Polarization Deflector in $\mathcal{P}\cdot\mathcal{T}\cdot\mathcal{D}$ - Symmetric Geometry – Part I: Theory

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$\mathcal{P}\cdot\mathcal{T}\cdot\mathcal{D}$-symmetric systems are known to eliminate reflections within a given incident mode [1]. Specifically, for a given arbitrary incident mode $f^+(r)$, the theory in [1] guarantees that this wave cannot backscatter into the ``companion'' mode defined as $\tilde{f}(r)=\tilde{\mathcal{T}}\cdot f^+(r')$, with $r'=V\cdot r$, where $\tilde{\mathcal{T}}=\mathcal{P}\cdot\mathcal{T}\cdot\mathcal{D}$ is the operator obtained by the composition of parity, time-reversal, and duality operators:

$$\tilde{\mathcal{T}}=\mathcal{P}\cdot\mathcal{T}\cdot\mathcal{D}=\begin{pmatrix}0 & \eta_0\mathbf{V}\\ -\eta_0^{-1}\mathbf{V} & 0\end{pmatrix}\mathcal{K},\quad \mathbf{V}=\begin{pmatrix}\mathbf{1} & \mathbf{0} & \mathbf{0}\\ \mathbf{0} & \mathbf{-1} & \mathbf{0}\\ \mathbf{0} & \mathbf{0} & \mathbf{1}\end{pmatrix}, \tag{1}$$

where $\mathcal{K}$ is the complex conjugation operator, and $\mathbf{V}$ is the y - coordinate inversion operator.

The effect of applying the $\mathcal{P}\cdot\mathcal{T}\cdot\mathcal{D}$ operator on a linear polarized incident polarization state $\mathbf{e}_0^+$ is seen in Fig. 1. The polarization direction ϕ^+ is rotated by $\tilde{\mathcal{T}}$ into $\tilde{\phi}$ by the amount $-2\phi^{\pm}90^0$ and $\tilde{\mathbf{e}}_0\cdot\hat{\boldsymbol{\eta}}=\mathbf{e}_0^+\cdot\hat{\boldsymbol{\eta}}$. The polarization direction is mirror-transformed by the $\mathcal{P}\cdot\mathcal{T}\cdot\mathcal{D}$ object. In the special cases of $\phi^+=45^0,135^0$ defining the coordinates (ξ,η), the directions of $\mathbf{e}_0^+$ and $\tilde{\mathbf{e}}_0$ coincide and no rotation occurs. These are the polarization "eigenstates" of the $\mathcal{P}\cdot\mathcal{T}\cdot\mathcal{D}$ operation, for which the co-polarized reflection coefficients vanish. Because a $\mathcal{P}\cdot\mathcal{T}\cdot\mathcal{D}$ system does not allow back-scatter towards the $\tilde{\phi}$ direction, the reflected wave $\mathbf{E}^-$ must be perpendicular to $\tilde{\mathbf{e}}_0$. Thus, unlike conventional mirrors (e.g., metallic or dielectric mirrors), a $\mathcal{P}\cdot\mathcal{T}\cdot\mathcal{D}$ mirror reverses the absolute sense of rotation of the reflected electric field compared to the incident field. Note that for a conventional mirror, the spin angular momentum direction is the same for both the incident and reflected waves, so that an RCP wave is reflected into a left-circularly polarized (LCP) wave, and vice versa.

Simulations and experiment verify the viability of the device, see [2].

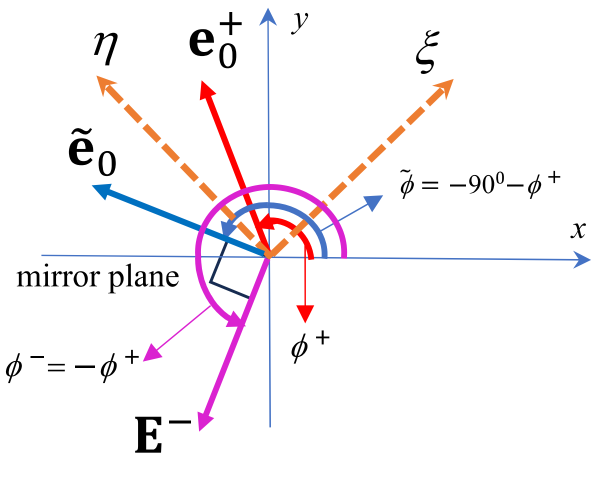

Figure 1. Polarization deflection with a $\boldsymbol{\mathcal{P}\cdot\mathcal{T}\cdot\mathcal{D}}$ symmetric medium.

References

[1] M. G. Silveirinha, "$\mathcal{P}\cdot\mathcal{T}\cdot\mathcal{D}$ Symmetry Protected Scattering Anomaly in Optics," *Physical Review* **B** 95 (2017).

[2] Roee Geva, Mário G. Silveirinha and Raphael Kastner, "Polarization Deflector in $\mathcal{P}\cdot\mathcal{T}\cdot\mathcal{D}$ - Symmetric Geometry – Part II: Experiment and Reconfigurability," This Symposium, Session S14.