Imaging Charge transport in Ge and Si Crystals

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The Cryogenic Dark Matter Search (CDMS) is a direct-detection dark matter experiment which employs high-purity germanium and silicon crystals as dark matter detectors. In order to improve our data analysis and detector design, we use Monte Carlo simulations to model carrier transport and phonon emission for electrons and holes in these semiconductors at cryogenic temperatures. Unlike the transport of holes, the transport of electrons in germanium and silicon at cryogenic temperatures is highly anisotropic. Excited electrons in the conduction bands of germanium and silicon collect into separate energy minima, or valleys, in momentum space. These local minima have highly anisotropic mass tensors which cause the electrons to travel in directions which are oblique to an applied electric field at sub-Kelvin temperatures and low electric fields.

For the first time, this experiment produces a two-dimensional image of the hole and oblique electron propagation and the quantum transitions of electrons between valleys. Charge carriers are excited with a focused laser pulse on one face of a germanium or

silicon crystal and then drifted through the crystal by a uniform electric field of strength between 0.5 and 6 V/cm. The pattern of charge density arriving on the opposite face is used to reconstruct the trajectories of the carriers. Measurements of the two-dimensional pattern of charge density are compared in detail with our Monte Carlo simulations.