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Report:

It is well known from infrared absorption, Raman and inelastic neutron scattering, that the low energy vibrational behavior of amorphous solids, compared to that of the corresponding crystalline solids, shows anomalous characteristics [l]. These anomalies, although beeing a matter of discussion for a couple of decades, are still not well understood.

This experiment has been a pilot experiment applying inelastic x-ray scattering with nuclear resonant scattering energy analysis to thin films of glassy materials. Since there is evidence that the characteristic low frequency vibrational properties of amorphous solids are related to localized vibrations of mesoscopic structural units [2], it is our hope that the structural confinement of our sample in one dimension could give some new hints on the structures responsible for the vibrational behavior of glasses.

The materials investigated in this experiment were B_2O_3, SiO_2, which both can be called model glasses, and sputtered amorphous $FeBO_3$. The experimental method used was, as mentioned before, inelastic x-ray scattering in grazing incidence geometry combined with subsequent elastic nuclear resonant forward scattering by an analyzing ^{57}Fe-foil, as described in [3]. Alternatively, in case of the $FeBO_3$ sample, a slightly different technique has been used, based on the incoherent inelastic nuclear resonant scattering by the ^{57}Fe nuclei contained in the sample itself [4].

Using these methods, the vibrational spectrum of the film is recorded by counting the 14.4 keV or the 6.4 keV nuclear fluorescence quanta, respectively, reemitted by the ^{57}Fe nuclei after excitation of the nuclear resonance, while the incident energy is scanned with a high resolution (4meV) monochromator. The resonant quanta are discriminated from the non-resonant quanta by time gating, which is possible due to the fairly long lifetime of the excited nuclear level, τ = 141ns. The analyzing detector is placed very close to the sample. In case of the nuclear fluorescence method making use of the incoherent nuclear resonat scattering by the ^{57}Fe nuclei in the sample, this leads to momentum-space integrated data, from which the vibrational density of states can be obtained directly. In case of the technique using the nuclear resonant analyzing foil the situation is a bit more complicated. The solid angle covered by the detector and the path length of the quanta through the analyzing ^{57}Fe and a subsequent aluminum foil must be taken into account.

A major problem in studying inelastic processes in thin films is, that countrates are limited due to small sample volumes. This limation can be overcome by employing an interference effect, based on the design of the sample as a x-ray waveguide [5]. This is a trilayer system where the layer to be studied is sandwiched between two thin layers of higher electron density, e.g. $Pd/B_2O_3/Pd$ coated on a very smooth substrate. At certain angles of incidence between the critical angles of both materials the radiation couples into guided modes where the intensity of the radiation is substantially enhanced relative to the incident intensity due to constructive interference or repeatedly reflected waves. Figure 1 illustrates this enhancement effect exemprarily for a Pd/BsOs /Pd layer system, designed as a waveguide with four guided modes.

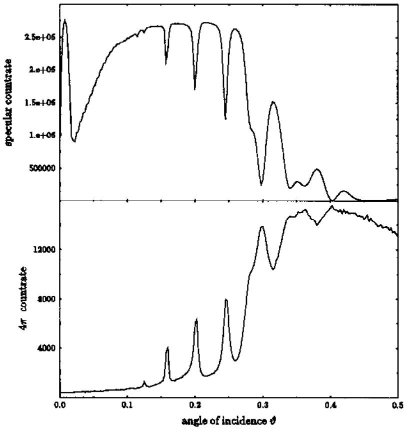

FIG. 1: Rocking curve and 4x scattering intensity with respect to the incedent angle; the maxima in the 4π scattering intensity below the critical angle $\vartheta \approx 0.275$" correspond the guided modes.

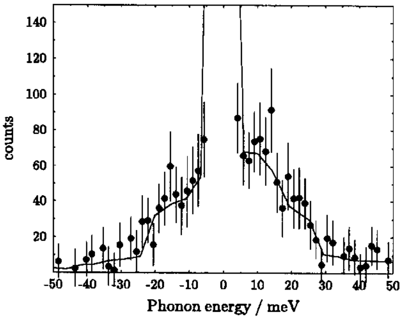

FIG. 2: Inelastic scattering spectrum of the $Pd/FeBO_3/Pd$ waveguide. The solid line is just a guide to the eye.

Experimental results

Unfortunately, for a considerable part of the experimental time only a l/3-fill of the storage ring instead of the scheduled hybrid-4 mode has been available. Since time gating is essential for this kind of experiment, this has been a strong restriction. Apart from that it has been seen that even hybrid-4 mode does not provide an overall intensity in the bunches sufficient for studying the samples not containing resonant nuclei. However, it was possible to record a vibrational spectrum of the thin amorphous $FeBO_3$ film (shown in figure 2) using the nuclear fluorescence technique.

Nevertheless we are convinced that the experimental technique for non-resonant films can be improved in a way, that, combined with an appropriate filling mode of the storage ring, also this technique will become feasible.

References

[I] see e.g. F.J.Bermejo et al., Phys.Lett.A **195,** 236 (1994), [2] e.g. L.Borjesson et al., Phys.Rev.Lett. 70, 1275 (1993), [3] A.I.Chumakov et al., Phys.Rev.Lett. 76, 4258 (1996), [4] W. Sturhahn et al., Phys.Rev.Lett. 74, 3832 (1995), [5] Y.P.Feng et al. Phys.Rev.Lett. 71, 537 (1993)