ATOMIC MOTION IN METALLIC GLASS STUDIED BY COHERENT X-RAYS

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INTRODUCTION

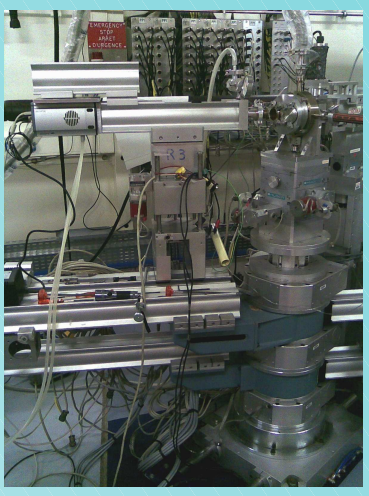
Diffusion in glasses is significantly different from diffusion in crystalline materials and so far not well understood. From the fundamental point of view metallic glasses are the paradigm of dense random packing of spheres and as such a rewarding topic from theoretical viewpoints. Studies of very slow dynamics in a metastable system are, however, quite demanding experimental work [1].

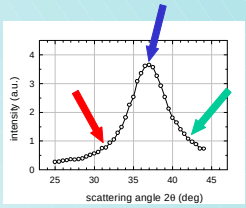
Especially X-ray photon correlation spectroscopy (XPCS) seems to be very promising in the study of dynamics with atomic resolution as it has been just demonstrated for the intermetallic alloy $Cu_{90}Au_{10}$ [2].

The sample under investigation was a Zr-based amorphous Inoue alloy $Zr_{65}Al_{7.5}Ni_{10}Cu_{17.5}$ measured at T=600K (calorimetric glass transition T_g=624K at 2K/min, extrapolated quasi-stationary T_g=605K) [3].

METHOD

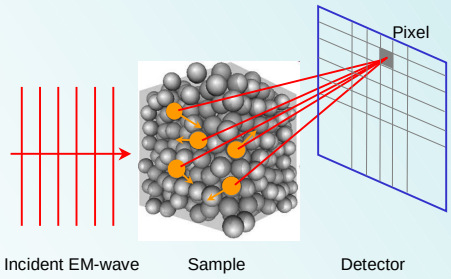
The **XPCS** method relies on the fact that a particular arrangement of atoms in a sample produces a characteristic "speckle" pattern when it scatters a coherent beam of X-rays. If the arrangement of atoms changes, the speckle pattern changes, and by studying these changes as a function of time, one can obtain information on the atomic dynamics at various wavevector transfer (i.e. at different length scales). In order to study the arrangement of atoms on the atomic scale, scattering angles of 30° and more are essential.

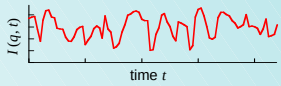




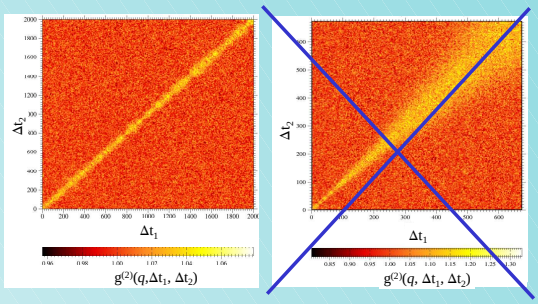
Measured scattering angles

MEASURING DYNAMICS





$$g^{(2)}(q,\Delta t) \equiv \frac{\langle I(q,t)I(q,t+\Delta t)\rangle}{\langle I(q,t)\rangle^2}$$

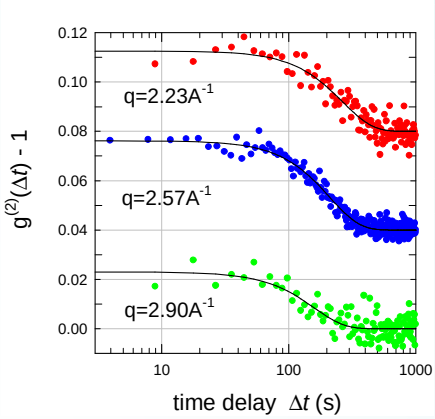


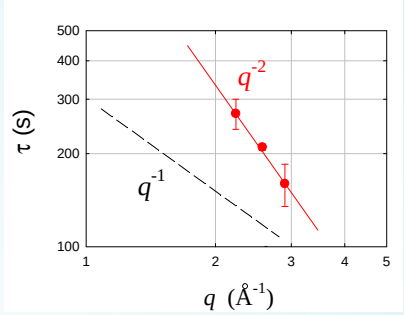
Calculating the autocorrelation (intensity-intensity correlation) function in one pixel of the detector and averaging over all pixels of the detector provides the correlation function $g^{(2)}(q,\Delta t)$. The measurement is repeated for three different wavevectors q close to the first diffraction peak.

Equilibration was checked by following the evolution of the dynamics via calculation of the two-time correlation function.

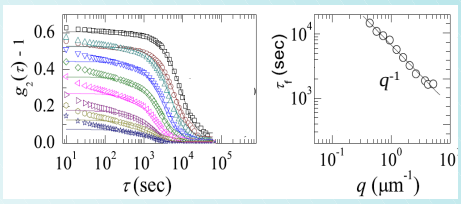
RESULTS

The data could be fitted via a compressed exponential function $g^{(2)}(q,\Delta t) - 1 = \exp[-(\Delta t/\tau)^{\beta}]$, where $\tau(q)$ denotes a correlation decay time and β is the *universal* compressing exponent, β = 1.8(1). The decay time $\tau(q)$, which is the life-time of fluctuations corresponding to the wavevector q, gauges the dynamics in the sample.





The decay time dependence $\tau(q)$ is in contrast to the behaviour of colloidal gels [4]. Due to heterogeneous dynamics of colloidal gels decay time scales with q^{-1}, while in our metallic glass with q^{-2}. The q^{-2} dependence is a hint at *Brownian dynamics* on the atomistic level in the metallic glass at temperatures lower than the glass transition temperature.



Taken from Duri& Cipeletti [4]

[1] F. Faupel, W. Frank, M-P. Macht, H. Mehrer, V. Naundorf, K. Rätzke, H.R. Schober, S.K. Sharma and H. Teichler, Rev. Mod. Phys. **73** (2003) 237-280

[2] M. Leitner, B. Sepiol, L.-M. Stadler, B. Pfau, G. Vogl, Nature Materials (26 July 2009) doi:10.1038/nmat2506

[3] T. Zhang, A. Inoue and T. Masumoto, Mater. Trans. JIM **32** (1991) 1005

[4] A. Duri and L. Cipelletti, Europhysics Letters **76** (2006) 972

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