

## 5. DYNAMICAL THEORY AND ITS APPLICATIONS

relevance to materials science, such as statistical properties of magnetic domain distributions (Korpiun, 1966) or precipitates (Rauch & Seidl, 1987); Rauch (1995) analyses the effect in terms of the neutron coherence function.

Many elegant experiments have been performed with neutron interferometers in efforts to set an upper limit to effects than can be considered as nonexistent, or to test expectations of basic quantum physics. Many papers are found in the same volumes as Bonse (1979) and Bonse (1988); excellent reviews have been given by Klein & Werner (1983), Klein (1988), and Werner (1995). Among the topics investigated are the effect of gravity (Colella *et al.*, 1975), the Sagnac effect, *i.e.* the influence of the Earth's rotation (Werner *et al.*, 1979), the Fizeau effect, *i.e.* the effect of the movement of the material through which the neutrons are transmitted (Arif *et al.*, 1988) and the Aharonov–Casher effect, *i.e.* the dual of the Aharonov–Bohm effect for neutral particles having a magnetic moment (Cimmino *et al.*, 1989).

## 5.3.7.4. Neutron diffraction topography and other imaging methods

These are the neutron form of the 'topographic' or diffraction imaging techniques, in which an image of a single crystal is obtained through the local variations in Bragg-diffracted intensity due to inhomogeneities in the sample. It is briefly described in Chapter 2.8 of *IT C*. It was pioneered by Doi *et al.* (1971) and by Ando & Hosoya (1972). Like its X-ray counterpart, neutron topography can reveal isolated defects, such as dislocations (Schlenker *et al.*, 1974; Malgrange *et al.*, 1976). Because of the small neutron fluxes available, it is not very convenient for this purpose, since the resolution is poor or the exposure times are very long. On the other hand, the very low absorption of neutrons in most materials makes it quite convenient for observing the gross defect structure in samples that would be too absorbing for X-rays (Tomimitsu & Doi, 1974; Baruchel *et al.*, 1978; Tomimitsu *et al.*, 1983; Kvardakov *et al.*, 1992), or the spatial modulation of distortion due to vibration, for example in quartz (Michalec *et al.*, 1975), and resonant magnetoelastic effects (Kvardakov & Some-

nkov, 1991). In particular, virtual slices of bulky as-grown samples can be investigated without cutting them using neutron section topography or neutron tomography (Schlenker *et al.*, 1975; Davidson & Case, 1976).

Neutron topography also shows the salient dynamical interference effect, *viz.* *Pendellösung*, visually, in the form of fringes (Kikuta *et al.*, 1971; Malgrange *et al.*, 1976; Tomimitsu & Zeyen, 1978). Its unique feature, however, is the possibility of observing and directly characterizing inhomogeneities in the magnetic structure, *i.e.* magnetic domains of all kinds [ferromagnetic domains (Schlenker & Shull, 1973) and antiferromagnetic domains of various sorts (Schlenker & Baruchel, 1978), including spin-density wave domains (Ando & Hosoya, 1972, 1978; Davidson *et al.*, 1974), 180° or time-reversed domains in some materials and helimagnetic or chirality domains (Baruchel *et al.*, 1990)], or coexisting phases at a first-order phase transition (Baruchel, 1989). In such cases, the contrast is primarily due to local variations in the structure factor, a situation very unusual in X-ray topography, and good crystal quality, leading to dynamical scattering behaviour, is essential in the observation process only in a few cases (Schlenker *et al.*, 1978). It is often crucial, however, for making the domain structure simple enough to be resolved, in particular in the case of antiferromagnetic domains.

Imaging can also be performed for samples that need be neither crystals nor perfect. Phase-contrast imaging of a specimen through which the neutrons are transmitted can be performed in a neutron interferometer. It has been shown to reveal thickness variations by Bauspiess *et al.* (1978) and ferromagnetic domains by Schlenker *et al.* (1980). The same papers showed that phase edges show up as contrast when one of the interferometer paths is blocked, *i.e.* when the sample is placed effectively between perfect, identical crystals set for diffraction in a non-dispersive setting. Under the name of neutron radiography with refraction contrast, this technique, essentially a form of Schlieren imaging, was further developed by Podurets, Somenkov & Shil'shtein (1989), Podurets, Somenkov, Chistyakov & Shil'shtein (1989), and Podurets *et al.* (1991), who were able to image internal ferromagnetic domain walls in samples 10 mm thick.