

4.2. X-RAYS

Table 4.2.6.2(a). Comparison between the *S*-matrix calculations of Kissel (K) (1977) and the form-factor calculations of Cromer & Liberman (C & L) (1970, 1981, 1983) and Creagh & McAuley (C & M) for the noble gases and several common metals; $f'(\omega, 0)$ values are given for two frequently used photon energies

Energy (keV)	Element	RDP (C & L)	<i>S</i> matrix (K)	RMP (C & M)
17.479 (Mo $K\alpha_1$)	Ne	0.021	0.024	0.026
	Ar	0.155	0.170	0.174
	Kr	-0.652	-0.478	-0.557
	Xe	-0.684	-0.416	-0.428
22.613 (Ag $K\alpha_1$)	Al	0.032	0.039	0.041
	Zn	0.260	0.323	0.324
	Ta	-0.937	-0.375	-0.383
	Pb	-1.910	-1.034	-1.162

$f'(\omega, 0)$. All the interferometers are transmission-geometry LLL devices (Bonse & Hart, 1965, 1966*a,b,c,d*, 1970), and initially they were used to measure the X-ray refractive indices of such materials as the alkali halides, beryllium and silicon using the characteristic radiation emitted by sealed X-ray tubes. Measurements were made for such characteristic emissions as Ag $K\alpha_1$, Mo $K\alpha_1$, Cu $K\alpha_1$ and Cr $K\alpha_1$ by a variety of authors (Creagh & Hart, 1970; Creagh, 1970; Bonse & Hellkötter, 1969; Bonse & Materlik, 1972).

The ready availability of synchrotron-radiation sources led to the adaptation of the simple LLL interferometers to use this new radiation source. Bonse & Materlik (1975) reported measurements at DESY, Hamburg, made with a temporary adaptation of a diffraction-beam line. Recent advances in X-ray interferometry have led to the establishment of a permanent interferometer station at DESY (Bonse, Hartmann-Lotsch & Lotsch, 1983*b*). This, and many of the earlier interferometers invented by Bonse, makes its phase measurements by the rotation of a phase-shifting plate in the beams emanating from the first wafer of the interferometer.

In contrast, the LLL interferometer designed by Hart (1968) uses the movement of the position of lattice planes in the third wafer of the interferometer relative to the standing-wave field formed by the recombination of two of the diffracted beams within the interferometer. Measurements made with and without the specimen in position enabled both the refractive index and the linear attenuation coefficient to be determined. The use of energy-dispersive detection meant that these parameters could be determined for harmonics of the fundamental frequency to which the interferometer was tuned (Cusatis & Hart, 1975, 1977). Subsequently, measurements have been made by Siddons & Hart (1983) and Hart & Siddons (1981) for zirconium, niobium, nickel, and molybdenum. Hart (1985) planned to provide detailed dispersion curves for a large number of elements capable of being rolled into thin foils.

Both types of interferometers have yielded data of high quality, and accuracies better than 0.2 electrons have been claimed for measurements of $f'(\omega, 0)$ in the neighbourhood of the *K*- and *L*-absorption edges of a number of elements. The energy window has been claimed to be as low as 0.3 eV in width. However, on the basis of the measured values, it would seem that the width of the energy window is more likely to be about 2 eV for a primary wavelength of 5 keV.

Table 4.2.6.2(b). A comparison of the real part of the forward-scattering amplitudes computed using different theoretical approaches: KPR (Kissel et al., 1980); C & L (Cromer & Liberman, 1970, 1981); W (Wagenfeld, 1975); and C & M (this data set)

Atom	Radiation	$f'(\omega, 0)$				
		KPR	C & L		W	C & M
			1970	1981		
¹³ Al	Cr $K\alpha_1$	13.320	13.328	13.316	13.376	13.326
	Cu $K\alpha_1$	13.209	13.204	13.203	13.235	13.213
	Ag $K\alpha_1$	13.039	13.032	13.020	13.078	13.041
¹⁴ Si	Cr $K\alpha_1$		14.333	14.354	14.441	14.365
	Cu $K\alpha_1$		14.244	14.242	14.282	14.254
	Ag $K\alpha_1$		14.042	14.029	14.071	14.052
³⁰ Zn	Cr $K\alpha_1$	29.161	29.316	29.314		29.383
	Cu $K\alpha_1$	28.369	28.388	28.383		28.451
	Ag $K\alpha_1$	30.323	30.260	30.232		30.324
³² Ge	Cr $K\alpha_1$		31.538	31.538	30.20	31.614
	Cu $K\alpha_1$		30.837	30.837	31.92	30.911
	Ag $K\alpha_1$		32.228	32.228	32.14	32.302
⁴⁷ Ag	Cu $K\alpha_1$	47.075	46.940	46.936		47.131
⁶² Sm	Ag $K\alpha_1$	58.307	56.304	56.299		56.676
⁷³ Ta	Ag $K\alpha_1$	72.625	72.063	71.994		72.617
⁸² Pb	Ag $K\alpha_1$	80.966	80.090	80.012		80.832

Apparently, the ångström-ruler design is the better of the two interferometer types, since the interferometer to be mounted at the EU storage ring is to be of this type (Buras & Tazzari, 1985).

Interferometers of this type have the advantage of enabling direct measurements of both refractive index and linear attenuation coefficients to be made. The determination of the energy scale and the assessment of the energy bandpass of such a system are two factors that may influence the accuracy of this type of interferometer.

One of the oldest techniques for determining refractive indices derives from measurement of the deviation produced when a prism of the material under investigation is placed in the photon beam. Recently, a number of groups have used this technique to determine the X-ray refractive index, and hence $f'(\omega, 0)$.

Deutsch & Hart (1984*a,b*) have designed a novel double-crystal transmission spectrometer for which they were able to detect to high accuracy the angular rotation of one element with respect to the other by reference to the *Pendellösung* maxima that are observed in the wave field of the primary wafer. In this second paper, data gained for beryllium and lithium fluoride wedges are discussed.

Several Japanese groups have used more conventional monochromator systems having Bragg-reflecting optics to determine the refractive indices of a number of materials. Hosoya, Kawamura, Hunter & Hakano (1978; cited by Bonse & Hartmann-Lotsch, 1984) made determinations of $f'(\omega, 0)$ in the region of the *K*-absorption edge for copper. More recently, Ishida & Katoh (1982) have described the use of a multiple-reflection diffractometer for the determination of X-ray refrac-