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1 Time domain interferometry: Analysis of results in the quantum beat and the radiative coupling regimes

U. van Bürck, G. V. Smirnov[1], H. Franz[2], T. Asthalter[3], O. Leupold[4], E. Schreier[5], W. Petry

[1]Russian Research Center 'Kurchatov Institute', Moscow
[2]Hasylab, Hamburg
[3]Institut für Physikalische Chemie, Universität Stuttgart
[4]Univ. Rostock; Univ. Paderborn; ESRF Grenoble
[5]TUM E13; ESRF Grenoble

The extreme sharpness of nuclear resonant scattering is a challenge calling for applications e.g. in the field of slow atomic motions. A method not limited to nuclear resonant samples is time domain interferometry (TDI), where the quasielastic scattering of synchrotron radiation (SR) by a non-resonant sample is analyzed by means of the delayed nuclear forward scattering (NFS) from two identical resonant targets. One target is mounted upstream and the other downstream of the sample. In case of a stiff sample, and when one nuclear target is at rest and the other moved at large constant velocity, interference of the waves scattered by the two targets leads to a fast quantum beat (QB) which modulates the slow dynamical beat (DB) of the single-target response. When both nuclear targets are at rest, the wave scattered by the upstream target can be scattered again by the downstream target, and this so-called radiative coupling (RC) creates a DB corresponding to twice the optical thickness (double-target DB). If however the sample exhibits dynamics, the phase of the radiation scattered by the upstream target becomes perturbed by the quasielastic scattering in the sample. This perturbation destroys interference and radiation coupling, leading for TDI in the QB-regime to a fading of the QB [1], whereas for TDI in the RC-regime a transition from the double-target DB to a single-target DB is expected [2].

These two regimes of TDI have been compared in an experiment [3], where the quasielastic scattering from a sample of glycerol at temperatures $T \sim 128$, 230 and 240K was analyzed by TDI both in the QB-regime and the RC-regime, using as targets a set of two 6μm thick stainless steel foils enriched to 95% in ^{57}Fe. Measurements at different scattering angles $\sim$ 8, 12, 16 and 20 degrees corresponding to scattering vectors of magnitudes

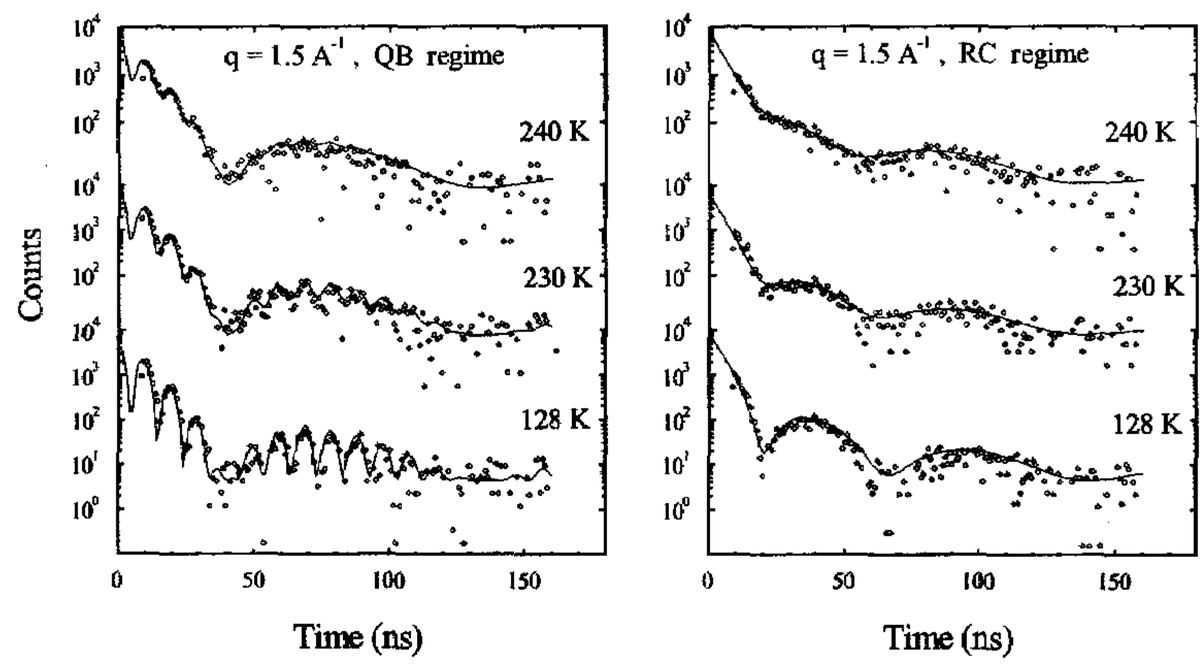

Рис. 1: TDI spectra of glycerol in the QB-regime (left) and the RC-regime (right) at $q \sim 1.5\text{Å}^{-1}$ at $T \sim 128$, 230 and 240K. The solid lines are fits based on the theory [2].

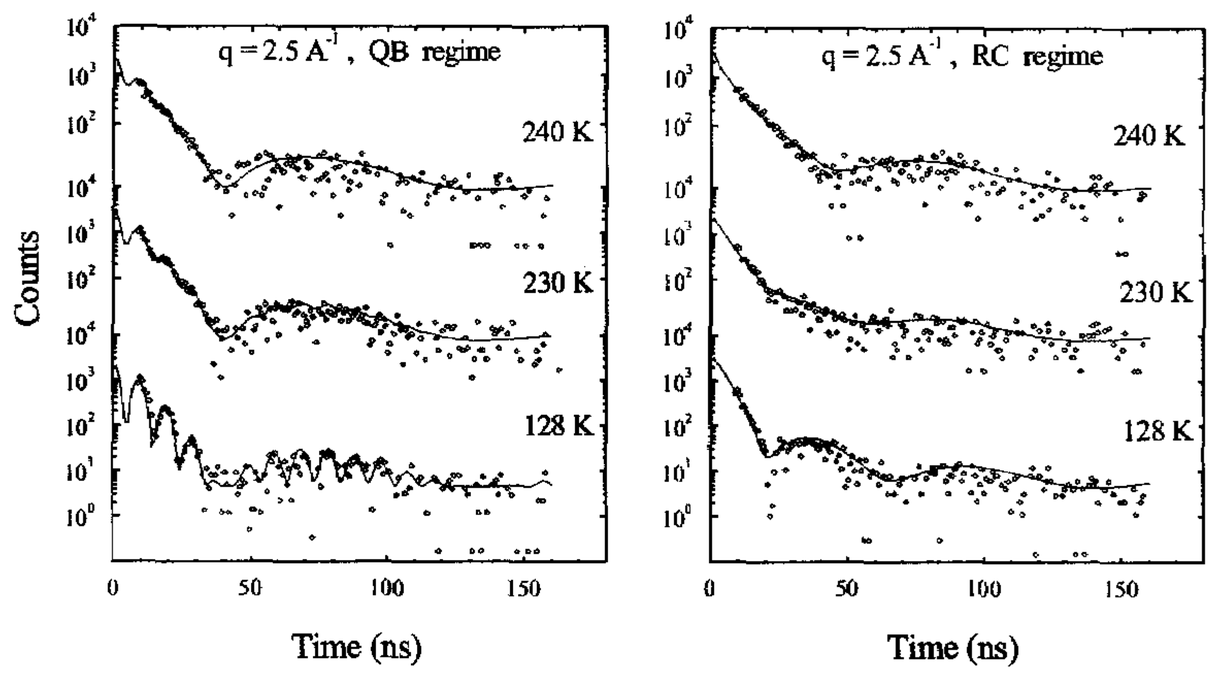

Рис. 2: TDI spectra of glycerol in the QB-regime (left) and the RC-regime (right) at $q \sim 2.5\text{Å}^{-1}$ at $T \sim 128$, 230 and 240K. The solid lines are fits based on the theory [2].

$q \sim 1$, 1.5, 2 and 2.5Å^{-1} were performed in parallel. As an example, we show in Figs. 1 and 2 the time evolutions measured at $q \sim 1.5\text{Å}^{-1}$ and $q \sim 2.5\text{Å}^{-1}$ for the QB- and the RC-regimes at different temperatures T, with background substracted. At 128K, where the scattering sample is stiff, the time evolutions in both regimes correspond to the instrumental functions measured in forward direction. At higher temperatures the sample exhibits dynamics, which gradually destroys interference and radiative coupling. In the QB-regime, the well-known fading of the QB [1] is observed, which varies

both with temperature and scattering angle. In the RC-regime, the predicted transformation [2] from a double-target DB (see e.g. 1.5Å^{-1} 128K: first DB minimum at ~20ns) to almost a single-target DB (see 2.5Å^{-1} 240K: first DB minimum at ~40ns) was observed for the first time.

This qualitative comparison has now been substantiated by a computer analysis. The solid lines in the figures are simulations based on Eqs. (32,33) of [2] in the approximation of weak scattering, where a Kohlrausch type of relaxation was assumed with parameter β =0.7 [4] fixed. At the given poor accuracy of the data, all time evolutions could be well described with a dominating self-part of the van Hove pair-correlation function. The most important point is that it was possible to find parameters by which the two sets of completely different time evolutions for the QB- and the RC-regimes were consistently fitted.

Since the QB is a very pronounced feature of the time evolution measured in the QB-regime, its fading due to sample dynamics is more easily recognized during the experiment than the corresponding changes of the DB in the RC-regime. The computer analysis, by contrast, is more sensitive to relaxation parameters when the time evolutions were measured in the RC-regime. Therefore in future at least some first measurements should be performed in the QB-regime for on-line orientation, and then the majority of the measurements in the RC regime. But we also feel that the consistent fit of such two different data sets increases the reliability of the data evaluation.

Список литературы

[1] A. Q. R. Baron, H. Franz, A. Meyer, R. Rüffer, A. I. Chumakov, E. Burkel, W. Petry: Phys. Rev. Lett. **79**, 2823 (1997)

[2] G. V. Smirnov, V. G. Kohn, W. Petry: Phys. Rev. B **63**, 144303 (2001)

[3] U. van Bürck, G. V. Smirnov, H. Franz, T. Asthalter, O. Leupold, E. Schreier, W. Petry: Ann. Report TUM Physik-Dep. E13, 42 (2001); ESRF report MI-533 (2002)

[4] J. Wuttke, W. Petry, S. Pouget: J. Chem. Phys. **105**, 5177 (1996)