

**Experiment title:**

Nuclear Exciton Perturbed by Ultrasound

Experiment**number:**

HS-122

Beamline:

ID 18

from: 3-12 15h

to: 6-12-96 7h

22-2-97

Shifts:

8

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- 3 MAR 1997**Names and affiliations of applicants** (* indicates experimentalists):

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Report:

Nuclear Exciton Perturbed by Synchronized Ultrasound

A nuclear exciton extending over two targets was perturbed by moving one of the targets by ultrasound (US). The perturbation was observed in the time evolution of nuclear forward scattering (NFS) of synchrotron radiation. The targets were thin foils of 1.4 μm thickness, made of stainless steel ($\text{Fe}_{55}\text{Cr}_{25}\text{Ni}_{20}$) enriched to 95% in ^{57}Fe . One target was at rest, or moved at constant velocity. The other target was mounted on a quartz crystal, or on a piezoelectric polyvinylidene fluoride (PVDF) foil, which were driven by US. The US was synchronised with the bunch frequency, so that the excitation of the nuclei was effectuated always at definite phases of the US motion.

At first, the effect of US motion produced by a quartz crystal was studied, which was synchronised at 14.91 MHz, relatively far above its thickness resonance of 14.12 MHz. In Fig.1a, the NFS response after nuclear excitation at constant US phase $\Phi_0 = 0$ is shown as a function of driving voltage. At 67 and 134 ns, i.e. at multiples of the US period, echo spikes appear, similar to those seen in previous measurements performed under conditions of averaging over US phase and amplitude /1,2/. Now, however, also in the regions between these echos pronounced structures are observed. There are in particular peaks at 33 and 100 ns halfway in between the echos, i.e. after half the US period, when the US vibrated nuclei are again in their initial positions, however with opposite velocities.

In order to increase the time window for observing these additional structures before the first echo, and to obtain a more homogeneous piston-like US motion (as studied beforehand by means of conventional US Mössbauer spectroscopy), the US motion was then generated by a PVDF foil at 10 MHz. Fig.1b depicts the voltage dependence of the perturbed time evolution of NFS with nuclear excitation at constant US phase $\Phi_0 = 0$. The echo at 100 ns and the maximum at half the US

period are sharpened with increasing driving voltage as expected from previous experiments /1/. In addition, intermediate maxima appear when the nuclei reach displacements corresponding to phase differences of multiples of 2π . Fig.1c depicts the time evolution of NFS at a driving voltage of 4.2 V as a function of the initial US phase Φ_o . It is clearly seen, that the maximum at half the US period appears only when the excitation is performed at the symmetry points 0 and π of the US phase. The time evolution has a periodicity of π in the US phase.

The US perturbation was also studied in the case, when the NFS contributions of the two targets are separated in energy. For that purpose the non-vibrated target was moved at constant velocities of ± 18 mm/s, yielding in the absence of US a quantum beat (QB) of 5 ns period. In the case of averaging over US phase and amplitude as studied previously, the QB vanishes in a characteristic way with increasing US voltage /3/. In the present case of synchronisation, by contrast, the QB remains visible at all times, and exhibits an interesting frequency modulation of the reemitted radiation (Fig.2). The QB is dilated, when the motions of both targets are in the same direction, and compressed in the case of opposite motions.

In summary, pronounced effects of the synchronised US vibration on the decay of the nuclear exciton were observed, which were strongly dependent on amplitude and phase of the US. The results are in agreement with model simulations. Detailed analysis and comparison with theoretical description are under way.

/1/ G.V. Smirnov, U. van Bürck, J. Arthur, et al., Phys. Rev. Lett. 77 (1996) 183

/2/ G.V. Smirnov, S.L. Popov, U. van Bürck, et al., HASYLAB Am. Rep. 1996, p. 890.

/3/ U. van Bürck, W. Potzel, P. Schindelman, et al., HASYLAB Ann. Rep. 1996, p. 888.

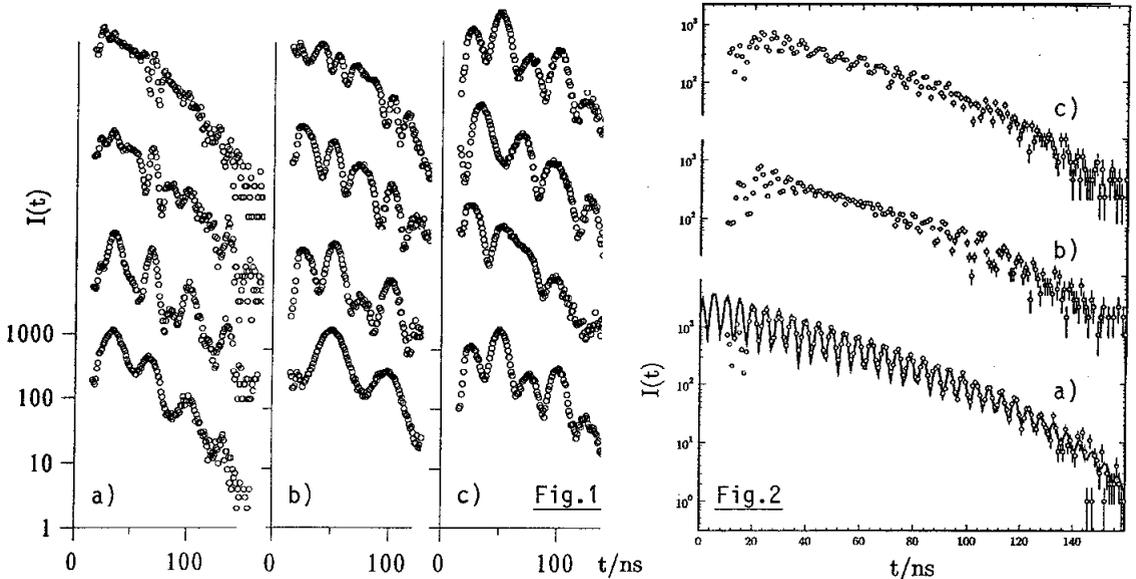


Fig.1 NFS time evolution for synchronized US perturbation. Dependence on the driving voltage for a quartz crystal at 14.91 MHz (a) (voltages from bottom to top: 5, 8.8, 12, and 18 V) and for a PVDF foil at 10 MHz (b) (voltages 2.5, 4.2, 5, and 10 V), all at fixed initial US phase $\Phi_o=0$. Dependence on the initial US phase ($\Phi_o = 0, \pi/4, \pi/2, \text{ and } \pi$) for PVDF motions at 4.2 V driving voltage (c).

Fig.2 Quantum beat analysis. No US applied, only second foil moving at constant velocities of ± 18 mm/s (a). Synchronized US of 15.5 V amplitude applied to PVDF at initial phase $\Phi_o=0$, with the second foil moving at +18 mm/s (b) and -18 mm/s (c).