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LONGITUDINAL AND TRANSVERSE THERMOMAGNETIC WAVES IN ANISOTROPIC CONDUCTING MEDIA

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Abstract- In this paper, the conditions for the excitation of thermomagnetic waves are theoretically investigated. It is shown that, depending on the value of the electrical conductivity tensor, thermomagnetic waves are excited in the longitudinal and transverse directions. It is proved that the excited wave is mainly of a thermomagnetic nature. In theory, the resulting dispersion equation is algebraically high powers with respect to the oscillation frequency. It is proved that if the value of the electrical conductivity tensor is the same, then the frequency of propagation of thermomagnetic waves is different.

Keywords: Purity, Increment, Thermomagnetic Waves, Transverse Waves, Longitudinal Waves, Growth, Electrical Conductivity Tensor, Inverse Tensor.

1. INTRODUCTION

It was proved in [1, 2] that hydrodynamic motions in a plasma, in which there is a constant temperature gradient, a magnetic field arises. In this case, the plasma has oscillatory properties that are noticeably different from ordinary plasma. In such a plasma, thermomagnetic waves are excited, in which only the magnetic field oscillates. In the presence of an external magnetic field, the wave vector of thermomagnetic waves is perpendicular to the magnetic field or lies in the plane $\vec{H},\vec{\nabla}T$. The speed of thermomagnetic waves is comparable to the speed of sound and the speed of the Alfven wave. The temperature gradient is independent of time and coordinates. The Larmor frequency of charge carriers is less than the frequency of their collisions, i.e.

$$\psi_\tau << 1,\ \psi = \frac{eH}{mc}$$

In the presence of an electric field E, a temperature gradient $\nabla T = \text{const}$, a concentration gradient of charge carriers $\vec{\nabla}n$ and hydrodynamic movements with a speed $\vec{\upsilon}\left(\vec{r},t\right)$, the electric current density has the form

$$\vec{j} = \eta\vec{E}^* + \eta'\left[\vec{E}^*\vec{H}\right] - \beta\nabla T - \beta'\left[\nabla TH\right]$$
$$E^* = \vec{E} + \frac{\left[\upsilon\vec{H}\right]}{c} + \frac{T}{e}\frac{\nabla n}{n},\ e>0 \qquad (1)$$

The definition E from the vector Equation (1) reduces to solving the vector equation

$$\vec{\chi} = \vec{a} + \left[\vec{b}\,\vec{\chi}\right] \qquad (2)$$

From Equation (2);

$$\left(\vec{b}\vec{\phi}\right) = \left(\vec{b}\vec{a}\right),\ \vec{x} = \vec{a} + \left[\vec{b}\vec{a}\right] + \left[\vec{b}\left[\vec{b}\,\vec{\chi}\right]\right]$$

At $b^2 << 1$, we will get:

$$\vec{E} = -\frac{\left[\vec{\upsilon}\vec{H}\right]}{c} - K'\left[\vec{\nabla}T\vec{H}\right] + \frac{c}{4\pi\eta}\text{rot}\vec{H} - \frac{c\eta'}{4\pi\eta^2}\left[\text{rot}\vec{H},\vec{H}\right] + \frac{T}{c}\frac{\nabla\rho}{\rho} + K\nabla T \qquad (2^*)$$

where, obtaining expression (2^*), the Maxwell equation $rot\vec{H} = \frac{4\pi}{c}\vec{j}$ was used, where $K = \frac{\alpha}{\eta}$, $K = \frac{\beta'\eta - \beta\eta'}{\eta^2}$. The σ is the electrical conductivity coefficient, η' is the differential thermopower, and η is the coefficient of the Nerst-Ettinshausen effect. Substituting (2) into the equation $\frac{\partial\vec{H}}{\partial e} = -c\text{rot}\vec{E}$, we obtain an equation containing $\vec{H}$ and $\vec{\nabla}T$. It was proved in [1, 2] that at $\vec{k}\perp\vec{H}'$, a thermomagnetic wave is excited with a frequency

$$\varpi_T = -cK'\vec{k}\vec{\nabla}T$$

It was proved in [3] that the flow of charge carriers in conductive solids creates hydrodynamic motions and, therefore, it is possible to excite thermomagnetic waves in conductive media. It was proved in [4] that, depending on the value of the electrical conductivity tensor η_{ik}, several thermomagnetic waves can be excited in anisotropic conducting media. In this theoretical work, we will prove that, depending on the value of the tensor η_{ik}, several thermomagnetic waves with different frequencies are simultaneously excited in anisotropic conducting media. When the wave vector of thermomagnetic waves is directed along the temperature gradient $\vec{k}\parallel\vec{\nabla}T$ (longitudinal wave), we determine the frequencies of thermomagnetic waves.

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Let us prove that at $\vec{k} \parallel \vec{\nabla} T$ (longitudinal wave) and at $\vec{k} \perp \vec{\nabla} T$ (transverse wave) thermomagnetic waves can grow (instability). The growth rate of the thermomagnetic wave differs significantly at $\vec{k} \parallel \vec{\nabla} T$ and at $\vec{k} \perp \vec{\nabla} T$.

2. THEORY

In the presence of a temperature gradient and an external magnetic field in an isotropic solid, the total electric field [4-6] has the form:

$$\begin{aligned} &\vec{E} = \xi \vec{j} + \xi'' \left[j\vec{H} \right] + \xi'' \left(\vec{j}\vec{H} \right) \vec{H} + \\ &+K \frac{\partial T}{\partial x} + K' \left[\vec{\nabla} T \vec{H} \right] + K'' \left(\vec{\nabla} T \vec{H} \right) \vec{H} \end{aligned} \tag{3}$$

In an anisotropic solid, all coefficients in Equation (3) are tensors. Then for an anisotropic solid body (3) we will have the form:

$$\begin{aligned} &E_i = \xi_{ik} j'_k + \left[j\vec{H} \right]_k j'_{ik} + \xi''_{ik} \left(\vec{j}\vec{H} \right) \vec{H}_k + \\ &+K_{ik} \frac{\partial T}{\partial x_k} + K'_{ik} \left[\vec{\nabla} T \vec{H} \right]_k + K''_{ik} \left(\vec{\nabla} T \vec{H} \right) \vec{H}_k \end{aligned} \tag{4}$$

where, j_{ik} is the reciprocal tensor of the ohmic resistance $\xi_{ik} = \frac{1}{\eta_{ik}}$, K_{ik} is the differential thermoelectric power, and Λ'_{ik} is the Nerist-Ettinizhausen coefficient. We will consider an external magnetic field in an anisotropic solid. Then in Equation (4) the terms containing $\xi'_{ik}, \xi''_{ik}, K''_{ik}$ is equal to zero. Then for our problem the system of Equations (5)-(7).

$$\begin{aligned} &E'_i = \xi_{ik} j'_k + K'_{ik} \left[\vec{\nabla} T H \right]_k \\ &rot\vec{E}' = -\frac{1}{c} \frac{\partial \vec{H}'}{\partial t} \\ &rot\vec{H}' = \frac{4\pi}{c} \vec{j}' + \frac{1}{c} \frac{\partial \vec{E}'}{\partial t} \end{aligned} \tag{5}$$

Let us assume that all variables have the character of a monochromatic wave. Then from Equation (5) we get;

$$\begin{aligned} &E'_i = \xi_{ik} j'_k + K'_{ik} \left[\vec{\nabla} T H \right]_k \\ &j' = \frac{ic^2}{4\pi\varpi} \left[\vec{k} \left[\vec{k}\vec{E}' \right] \right] + \frac{i\varpi}{4\pi} E'_{ik} \end{aligned} \tag{6}$$

From Equation (6) we will get

$$\begin{aligned} &E'_i = \frac{ic^2}{4\pi\varpi} \xi_{ik} \left(\vec{k}\vec{E}' \right) \Lambda_k + \frac{i\left(\varpi^2 - c^2 k^2 \right)}{4\pi\varpi} \xi_{ik} E'_k + \\ &+\frac{cK'_{ik}}{\varpi} \left(\vec{\nabla} T \vec{E}' \right) \Lambda_k - \frac{cK'_{ik}}{\varpi} \left(\vec{k} \vec{\nabla} T \right) E'_k \end{aligned} \tag{7}$$

2.1. Transverse Thermomagnetic Waves $\vec{k} \perp \vec{\nabla} T$

When $\vec{k} \perp \vec{\nabla} T$ you can choose the coordinate system

$$\begin{aligned} &k_1 \neq 0 \ , \ k_2 = k_3 = 0 \ , \ k_1 \frac{\partial T}{\partial x_1} = \left(\vec{k} \vec{\nabla} T \right) = 0 \\ &\frac{\partial T}{\partial x_2} \neq 0 \ , \ \frac{\partial T}{\partial x_3} = 0 \end{aligned} \tag{8}$$

With this choice, from Equation (7) we easily obtain;

$$\begin{aligned} &E'_i = \left(C\xi_{il} k_l k_k + D\varsigma_{ik} + \frac{cK'_{ik}}{\varpi} k_l \frac{\partial T}{\partial x_k} \right) E'_k \\ &E'_i = \delta_{ik} E'_k \ , \ \delta_{ik} = \begin{cases} 1 \ , \text{ if } \ i = k \\ 0 \ , \text{ if } i \neq k \end{cases} \\ &C = \frac{ic^2}{4\pi\varpi} \ , \ D = \frac{i\left(\varpi^2 - c^2 k^2 \right)}{4\pi\varpi} \end{aligned} \tag{9}$$

Denote

$$\phi_{ik} = C\xi_{il} k_l k_k + D\varsigma_{ik} + \frac{cK'_{il}}{\varpi} k_l \frac{\partial T}{\partial x_k} \tag{10}$$

Then, from (9) we will get

$$\begin{aligned} &\psi_{11} = \frac{i\varpi}{4\pi} \varsigma_{11} \ , \ \psi_{12} = i\eta\varsigma_{12} + \frac{\varpi_{12}}{\varpi} \\ &\psi_{13} = i\eta\varsigma_{13} \ , \ \eta = \frac{\varpi^2 - c^2 k^2}{4\pi\varpi} \\ &\psi_{21} = \frac{i\varpi}{4\pi} \eta_{21} \ , \ \phi_{22} = i\eta\xi_{22} + \frac{\varpi_{22}}{\varpi} \\ &\psi_{23} = i\eta\xi_{23} \\ &\psi_{31} = \frac{i\varpi}{4\pi} \xi_{31} \ , \ \psi_{32} = i\eta\xi_{32} + \frac{\varpi_{32}}{\varpi} \\ &\psi_{33} = i\eta\xi_{33} \end{aligned} \tag{11}$$

Substituting (11) into (9) we get

$$\left| \left(\psi_{ik} - \delta_{ik} \right) \right| = 0 \tag{12}$$

or

$$\begin{aligned} &\psi_{31}\psi_{12}\psi_{23} + \psi_{21}\psi_{32}\psi_{13} + \\ &+\left(\psi_{11} - 1 \right)\left(\psi_{22} - 1 \right)\left(\psi_{33} - 1 \right) - \\ &-\psi_{31}\psi_{13}\left(\psi_{22} - 1 \right) - \\ &-\psi_{32}\psi_{23}\left(\psi_{11} - 1 \right) - \psi_{21}\psi_{12}\left(\psi_{33} - 1 \right) = 0 \end{aligned} \tag{13}$$

Dispersion Equation (13), taking into account (11), has the form

$$\sum_{i=1}^{5} u_i \varpi_i + u_0 = 0 \tag{14}$$

The fifth degree relative to the purity of the vibration of Equation (14) has a very complex form. Simplification of Equation (14) requires a lot of mathematical approximations. However, Equation (14) is easily simplified depending on the tensor ς_{ik}. If

$$\begin{aligned} &\xi_{12} = \xi_{13} = \xi_{22} = \xi_{23} = \xi_{32} = \xi_{33} \\ &\xi_{11} = \xi_{21} = \xi_{31} \end{aligned} \tag{15}$$

The dispersion equation has the form:

$$\begin{aligned} &\frac{1}{2\pi} \left(\frac{i\xi_{11}}{2} + \xi_{22} \right) \varpi^2 + \\ &+\left[\frac{i\xi_{11}}{4\pi} \left(\varpi_{13} + \varpi_{12} - \varpi_{22} \right) - 1 \right] \varpi + \\ &+\varpi_{22} + \varpi_{33} - \frac{ic^2 k^2}{2\pi} \xi_{22} = 0 \end{aligned} \tag{16}$$

Substituting $\varpi = \varpi_0 + i\varphi$.

Then we obtain from Equation (16) the following two equations for determining ϖ_0 and φ

$$\frac{1}{2\pi}\xi\varpi_0^2-\frac{1}{4\pi}\xi\varpi_0\varphi-\frac{\xi}{4\pi}\left(\varpi_{13}+\varpi_{12}-\varpi_{22}\right)\varphi- -\varpi_0+\varpi_{22}+\varpi_{33}=0 \quad (17)$$

$$\frac{1}{4\pi}\xi\varpi_0^2+\frac{1}{2\pi}\xi\varpi_0\gamma+\frac{\xi}{4\pi}\left(\varpi_{13}+\varpi_{12}-\varpi_{22}\right)\varpi_0- -\varphi-\frac{c^2k^2\xi}{2\pi}=0 \quad (18)$$

From Equation (18)

$$\varphi=\frac{1}{4\pi}\xi\varpi_0^2+\frac{\xi}{4\pi}\left(\varpi_{13}+\varpi_{12}-\varpi_{22}\right)\varpi_0-\frac{c^2k^2\xi}{2\pi} \quad (19)$$

Substituting Equation (19) into Equation (17)

$$\frac{1}{2\pi}\xi\varpi_0^2-\frac{\xi}{4\pi}\left(\varpi_{13}+\varpi_{12}-\varpi_{22}\right)\times \times\left[\frac{1}{4\pi}\xi\varpi_0^2+\frac{\xi}{4\pi}\left(\varpi_{13}+\varpi_{12}-\varpi_{22}\right)\varpi_0-\frac{c^2k^2\xi}{2\pi}\right]- -\varpi_0+\varpi_{22}+\varpi_{33}=0 \quad (20)$$

From Equation (20) it can be seen that at

$$\varpi_{22}=\varpi_{13}+\varpi_{12},\ \xi=\frac{\pi}{2\left(\varpi_{22}+\varpi_{33}\right)}\ \ \varpi_0=2\left(\varpi_{22}+\varpi_{33}\right) \quad (21)$$

Thus, a purely thermomagnetic wave. Substituting Equation (21) into Equation (19) we get

$$\varphi=\frac{1}{2}\left(\varpi_{22}+\varpi_{33}\right)-\frac{1}{2}\frac{c^2k^2}{\varpi_{22}+\varpi_{33}} \quad (22)$$

It can be seen from Equation (22) that the wave with frequency Equation (21) grows if $\varpi_{22}+\varpi_{33}>>ck$.

2.2. Longitudinal Thermomagnetic Wave $\vec{k}\parallel\vec{\nabla}T$

Under the condition $\vec{k}\parallel\vec{\nabla}T$, you can choose the axes so that

$$k_1=k\ ,\ k_2=k_3=0\ ,\ \frac{\partial T}{\partial x_2}=\frac{\partial T}{\partial x_3}=0\ ,\ k_1\frac{\partial T}{\partial x_1}\neq 0$$

$$\frac{\partial T}{\partial x_2}\neq 0\ ,\ \frac{\partial T}{\partial x_3}=0$$

With this choice, the tensors have the form ϕ_{ik}

$$\psi_{11}=\frac{i\varpi}{4\pi}\xi_{11}\ ,\ \ \psi_{12}=i\eta\xi_{12}+\frac{\varpi_{12}}{\varpi}$$
$$\psi_{13}=i\eta\xi_{13}+\frac{\varpi_{13}}{\varpi}\ ,\ \ \psi_{21}=\frac{i\varpi}{4\pi}\xi_{21}$$
$$\psi_{22}=i\eta\xi_{22}+\frac{\varpi_{22}}{\varpi}\ ,\ \ \psi_{23}=i\eta\xi_{23}+\frac{\varpi_{23}}{\varpi} \quad (23)$$
$$\psi_{31}=\frac{i\varpi}{4\pi}\xi_{31}\ ,\ \varphi_{32}=i\eta\xi_{32}+\frac{\varpi_{32}}{\varpi}$$
$$\varphi_{33}=i\eta\xi_{33}+\frac{\varpi_{33}}{\varpi}$$

Substituting Equation (23) into Equation (13) we get:

$$-\frac{i}{64\pi^3}\left(\xi_{31}\xi_{21}\xi_{23}+\xi_{31}\xi_{13}\xi_{32}\right)\varpi^4+ +\frac{1}{64\pi^2}\left(\xi_{11}\xi_{22}+\xi_{11}\xi_{33}\right)\varpi^3+ +\left[\frac{i}{64\pi^3}\left(\xi_{31}\xi_{21}\xi_{23}+2\xi_{31}\xi_{13}\xi_{32}\right)c^2k^2+ +\frac{i}{4\pi}\left(\xi_{11}+\xi_{22}+\xi_{33}\right)+\frac{\varpi_{22}}{16\pi^2}\left(\xi_{11}\xi_{33}+2\xi_{31}\xi_{13}\right)\right]\varpi^3+ +\left[-\frac{1}{64\pi^3}\left(\xi_{11}\xi_{22}+\xi_{11}\xi_{33}\right)c^2k^2-1+\frac{i\varpi_{22}}{4\pi}\left(\xi_{11}-\xi_{21}\right)\right]\varpi- -\frac{ic^2k^2}{4\pi}\left(\frac{1}{64\pi^2}\xi_{31}\xi_{13}\xi_{32}c^2k^2-\xi_{22}-\xi_{33}\right)- -\frac{1}{64\pi^2}\varpi_{22}c^2k^2\left(\xi_{11}\xi_{33}+\xi_{13}\xi_{31}\right)-\varpi_{22}=0 \quad (24)$$

If the tensors have the same values in all directions ξ_{ik} , then from Equation (24) we get:

$$x^4+16\pi ix^3+\left(-48\pi^2+12\pi i\varpi_{22}\xi\right)x^2+ +64\pi^3 i\left(-1+i\frac{\varpi_{22}\xi}{2\pi}\right)x-\varpi_{22}\xi=0 \quad (25)$$
$$x=\xi\varpi$$
$$ck\xi<<1$$

Assuming $x=x_0+ix_1, x_1<<0$ from Equation (25), we get:

$$x_0^4-48\pi x_0^2x_1-48\pi^2x_0^2-24\pi\varpi_{22}\xi x_0x_1+ +64\pi^3\frac{\varpi_{22}\xi}{2\pi}x_0+64\pi^3x_1-\varpi_{22}\xi=0 \quad (26)$$

$$4x_0^3x_1+16\pi x_0^3-96\pi^2x_0x_1+12\pi\varpi_{22}\xi x_0^2- -64\pi^3x_0-32\pi^2\varpi_{22}\xi x_1=0 \quad (27)$$

From Equations (26) and (27), it can be seen that at $x_0>>1$, thermomagnetic waves do not exist, then Equations (26) and (27), we have

$$-24\pi\varpi_{22}\xi x_0x_1+32\pi^2\varpi_{22}\xi x_0+64\pi^3x_1-\varpi_{22}\xi=0 \quad (28)$$
$$-96\pi^2x_0x_1-64\pi^3x_0-32\pi^2\varpi_{22}\xi x_1=0 \quad (29)$$

From Equation (29), we will get $x_0=-\frac{\varpi_{22}\xi}{2\pi}x_1$, $x_0<\frac{1}{3\pi}\varpi_{22}\xi$. Substituting into Equation (28) we get:

$$\chi_1=\frac{2\pi}{3}\ \ ,\ \ \varpi_1=\frac{2\pi}{3}\times\frac{1}{\varsigma}$$
$$\varpi_0=-\frac{\varpi_{22}}{2\pi}\times\frac{2\pi}{3}=-\frac{\varpi_{22}}{3} \quad (30)$$

From Equation (30) it can be seen that the wave with frequency $\varpi_0=-\frac{\varpi_{22}}{3}$ is increasing.

$$\frac{\varpi_0}{\varpi_1}=\frac{\varpi_{22}}{3}\times\frac{3\xi}{2\pi}=\frac{\varpi_{22}\xi}{2\pi}<<1\ ,\ \varpi_{22}\xi<<2\pi$$

Output figures and outcome the following results:

1. Thermomagnetic waves with different frequencies are excited in anisotropic conducting media. These waves can be longitudinal $\vec{k} \parallel \vec{\nabla} T$ and transverse $\vec{k} \perp \vec{\nabla} T$.

2. Frequencies in anisotropic media change depending on the value of electrical conductivity in these media. These waves are growing in all experimental values of the electrical conductivity of the medium.

3. In contrast to isotropic media, in anisotropic media, thermomagnetic waves are excited with some values without an external magnetic field. Dispersion Equations (26) and (27) have solutions in different approximations with respect to the real frequency of thermomagnetic waves. Naturally, thermomagnetic waves can propagate in different approximations. We managed to solve dispersion Equations (26) and (27) in approximations under existing experimental conditions. In anisotropic media, we have chosen the tensor in the form Equation (23) for $\vec{k} \parallel \vec{\nabla} T$ and in the form Equation (11) for $\vec{k} \perp \vec{\nabla} T$.

The studied excited thermomagnetic waves in other directions (i.e., k makes some angle with $\vec{\nabla} T$) shows that the growth of such thermomagnetic waves is weaker than $\vec{k} \parallel \vec{\nabla} T$ and $\vec{k} \perp \vec{\nabla} T$.

3. CONCLUSIONS

From the above conclusions, it follows that in anisotropic conducting media, it is possible to excite a number of thermomagnetic waves with frequency frequencies. However, at present, there are no experimental data on thermomagnetic waves in the public domain. From Equation (30) one can calculate the frequency of these waves.

$$\varpi_0 = -\frac{\varpi_{22}}{3} = \frac{cK\vec{k}\vec{\nabla} T}{3} = \frac{\varpi_T}{3}$$

This frequency is three times less than the frequency of thermomagnetic waves in plasma (i.e., than the frequency ϖ_T).

REFERENCES

[1] L.E. Gurevich "Plasma Theory", Development of Physics in the USSR, ZhETF, Vol. 44, No. 1, p. 166, Moscow, Russia, 1963.

[2] L.E. Gurevich, E.R. Gasanov, "Theory of Spontaneous Oscillations of Current in Crystals of the Type of Germanium Doped with Gold", FTP, Vol. 3, No. 8, pp. 1201-1206, St. Petersburg, Russia, 1969.

[3] E.R. Hasanov, A.V. Islamzade, H.Sh. Hasanov, "Thermomagnetic Waves in Anisotropic Conductors", International Journal on Technical and Physical Problems of Engineering (IJTPE), Issue 26, Vol. 8, No. 1, pp. 50-54, March 2016.

[4] E.R. Hasanov, M.F. Novruzov, A.Z. Panahov, A.I. Demirel, "Instability of Thermomagnetic Waves in the GeAu Semiconductors with Impurities", India, International Journal of Pure and Applied Physics, ISSN 0973-1776, Vol. 4, No. 1, pp. 23-28, 2008.

[5] E.R. Hasanov, M.F. Novruzov, A.Z. Danahov, A.I. Demirel, "Energy Generation and Amplitude of Thermomagnetic Waves in the Conducting Medium", Modern Phys. Lett., B, Vol. 22, No. 6, pp. 455-457, London, England, 2008.

[6] A.N. Novruzov, E.R. Hasanov, "Thermomagnetic Waves in Impurity Semiconductors", AMEA, Institute of Physics, Fizika, No. 1-2, Vol. XIII, pp. 134-136, Baku, Azerbaijan, 2007.

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