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Electron Focusing - Imaging of Ballistic Carrier Propagation in Bi, Ag and W Single Crystals

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At low temperatures T in the K-range, the mean free path l^* of carriers in very pure single crystals can attain several $100\mu m$. The propagation of these so-called ballistic carriers is investigated using a small illuminated spot on a sample surface as a source of excited carriers, which is scanned over the sample surface. On the other side of the sample a point contact is fixed within a distance of l^* as a carrier detector. By measuring the voltage at the point contact with respect to a peripheral electrode as a function of the source position the anisotropic carrier propagation can be probed. Electron Focusing (EF), i.e. directions of enhanced or singular electron flux can be observed. The experimental focusing patterns for Bi, Ag, and W are presented, they turn out to be a characteristic fingerprint of the corresponding Fermi surface.

1. Experiment and Setup

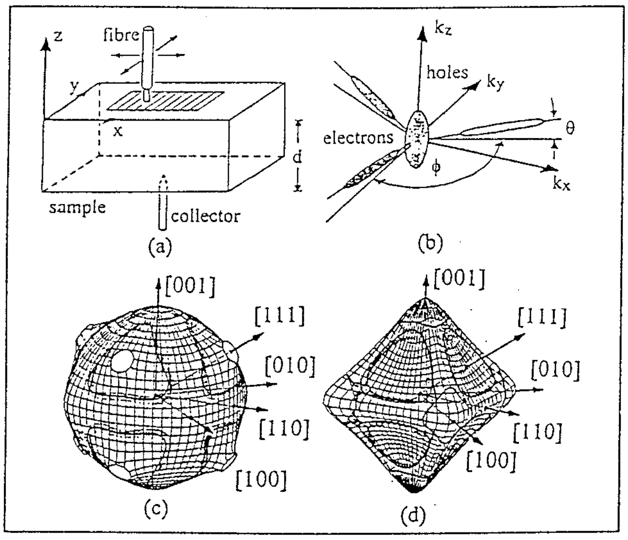

Figure 1: (a) Scheme of the experimental setup. (b,c,d) Fermi surface (FS) of Bi, Ag and W. The regions of small gaussian curvature ($\leq 10^{-21}m^2$ in (c) and $\leq 2 \cdot 10^{-21}m^2$ in (d)) are shaded, the heavy lines show regions of zero gaussian curvature.

The setup is shown in Fig.1(a). The beam of an Ar-ion-laser is coupled into an optical fibre which illuminates a small spot (source) on the sample surface with $\approx$ 3mW power. On the other side of the sample of thickness $d \approx l^*$ a Cu point contact (collector) detects the carriers. Here the voltage V_C with respect to a reference contact on the sample edge is measured. The light is chopped with $\approx$100 Hz for lock-in detection of V_C. The fibre is moved across the sample surface by a cryogenic scanner [1]. By recording V_C as a function of the source position the anisotropic carrier propagation can be probed [2]. The experiments are performed in ^4He at $T \approx 1.5$K.

2. Results for the semimetal Bi

Measurements for the c-surface of a Bi are shown in Fig.2(a,b,c). V_C is presented in greyscale as a function of the fibre position, such that the electron signal appears bright ($40nV \leq V_C \leq 160nV$, image frame $\approx (500\mu m)^2$, $d \approx 200\mu m$). Fig.2(a) with B = 0 shows threefold symmetry. Three bright lines form a triangle in the center of the image. They originate from the three extremely stretched electron ellipsoids of the Fermi surface (FS) of Bi depicted in Fig.1(b).

Because the group velocity of an electron on the FS is always perpendicular to the FS, an increased electron flux occurs in planes perpendicular to the long axes of the ellipsoids. For a point-like source on one side of the sample these planes intersect with the opposite surface in three straight lines, where enhanced electron flux is observed. As the long axes are tilted by $\Theta \approx 6°$ out of the c-plane, these lines do not intersect in one point but leave a triangular void in the center.

To investigate the influence of a magnetic field B