fields in two closely placed flat chiral irises. It is shown that this approach due to strong multi-mode and near-field interaction allows rotating the polarization plane by 90° in the several percent bandwidth with the loss level not worse than 0.1 dB.

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A waveguide twist is used in microwave devices for rotating the polarization plane of electromagnetic wave by the needed angle in the whole operating frequency of a square waveguide while providing insignificant reflection losses. A disadvantage of such structure is its significant length. Recently several attempts were made to create a more compact twist [1], but they lack broad operating bandwidth. Devices that rotate the polarization plane of a dominant mode in rectangular waveguide are also well-known and are based on arranging the needed 180° differential phase shift between the two orthogonal components. The latter ones may propagate along different paths in waves with different propagation constants or along the long path for some component in reflection-based devices. Another type of polarization plane rotating devices is based on using special properties of propagation media, for instance, the Faraday effect when waves with right and left polarizations propagate with different phase velocities. Anyway, the longitudinal dimension of the known devices for rotating the polarization plane is compared to the wavelength. Further we suggest an ultra-compact device for rotating the polarization plane of electromagnetic wave in a square waveguide, whose longitudinal dimension is much (at least an by an order) less that wavelength. It is designed on the basis of a composite element that consists of two closely placed chiral irises, which strongly interact in near-field.

A medium that contains mirror-asymmetrical elements (molecules, crystals) is considered chiral in optics. In our case by flat chiral object we mean a waveguide iris possessing rotational symmetry, for instance, of the fourth order C_4 [2], which at the same time does not have a symmetry plane (Fig. 1a). Such iris possesses easily predicted resonant properties and does not show any "optical activity". This term in optics refers to rotation of the wave's polarization plane during propagation in natural media, which are called chiral due to special properties of their molecules. Such media exist in nature or may be created artificially like, for example, meta-material consisting of micro-helices [3].

Among the objects that cause optical activity the flat chiral ones form a separate "provoking" class, because by these objects by themselves do not transform the wave's polarization, which may be easily proven using the reciprocity principle. However being placed near other objects they may cause rotation of the polarization plane. Auxiliary (to flat chiral) elements causing optical activity may be rather different and in waveguide problems may be classified as follows based on the reflection matrix:

– dielectric layer (does not cause interaction of waveguide modes with each other);

– double step of the waveguide cross-section's dimension (there is no interaction between waves of different groups of symmetry);

– another chiral element with the same or the opposite chirality sign (spectrum of waves in the interaction space is denser, but gets rather special [4]).

Among the common properties of the phenomenon we should point out that fact that there is always no cross-polarization dominant component in the reflected wave, while presence of longitudinal symmetry in