Magneto – optical detection of time-reversal symmetry breaking in antiferromagnets

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Optical probes are naturally well suited to detecting broken symmetries, including time-reversal symmetry ($\mathcal{T}$), and are frequently used in this way, for example, to map ferromagnetic domains. But the conditions under which optics can detect $\mathcal{T}$ - breaking in antiferromagnets with no net magnetization are far more subtle. The key distinction is whether the effect of $\mathcal{T}$ can be undone by a simple translation ($\mathcal{S}_{1/2}$); if it can, the product $\mathcal{T}\mathcal{S}_{1/2}$ is a symmetry of the system and $\mathcal{T}$ - breaking is usually invisible to bulk probes. In contrast, antiferromagnets that do not preserve $\mathcal{T}\mathcal{S}_{1/2}$ display a range of bulk $\mathcal{T}$- breaking phenomena, such as the magnetoelectric and piezomagnetic effect.

But what exactly does “bulk” mean? And more specifically, are optical probes “bulk”: can they detect $\mathcal{T}$-breaking in $\mathcal{T}\mathcal{S}_{1/2}$ - invariant antiferromagnets? We address these questions by comparing three antiferromagnets: non-collinear $EuIn_2As_2$ and altermagnetic MnTe that break $\mathcal{T}\mathcal{S}_{1/2}$ and $MnBi_2Te_4$ that does not. In $EuIn_2As_2$ we show how an unconventional optical probe, linear magneto-birefringence, can reveal symmetry breaking invisible to more standard measurements [1-3]. In MnTe, simultaneous measurements of linear and circular dichroism reveal microscopic orientation of the $\mathcal{T}$ - breaking order parameter [4]. In $MnBi_2Te_4$, we demonstrate how perhaps the most standard optical probe of magnetism, reflection circular dichroism, can in fact detect antiferromagnetism even when $\mathcal{T}\mathcal{S}_{1/2}$ is preserved in the bulk [5].

Together, these experiments demonstrate both the power and the versatility of optics as a probe of symmetry breaking in quantum materials.

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