GYROSCOPIC QUASIRELATIVISTIC DYNAMICS OF MAGNETIC VORTICES ON THE DOMAIN WALL OF YTTRIUM ORTHOFERRITE

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Introduction

Existence of spin vortices in the thin films of ferromagnets follows from the Landau-Lifshits equations [1]. M.M. Farztdinov [2] proposed the existence of the magnetic vortices in the orthoferrites domain wall (DW) theoretically. Investigation of these vortices is of essential interest for the nonlinear magnetodynamics, spintronics and the theory of reversible magnetization in ferromagnets and antiferromagnets. The method of magnetic vortices generation was proposed in our laboratory.

This publication is dedicated to experimental investigations of the antiferromagnetic (AFM) vortices dynamics in the yttrium orthoferrite domain wall moving with velocities in a wide range up to the limiting one, which is equal to the spin waves velocity on the main linear part of their dispersion curve. It has been shown experimentally that the dynamics of AFM vortices in the domain wall of yttrium orthoferrite for different values of topological charges, as well as the domain wall dynamics, is quasirelativistic with the limiting velocity 20 km/s equal to the spin-wave velocity.

Experimental

We present experimental data on the dynamics of the solitary deflection waves (SDWs), which accompany the AFM vortices, as functions of the domain wall velocity. The SDWs amplitudes are proportional to the velocity of AFM vortices along the domain wall. A similar relation was known for garnet films but the velocities of spin vortices in that case do not exceed several tens or hundreds meter per second. This result confirms the gyroscopic origin of AFM vortices dynamics in the canted antiferromagnetic – yttrium orthoferrite with Dzialoshinsci-Moriya interaction.

The domain wall velocity in orthoferrites linearly grows with increasing magnetic field reaching the transversal sound velocity. Then the domain wall moves with this velocity in the magnetic field ranging from several tens oersted, for the plates with thickness of the order of hundred micrometers, to several hundred oersted in thinner plates of the order of 10 micrometers. After the motion with the transversal sound velocity, there occurs a very sharp hysteresisless increase of domain wall velocity up to the supersound value of 10-12 km/s and 12-14 km/s in the plates of 50-80 and 30-40 micrometers thick correspondingly. In this case, the visible thickness of the domain wall increases; it inclines to the surface of the sample and becomes unstable. In this range, the sharp local domain wall deceleration, achieved by means of the local magnetic field produced by a single wire or a local defect, generates a pair of solitary deflection waves. After local sharp decelerations of the part of supersonic domain wall the pair AFM vortices moving in opposite direction was generated [3].

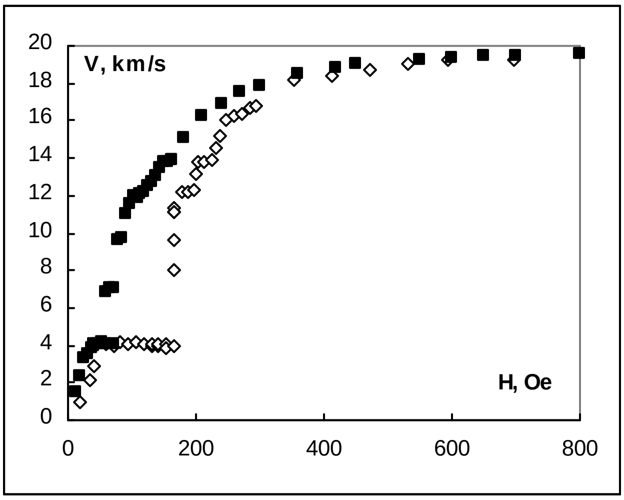

Fig.1 The dependence of the domain wall velocity from magnetic field. The thickness simple is 40 mkm (◊) and 80 mkm (■).

The increase of the DW velocity in the orthoferrites did not generated magnetic vortices up to limiting DW velocity. The solitary deflection waves accompanying AFM vortices in orthoferrites were used for investigation of AFM vortices dynamic [4].

Up to several time ago in this scientific area contradictory situation took place. From one side in the theoretical works gyroscopic force in the orthoferrites was equal to zero. However, from another side experimental results demonstrate the existence of gyroscopic force in the vortex dynamics in the orthoferrites. This contradiction can be resolved in the experiment priority in this question.

Results and Discussion

Dynamics of AFM vortices on DW in the yttrium orthoferrite was investigated experimentally. From digital high-speed real time photographs the DW velocity **v**, the AFM vortices velocity along DW **u** and the total AFM vortices velocity **w** were determined. (Fig.1)

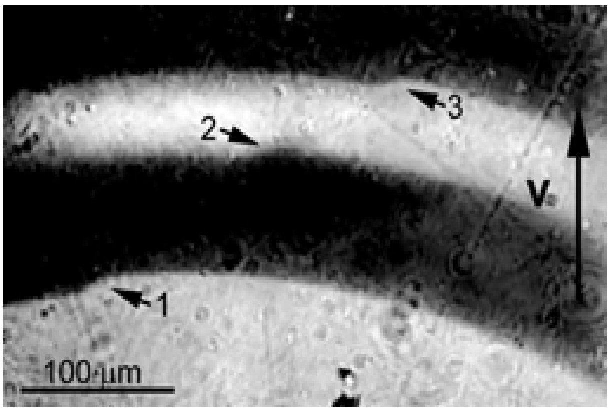

Fig.2 The three-fold photograph of the solitary deflection wave accompanying the AFMV on the moving orthoferrite domain wall. The delay time between first and second positions of the domain wall is 8 ns. The delay time between second and third positions of the domain wall is 6 ns.

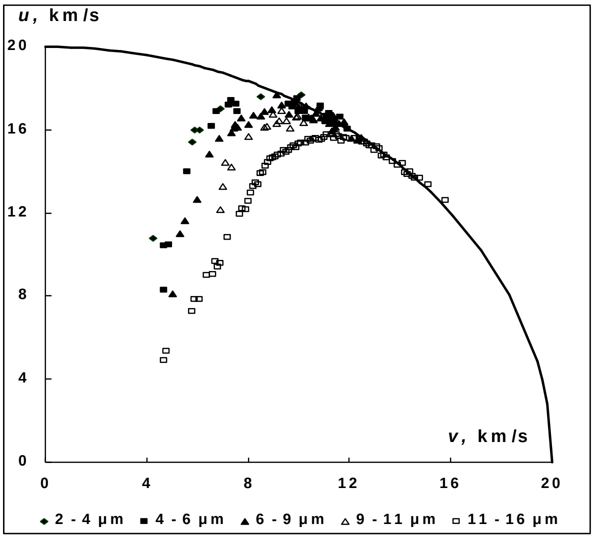

Fig.3 The velocity along moving domain wall of solitary deflection waves with different amplitudes.

The experimental dependence **u(v)** first grows nonlinearly, reaches a maximum, and then follows the relation $\mathbf{u}^2 + \mathbf{v}^2 = \mathbf{c}^2$, where **c** is the spin wave velocity. (Fig.2) The maximum on the **u(v)** curve shifts to higher velocities with increase of the AFM vortex topological charge [4]. The curves **w(v)** demonstrate a nonlinear increase and reach saturation at the level 20 km/s. (Fig. 3)

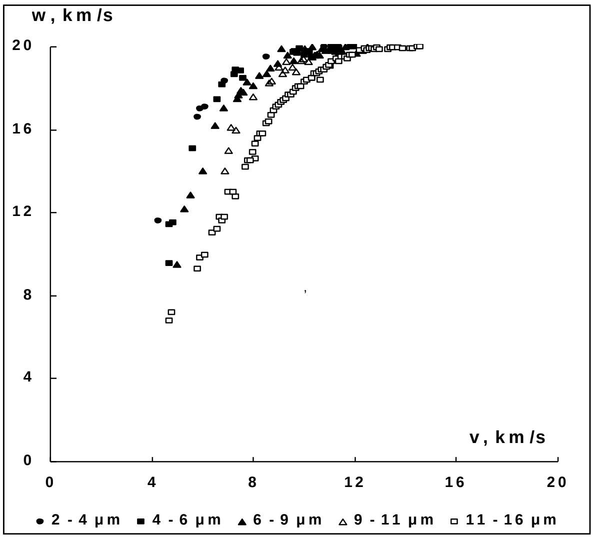

Fig.4 The total velocity of solitary deflection waves with different amplitudes, accompanying the antiferromagnetic vortices with different topological charges.

Conclusion

The AFM vortices dynamics as well as the DW dynamics is quasirelativistic. The gyroscopic force in ortoferrites is proportional to Dzialoshynski field and was successfully used for description of experimental dependences u(v) and w(v) [5].

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References

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