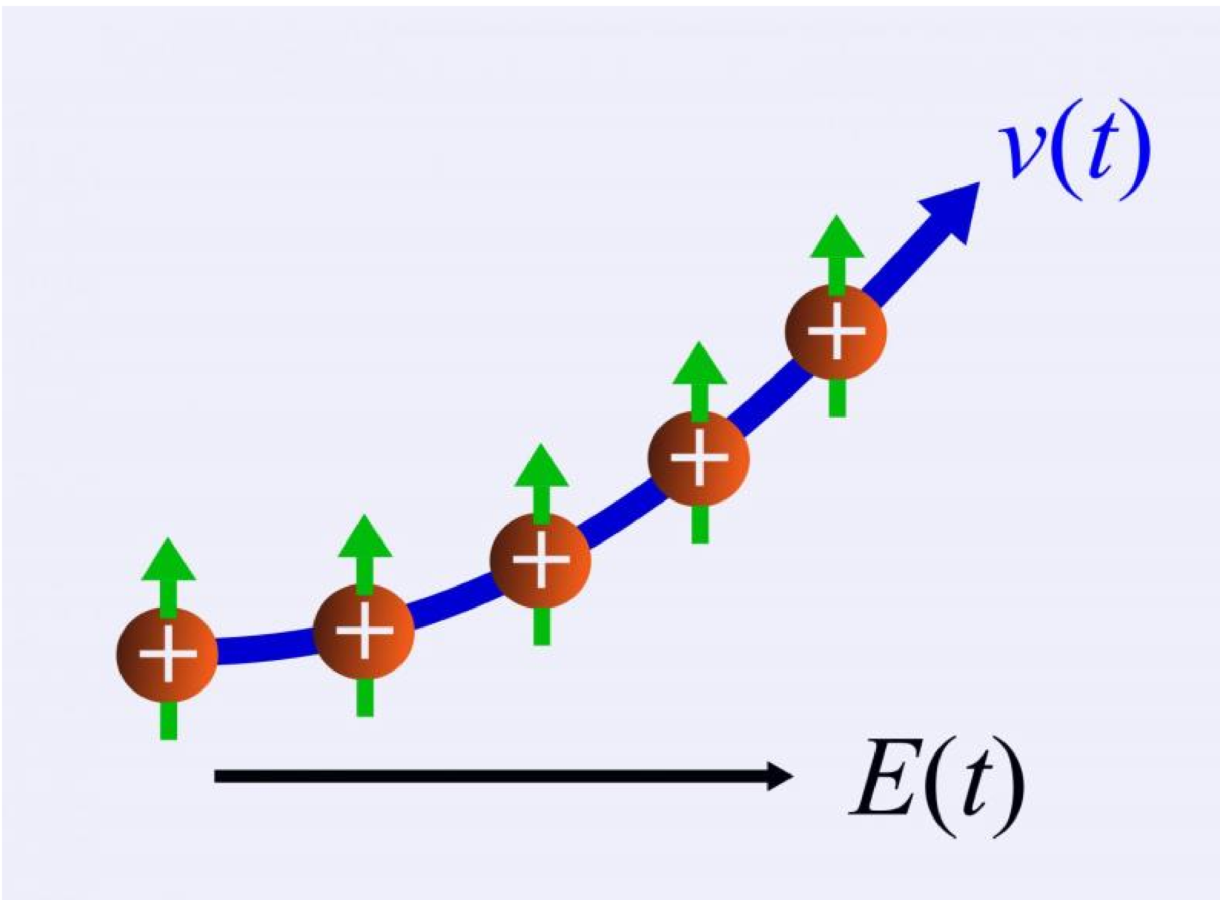
Time-resolved measurement of the anomalous velocity

December 16 2015



Schematic visualization of the anomalous velocity. Charge carriers having a particular spin (green arrows) are accelerated in an electric field and experience a velocity perpendicular to the electric field. Credit: PTB

The movement of charge carriers perpendicular to an electric driving field – even without a magnetic field – constitutes one of the most intriguing properties of carriers in solids. This anomalous velocity is at the origin of fascinating physical phenomena – with the spin Hall effect and the anomalous Hall effect being two prominent examples – and might be important for future spintronic applications or even new quantum computers. At PTB, researchers have now succeeded in detecting the anomalous velocity in a semiconductor made of GaAs with a sub-picosecond time resolution. On the one hand, this work gives new insight into the microscopic origins of the anomalous velocity. On the other hand, it opens a new area of research for studying important physical effects on ultrafast time scales.

The results have been published in the present issue of the renowned journal *Physical Review Letters*.

The anomalous velocity has different microscopic origins; one typically distinguishes between intrinsic and extrinsic contributions. The intrinsic contribution depends on the intrinsic properties of the solid (i.e. on the so-called Berry curvature), while the extrinsic contribution is caused by carrier scattering. Despite intensive investigations of the anomalous velocity in the past years, no simple technique has been developed which would enable the distinction between intrinsic and extrinsic contributions in a straightforward way. Moreover, the anomalous velocity has not yet been studied on ultrafast time scales on which factors such as coherent effects might significantly influence the anomalous velocity.

At PTB, the anomalous velocity has now, for the first time, been detected with sub-picosecond time resolution. For this purpose a semiconductor made of GaAs was excited by means of an optical femtosecond laser and a pulsed high-frequency electric field. While the optical laser pulse excites carriers with a particular spin direction, the high-frequency field accelerates these carriers. During this process, the carriers gain not only a velocity parallel to the electric field, but also the anomalous velocity perpendicular to it. This velocity was detected by a time-resolved study of the electromagnetic radiation emitted from the sample.

The PTB researchers have shown that the time-resolved detection of the anomalous velocity is very important for its further understanding. On the one hand, such investigations enable the distinction between intrinsic and extrinsic contributions, since these contributions have different time-domain shapes. On the other hand, it is now possible to investigate the dependence of the anomalous velocity on the momentum and energy of the carriers involved which, in turn, allows new studies of other important physical phenomena.

More information: Shekhar Priyadarshi et al. Detection of the Anomalous Velocity with Subpicosecond Time Resolution in Semiconductor Nanostructures, *Physical Review Letters* (2015). DOI: 10.1103/PhysRevLett.115.257401

Provided by Physikalisch-Technische Bundesanstalt