Flying donuts: toroidal electromagnetic excitations in matter and free space

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The toroidal dipole is a localized electromagnetic excitation, distinct from the magnetic and electric dipoles. While the electric dipole can be understood as a pair of opposite charges and the magnetic dipole as a current loop, the toroidal dipole corresponds to currents flowing on the surface of a torus. Toroidal dipoles provide physically significant contributions to the basic characteristics of matter including absorption, dispersion and optical activity. Toroidal excitations also exist in free space as spatially and temporally localized electromagnetic pulses propagating at the speed of light and interacting with matter. We review recent experimental observations of resonant toroidal dipole excitations in metamaterials and the discovery of anapoles, non-radiating charge-current configurations involving toroidal dipoles. While certain fundamental and practical aspects of toroidal electrodynamics remain open for the moment, we envision that exploitation of toroidal excitations can have important implications for the fields of photonics, sensing, energy and information.

References

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