STUDY OF SPIN WAVES IN AMORPHOUS FERROMAGNET Fe-Ni-Cr-P BY SMALL-ANGLE POLARIZED NEUTRON SCATTERING

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As it is well known in theory, the spin waves (s—w) represent the main type of long wavelength magnetic exitations in Hesenberg ferromagnets. This has been proved by an anormous number of experiments usually employing the inelastic neutron scattering technique. Nevertheless there still exist some fundamental problems of the spin hydrodynamics both from theoretical and experimental points of view. The first these are influence of disorder on the low laying branches of the magnetic excitations and the role of dipole-dipole (d—d) magnetic interaction especially in the case of disordered and amorphous magnets when d-d interaction randomly changes it's sign for different pairs of spins. For amorphous ferromagnets the relevant experiments

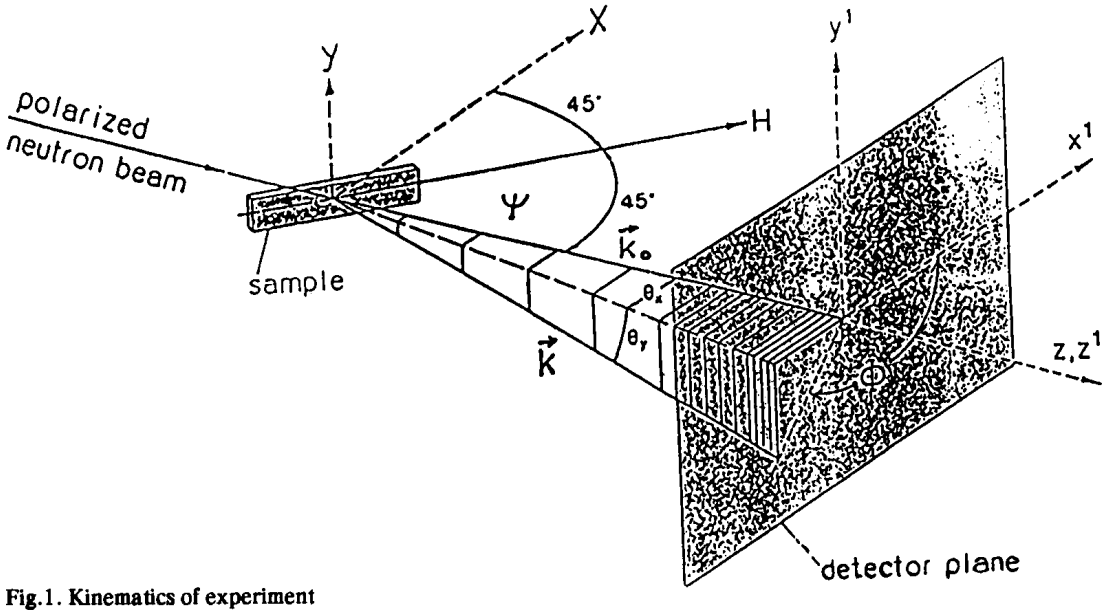

Fig.1. Kinematics of experiment

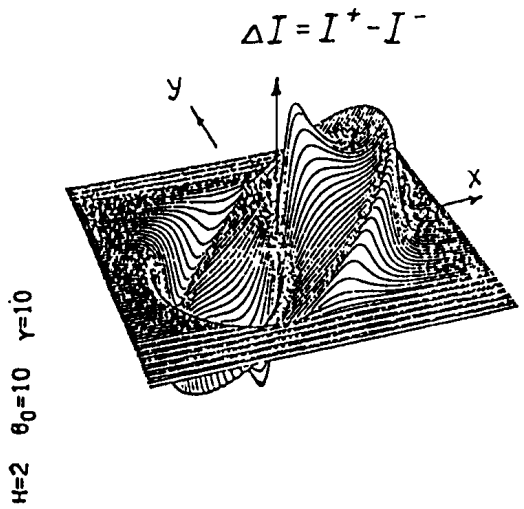

Fig.2. Calculated two-dimensional picture of s—w scattering $\Delta I = I^+ - I^-$

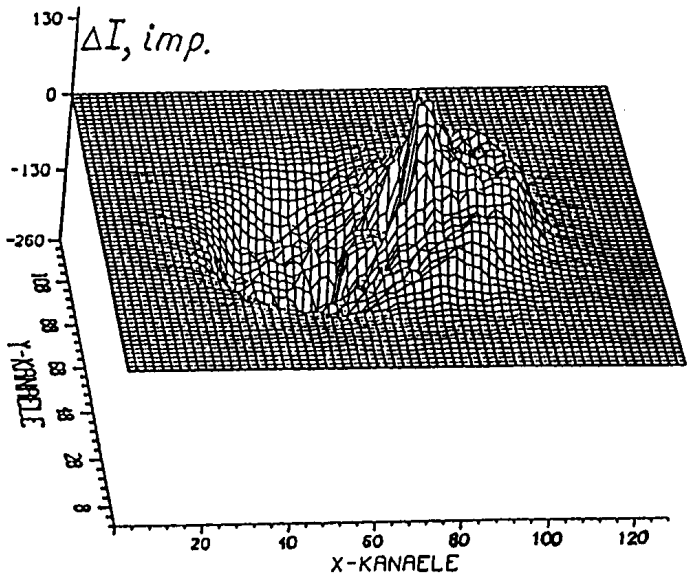

Fig.3. Experimental picture of s—w scattering

should be done at low scattering angles Θ by measuring rater small energy transfers $\omega = E - E_0$ at low momentum $\vec{q} = \vec{k} - \vec{k}_0$ (E_0, E, $\vec{k}_0$, $\vec{k}$ are the initial and final neutron energies and wave vectors). In this experiment we have used a technique of the low angle polarized neutron scattering in a special configuration as proposed in [1] (fig.1). We have measured the small angle scattering intensities of neutrons previosly polarized parallel (I^+) and antiparallel (I^-) to the magnetization $\vec{M}$ of the sample. As it was shown in [1] the magnetic inelastic contribution has left-right asymmetry and can be separated from the intensities of scattering at angle Θ as the odd part $J(\Theta) = \frac{1}{2}[\Delta I(\Theta) - \Delta I(-\Theta)]$ of difference $\Delta I(\Theta) = I^+(\Theta) - I^-(\Theta)$. This odd term is connected with the magnetic scattering amplitude A_m, the normalized magnetization ($\vec{m} = \vec{M}/M$) and scattering ($\vec{e} = \vec{q}/q$) vectors and with Green function of the "scrue" spin correlations $G^a_q(\omega)$:

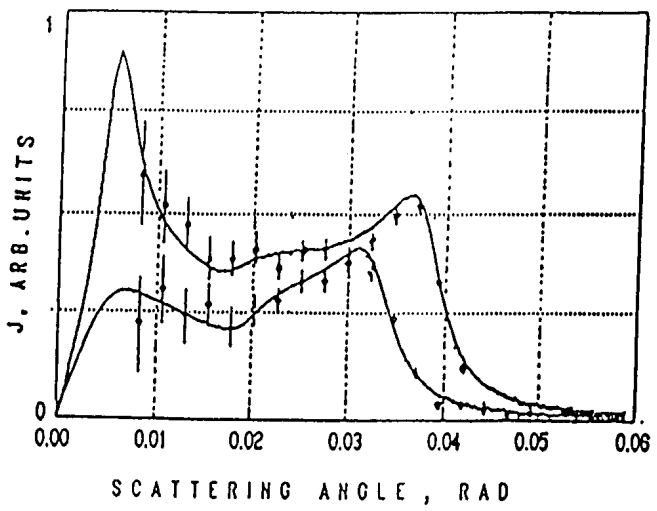

Fig.4. Angle dependence of s—w scattering at $\Phi = 0$ (upper curve) $\Phi = 60^0$ (lower surve). Points are experimental data.Solid lines are theoretical calculation with parameters adduced in text including d—d interaction

$$J(\Theta) = A_m^2\ T/2\pi \int d\omega/\omega\ (\vec{e}\vec{m})^2\ \mathrm{Im}\ G_q^a(\omega) \qquad (1)$$

As far as $\omega^{-1}\ \mathrm{Im}\ G_q^a(\omega)$ is an odd function of ω, the integration over ω gives a nonzero result if one takes into acoount the dispersion of $q(\omega) \approx k(\Theta^2 + Z^2)^{1/2}$, where $z = \omega/2E << 1.0 << 1$ and an odd of z term in $(\vec{e}\vec{m})^2 = (z\,Cos\Psi + \Theta_x \sin\Psi)^2\,(z^2 + \Theta^2)^{-1}$, where $\Theta^2 = \Theta_x^2 + \Theta_y^2$, where $\Theta^2 = \Theta_x^2 + \Theta_y^2$ (fig.1). The odd term $z\,\Theta_x \sin 2\Psi$ is also an odd of Θ_x and is nonzero at $\Psi = 0, \pi/2$.

In the limits $q \to 0$ and $\omega \to 0$ the function $G_q^a(\omega)$ can be writen as $G_q^2(\omega) = G_q(0)\omega\,\varepsilon_q\,[\,(\omega + i\Gamma_q)^2 - \varepsilon_q^2\,]^{-1}$, where $\varepsilon_q = \{\varepsilon_0(\varepsilon_0 + \omega_0[1 - (\vec{e}\vec{m})^2]\}^{1/2}$ is s-w spectrum, $\Gamma_q = \gamma_0 q^2\{\varepsilon_0 + \omega_{0/2}[1 - (\vec{e}\vec{m})^2]\}$ is effective damping, $\varepsilon_0 = Dq^2 + g\mu H_i$, D is s—w stiffness, H_i is internal field strength, ω_0 is dipole energy.

The experiment was carried in Geesthacht (FRG) at CANS-2 scattering fasility of the FRG-1 research reactor. We used 128×128 c area detector and polarized neutron beam with a mean wavelength of $\lambda = 5.25$ Å and 9.6 Å ($\Delta\lambda/\lambda = 10\%$) and divergences of 1.7 *mrad*. The sample of $50\times10\times1\ mm^3$ of amorphous ribbons $Fe_{50}Ni_{22}Cr_{10}P_{18}$ was magnetized to its longest dimension by external magnetic field of 30—300 *mT* applied at an angle $\Psi = 45^0$ with respect to the incident beam direction. The scattering was measured at room temperature.

In fig.2 the calculated two-dimensional profile of $\Delta I(\Theta)$ is shown and fig.3 shows the measured one. The details of this profile including angle Φ dependence contain an information about s-w parameters.

As one can see from fig.4 there is rather good agreement between the theoretical curve for $J(\Theta)$ and the experimental data. From the treatment the folowing parameters were found: s—w stiffness $D = (54 \pm 0.50)\cdot10^{-3}\ eV\,Å^2$, damping factor $\Gamma_0 kR_c = 16.6 \pm 0.5$ (R_c is correlation radius), dipole energy $\omega_0 = (64 \pm 1)\times10^{-6}\ eV$, $\Theta_0 = E/Dq^2 = (38.5 \pm 0.4)\times10^{-3}$.

By this first experiment with the analysis of two-dimensional picture we have shown that spin dynamics in amorphous ferromagnets can be studied in detail including dipole constant with sufficient accuracy.

Reference

1. Okorokov A.I., Runov V.V., Toperverg B.P., Tretyakov A.D., Maltzev E.I., Puzei I.M., Mikhailova V.E. //JETP Lett., 1986. V.43. P.503.