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Magnetic excitations and optical transitions in the multiferroic spin-$\frac{1}{2}$ system $LiCu_2O_2$

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A class of materials where multiferroicity can exist are spin cycloidal compounds. $LiCu_2O_2$ is the first copper-based multiferroic material where spin cycloidal and polar orders develop simultaneously and is also one of the very few spin-$\frac{1}{2}$ multiferroics. Coupled ferroelectric and magnetic orders in multiferroics can lead to strong mixing between phonons and magnons rendering some magnons electric dipole active. These electroactive magnons or electromagnons can give, due to their low resonance frequency, significant contribution to the static dielectric constant. We explore magnetic excitations in $LiCu_2O_2$ using THz absorption spectroscopy in magnetic fields up to 30 T. Below the cycloidal ordering temperature, T=24 K, eight optically active transitions are observed in the spin system of $LiCu_2O_2$ in the range from 4 to 30 cm^{-1}. In magnetic field the number of modes increases, some modes anticross and the electric polarization flop is seen as a change in magnetic field dependence of mode energies. The polarization dependence of two of the modes fits the selection rules for the spin cycloid tilted from the *bc* plane. For the remaining six modes electric and magnetic dipole approximations cannot explain the observed polarization dependence. The electromagnon is not directly seen in the explored energy range although there is evidence that it could exist below 4 cm^{-1}. Comparisons will be made to non-multiferroic isostructual spin cycloidal compound $NaCu_2O_2$.