Electron energy loss spectroscopy

Abb. XI.2. Elektronenspektrometer für die Transmissionspektroskopie. (Nach Raether [XI.4])
Abb. XI.3. Vergleich von $\varepsilon_2(\omega)$ für Gold aus Elektronenspektroskopie (ausgezogene Linie) und aus Messungen des optischen Reflexionsvermögens. (Nach Daniels et al. [XI.5])
EELS on Si(111) 7x7

\( h_p \): bulk plasmon
\( h_s \): surface plasmon
\( E_1, E_2 \): bulk interband transitions
\( S_2, S_2, S_3 \): transitions from occupied surface states

\( \hbar \omega_p \): bulk plasmon energy
\( \hbar \omega_s \): surface plasmon energy

**FIG. 2.** Negative second derivative of the loss spectrum of a clean silicon (111) 7x7 surface (curve 1) and spectra of increasing coverage with oxygen. Primary energy is 100 eV.
Fig. 5.15. A typical experimental set-up used for high-resolution electron energy loss spectroscopy. It comprises a cathode emission system, a monochromator, two lens systems, an analyzer, and an electron detector. Both analyzer and monochromator utilize $127^\circ$-angle cylindrical sector deflectors as the energy dispersive elements (after Ibach [5.11])
HREELS example: graphene

Figure 3. The HREEL spectra of graphene sheets on BC$_3$/NbB$_2$(0001) measured along the Γ – M direction in the surface Brillouin zone.

Figure 4. Phonon energy dispersion curves of the graphene sheets determined experimentally (solid circles) and theoretically (solid curves). Phonons in the bulk graphite surfaces are also shown for comparison (open circles).
Surface plasmon (polariton)

FIG. 1. Spectra of attenuated total reflection (parallel polarization) at room temperature. Different values of \( k \) according to Eq. (3). Spacings: \( d = 40, 25, 12 \), and 2.5\( \mu \)m, ordered to increasing values of \( k \). Inset shows experimental arrangement.

FIG. 2. Dispersion of surface polaritons in GaP. Experimental accuracy is given by size of rectangles. Theoretical curve is calculated from Eq. (1).
Types of magnetic order

Fig. 5.1 Various spin arrangements in ordered systems: (a) ferromagnets, (b) antiferromagnets, (c) spin glasses and (d) spiral and (e) helical structures.
Fig. 5.3 The mean-field magnetization as a function of temperature, deduced for different values of $J$. 
Fig. 5.5 The mean-field magnetization as a function of temperature for $J = \frac{1}{2}$, calculated for different values of the applied field $B$. The phase transition is only present when $B = 0$. 
Fig. 5.7 The Curie Weiss law states that $\chi 1/(T - \theta)$ for $T > \theta$. This is shown in (a) for three cases: $\theta = 0$ (paramagnet), $\theta = \Theta > 0$ (ferromagnet) and $\theta = -\Theta < 0$ (antiferromagnet). Straight-line graphs are obtained by plotting $1/\chi$ against $T$ as shown in (b) with the intercept on the temperature axis yielding $\theta$. A graph of $\chi T$ against $T$ can be constant ($\theta = 0$), increasing for decreasing $T$ ($\theta > 0$) or decreasing for decreasing $T$ ($\theta < 0$), shown in (c).
Susceptibility of an antiferromagnet
Fig. 6.24 A hysteresis loop showing the saturation magnetization $M_s$, the remanent magnetization $M_r$ and the coercive field $H_c$.

Fig. 6.25 Effect of an applied field on the domain pattern on the surface of a single crystal iron whisker showing domain wall displacement, as the applied $B$ field increases from 0 up to a maximum value.
Vibrating sample magnetometer (VSM)

System diagram of Vibrating Sample Magnetometer

\[ U = -N \Phi \propto MV \dot{x} \]
SQUID
EuO facts

- Ionic rocksalt structure
- Ferromagnetic semiconductor, $T_C = 69$ K
- $T_C$ increased up to 125 K by doping with Gd
- Colossal magnetoresistance (CMR)
- Photoconductivity
- Large magneto-optical Kerr effect (MOKE): Kerr rotation 7.1°
- Almost 100 % spin polarisation of the charge carriers [1]
- Metal insulator transition (MIT) in EuO$_{1-x}$ with $\Delta R/R$ up to 1000

SQUID-example: EuO

Figure 5.2: Temperature dependence of the normalized magnetization of epitaxial Gd-doped EuO films on YSZ (001) for various Gd concentrations from undoped to 7.7% (top panel) and from 7.7% to 20% (bottom panel). The SQUID measurements were performed at applied magnetic field of 10 G. Taken from [17].
Magneto-optical effects

Faraday-effect

Kerr-effect
MOKE experimental setup
MOKE: sketch of measurement
MOKE microscope

Fig. 6 Schematic representation of the main components of a magneto-optical Kerr microscope. The inset shows the beam path of an optical reflected light microscope. The aperture iris is displaced from the optical axis to generate oblique incidence of light.
Nd$_2$Fe$_{14}$B

MOKE microscope