The acoustoelectric transformation in the mixed state in superconducting chalcogenides $FeSe_{1-x}S_x$ (x=0.075)

G. A. Zvyagina[1], V. D. Fil[1], I. V. Bilych[1], K. R. Zhekov[1], D. V. Fil[2,3]

[1]*B.Verkin Institute for Low Temperature Physics and Engineering of NAS of Ukraine, 47 Nauky Avenue, Kharkiv, 61103, Ukraine*
[2]*Institute for Single Crystals, NAS of Ukraine, 60 Nauky Avenue, Kharkiv, 61072, Ukraine*
[3]*V.N. Karazin Kharkiv National University, 4 Svobody Square, Kharkiv, 61022, Ukraine*
e-mail: bilich@ilt.kharkov.ua

Acoustoelectric transformation (AET) is a new method that has made it possible to obtain various information about piezomagnetic and electromagnetic effects in studied media. In particular, it permits to study the temperature and magnetic field dependence of the AE response of the systems with superconducting ordering. Recently, at temperatures below the temperature of the structural phase transition T_s the AE transformation revealed the hidden magnetism in FeSe.

The scheme of the AET experiment is shown in Fig. 1. The shear deformation of a given polarization, generated by the piezoelectric transducer, is introduced into the sample through an acoustic delay line. The electromagnetic field, arising in the sample under deformation, is radiated into free space and registered by a frame antenna placed near the sample. The interface radiating surface is orthogonal to the wave vector of the sound mode.

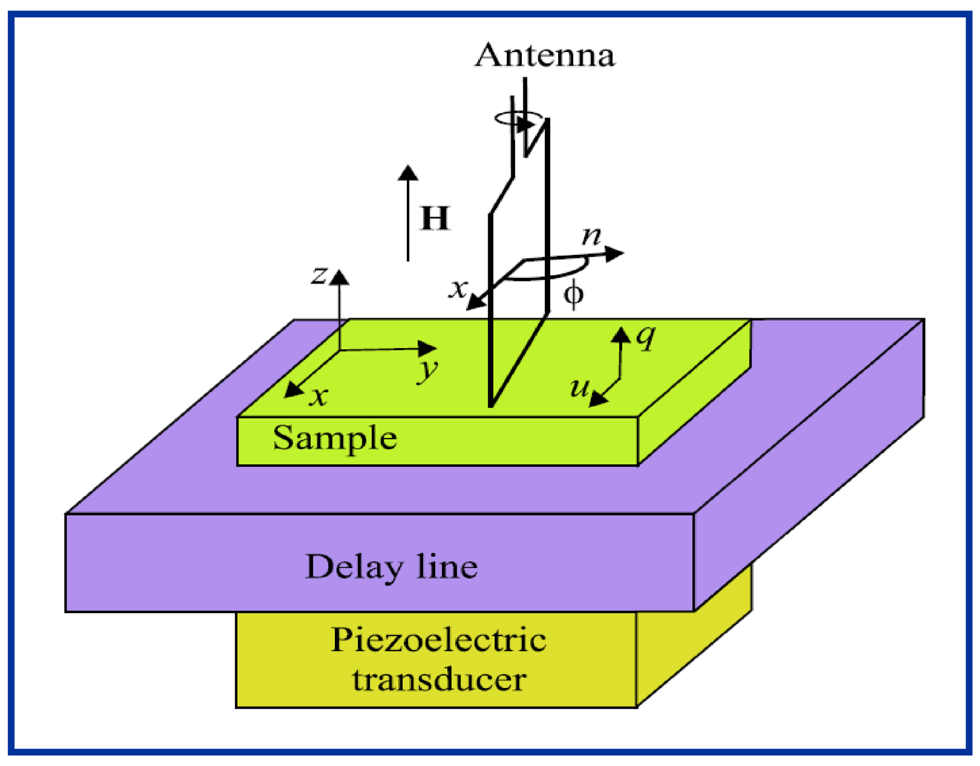

Fig. 1. Geometry of the AET experiment

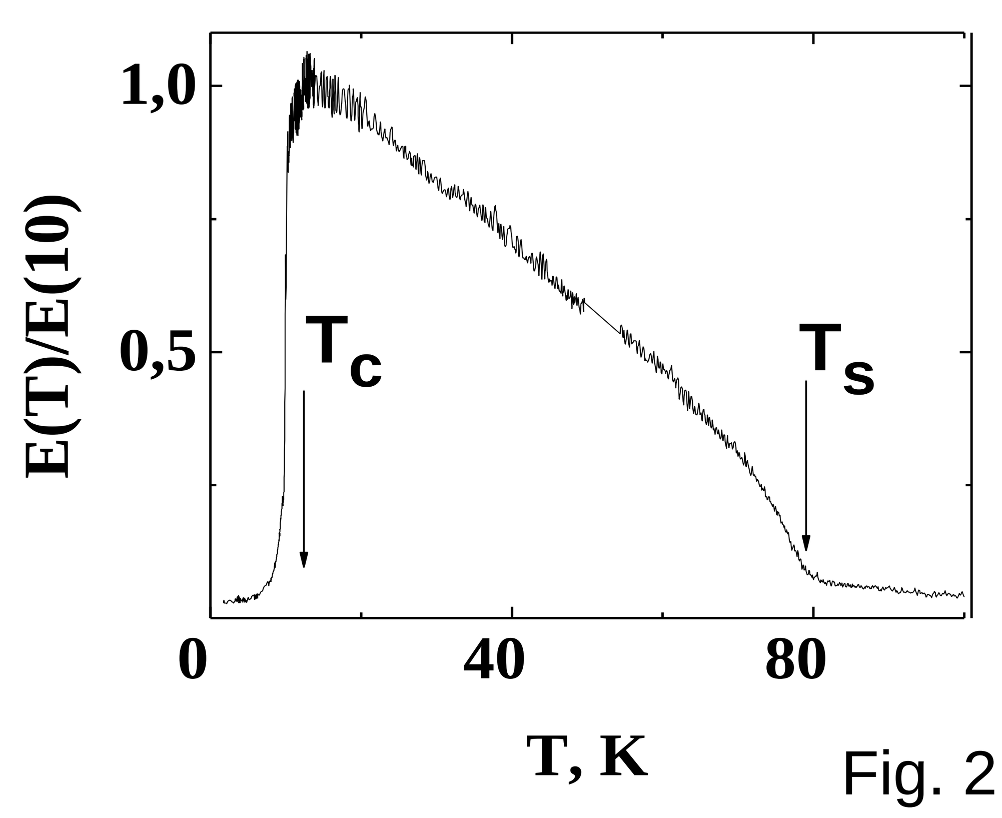

Fig. 2.

Fig. 2. Temperature dependence of the amplitude of the radiation field in $FeSe_{0.925}S_{0.075}$.
T_s is the temperature of the structural transformation.
T_c is the superconducting transition temperature.

The temperature dependence of the amplitude of the radiation field obtained in the experiment is shown in Fig. 2. The AET signal increases rapidly below Ts, but at the point of the superconducting transition Tc, it sharp decreases almost to zero. This fact allows us to assume that this signal exists only in the normal state.

We studied the behavior of the phase (a) and amplitude (b) of the AET signal in weak magnetic fields, Fig.3. Red and green curves correspond to the opposite directions of the magnetic field . The measurements were done at the temperature $T=0.9T_c$ (about 11 Kelvin), that allows us to neglect the contribution of the normal component to the AET signal. The measurements presented in Fig.3 were done in the range of H corresponding to the initial stage of magnetic flux penetration into the sample.

From the amplitude measurements it can be concluded that the **low critical field** is equal to H_{c1} ~15Oe. Above this field, the response amplitude changes linearly with the magnetic field and the phases for the two directions of H practically coincide each other.

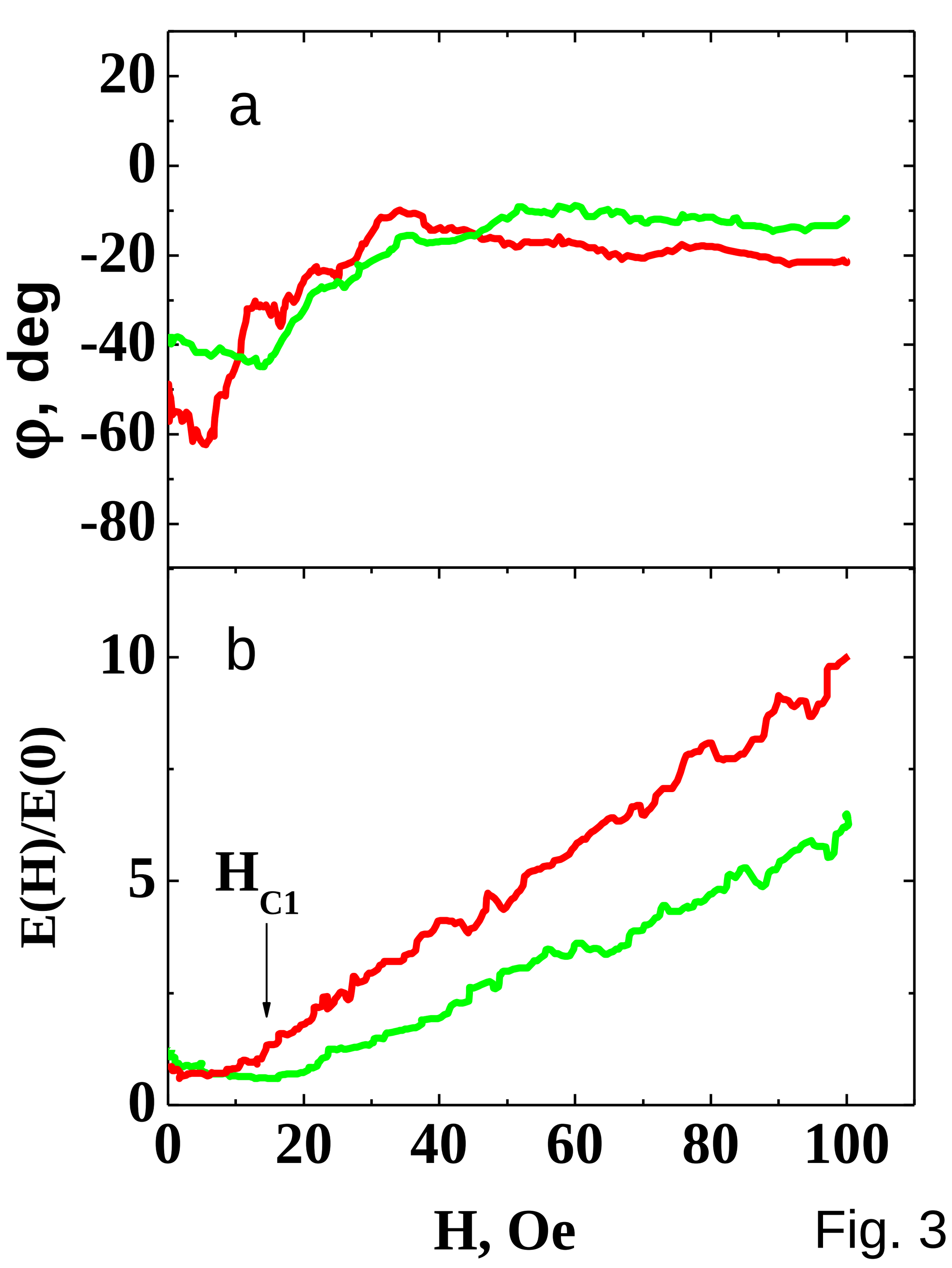

Fig. 3

This indicates the presence of two signals of a different nature linearly dependent on the external field, a weak one whose phase depends on the direction of the magnetic field (odd signal) and a stronger one whose phase does not depend on the direction of the field, but depends only on the magnitude (even signal) (Fig. 4).

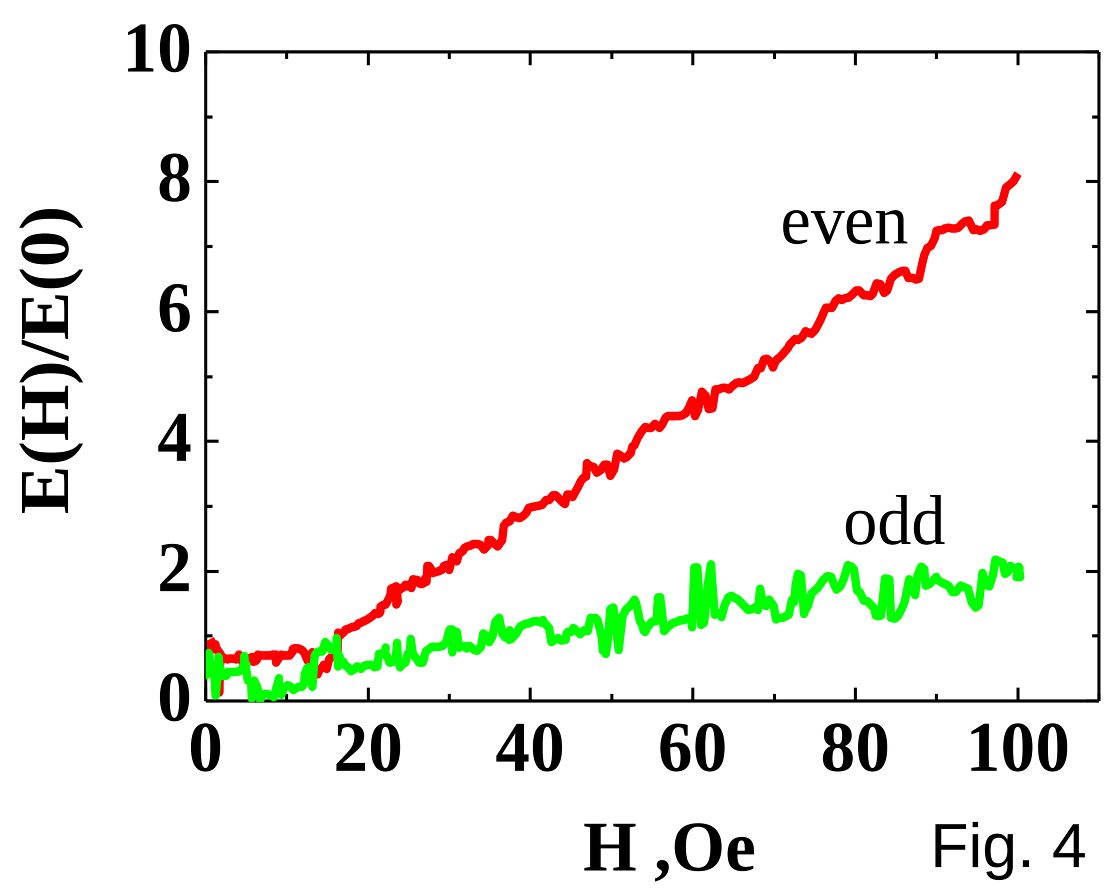

Fig. 4

In a mixed state in a superconductor with such polarization of the antenna, the existence of two sources of "even on the field" signals is possible.

The first is the sound movement of the vortex lattice, but at our sound frequencies and small fields it is practically independent of the field,

and the second is **piezomagnetism**.

The following results were obtained:

The AET in the mixed state of superconducting chalcogenides based on FeSe has been studied.

The low critical field H_{c1}~15Oe was determined in $FeSe_{0.925}S_{0.075}$ single crystal.

The dependence of the AET signal from the magnetic field we got at the initial stages of flux penetration was demonstrated a behavior that can be explained, in our opinion, only if the **piezomagnetism** is included in the consideration. The existence piezomagnetic response in FeSe-based chalcogenides can be considered a direct confirmation of **breaking of time-reversal symmetry** in $FeSe_{1-x}S_x$ single crystals.