Twisted electromagnetic beams
Swedish Institute of Space Physics and Uppsala University

Electromagnetic radiation can carry angular momentum both as polarization (spin) and orbital angular momentum (OAM). Whereas polarization is a well-known property of electromagnetic waves, OAM is relatively unexplored degree of freedom for the radiation.

Electromagnetic beams that carry OAM appear twisted. The twist can be used to interact with matter, such as a plasma in space. Further, twisting enables the transfer of significantly more information than with regular beams. Even single photons can carry a twist, in addition to their spin.

Hall effect in gradient-index medium
The Hall effect is a transverse deviation of a beam due to its angular momentum content. Our PhD student Erik Nordblad has studied analytically and numerically the Hall effect of a conical non-paraxial Bessel beam in a weak refractive index gradient in an isotropic medium with the gradient transverse to the beam direction.

The twisted Bessel beam is modelled by decomposing the beam into plane wave modes and treating the refraction of each mode separately by applying geometrical optics. Then superposing the refracted modes, we obtain the transverse shift of the entire beam.

The transverse shift of the main cone of the beam:

\[
\frac{dy}{dz} = \frac{G}{k} \left( -\sigma + \frac{l - 3s}{4} \theta^2 \right)
\]

where \(\sigma = \pm 1\) denotes the spin and \(\theta\) is the inclination of the wave vectors \(k\). In the case of only spin angular momentum \((l=0)\), the results agree with previous, paraxial theory (Liberman & Zel’dovich, Phys. Rev. A, 46, 5199, 1992). In the OAM case \((l\neq 0)\), however, there are discrepancies which are yet to be fully understood.

Radio beam experiments
Whereas laser beams have been twisted for two decades, it has only recently been possible to produce radio beams with a twist. The first experiments were performed by us at the High frequency Active Auroral Research Program (HAARP) in Alaska, USA, in which a powerful beam was transmitted into the ionosphere and the excited plasma turbulence was studied.


\(l = \text{OAM quantum number which measures azimuthal phase shift around beam axis.}\)

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Incoherent scatter radar experiments
The first experiments with twisted incoherent scatter radar beams were performed in the autumn of 2010 with the Poker Flat incoherent scatter radar in Alaska. One purpose was to observe vortex structures in the aurora. The data is currently being analyzed.

Poker Flat Incoherent Scatter Radar in Alaska (from amisr.com).

Present PhD student (supervisor)
Erik Nordblad (Thomas Leyser)