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Unidirectional THz radiation propagation in BiFeO3.

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The mutual coupling between magnetism and electricity present in many multiferroic materials permit the magnetic control of the electric polarization and the electric control of the magnetization. These static magnetoelectric (ME) effects are of enormous interest: The ability to write a magnetic state current-free by an electric voltage would provide a huge technological advantage. However, ME coupling changes the low energy electrodynamics of these materials in unprecedented way – optical ME effects give rise to unidirectional light propagation as recently observed in low-temperature multiferroics. The transparent direction can be switched with dc magnetic or electric field, thus opening up new possibilities to manipulate the propagation of electromagnetic waves in multiferroic materials. We studied the unidirectional transmission of THz radiation in BiFeO3 crystals, the unique multiferroic compound offering a real potential for room temperature applications. The electrodynamics of BiFeO3 at 1THz and below is dominated by the spin wave modes of cycloidal spin order. We found that the optical magnetoelectric effect generated by spin waves in BiFeO3 is robust enough to cause considerable nonreciprocal directional dichroism in the GHz-THz range even at room temperature. The supporting theory attributes the observed unidirectional transmission to the spin-current-driven dynamic ME effect. Our work demonstrates that the nonreciprocal directional dichroism spectra of low energy excitations and their theoretical analysis provide microscopic model of ME couplings in multiferroic materials. Recent THz spectroscopy studies of multiferroic materials are an important step toward the realization of optical diodes, devices which transmit light in one but not in the opposite direction.