The Three Phonon Fields in Superconductors

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Abstract: The Scale-Symmetric Theory (SST) shows that the internal dynamics of the core of proton leads to superconductivity. The first, second and third phonon fields are created due to the electroweak interactions of the oscillation masses, radiation masses and masses of the electron-positron pairs, respectively. The composite phonons (they are the entangled spacetime condensates) are responsible for creation of both the spin-0 Cooper pairs and boson condensate composed of the Cooper pairs. We calculated that at atmospheric pressure, critical temperature of the Type II superconductors can be from 4.4 K up to 148 K. We calculated also that at extreme pressure, for relative volume equal to 0.67, critical temperature is 304 K. We show that it is impossible to make a material that is a superconductor at room-temperature and atmospheric pressure.

1. Introduction

Superconductivity is a flow of a condensate of electron pairs (the Cooper pairs) without electrical resistance.

Our model of the superconductivity is as follows. In surroundings of the core of proton described in SST [1], the electroweak interactions of the oscillation masses, radiation masses and masses of the electron-positron pairs (and their associations due to the quantum entanglement) create the composite phonons which are the entangled condensates of the Scale-Symmetric Theory (SST) absolute spacetime (SST-As) components (they are the neutrino-antineutrino pairs). The SST-As components are the carriers of photons and gluons [1]. Such composite phonons are exchanged between the electrons in the spin-0 Cooper pair (it defines the binding energy) – such is the origin of the attractive interactions among electrons in the Cooper pairs. The composite phonons are exchanged also between the Cooper pairs so there is created a boson condensate composed of the Cooper pairs – it is the critical field responsible for superconductivity. In the Type I superconductors, there is the phonon field produced by both the oscillation masses and radiation masses, while in the Type II superconductors, there are the three phonon fields. Size of the Cooper pairs (here it is also the SST coherence length ξ_{SST}) is inversely proportional to the phonon energy. Different values for the coherence length result from different energies of the composite phonons. In superconductors, at higher intrinsic pressure (it depends on internal structures of the atomic nuclei and lattice of a superconductor as a whole), the composite phonons contain more the elementary phonons (more the entangled elementary condensates). Good superconductors are substances in which the number density of the created electron-positron pairs is relatively high – then the intrinsic pressure is higher so the boson condensate of the Cooper pairs is very stable. Moreover, in superconductor lattice, vibrational energies of the atomic nuclei increase with increasing intrinsic pressure – it validates the BCS theory.

According to the Scale-Symmetric Theory (SST) [1], the core of baryons consists of the spin-1/2 torus/electric-charge (it is responsible for the electromagnetic interactions) and the spin-0 central condensate with a mass of $Y = 424.12174(41)$ **MeV** (it is responsible for the nuclear weak interactions). On the circular axis inside the torus/electric-charge are produced the virtual fundamental gluon loops (FGLs) with a mass of $m_{FGL} = 67.544410(65)$ **MeV** (they are responsible for the nuclear strong interactions). The FGLs are exchanged between the proton core and the relativistic pion placed outside it.

On the other hand, the electron [1] consists of the spin-1/2 torus/electric-charge (outside it there are creations and annihilations of a virtual electron-positron pair) and the spin-0 central condensate (it is responsible for the weak interactions of electron).

Both tori/electric-charges, i.e. of proton and electron, consist of the same objects and number of the objects is the same so both electric charges have the same value but their sizes are different [1].

In our calculations appear also following quantities calculated within SST [1].

*Fine-structure constant: $\alpha_{em} = 1 / 137.035998889019$.

*Coupling constant for the nuclear weak interactions: $\alpha_{w(p)} = 0.018722909$.

*Coupling constant for the weak interactions of electrons: $\alpha_{w(e)} = 0.95111861 \cdot 10^{-6}$.

*Radius of the circular axis in the core of proton: $R_{FGL} = 2A/3 = 0.46496165$ **fm**.

*Radius of the spacetime condensate in electron: $r_{C(e)} = 0.73541849 \cdot 10^{-18}$ **m**.

*Mass of electron: $m_e = 0.51099880(49)$ **MeV**.

*Bare mass of electron: $m_{e,bare} = 0.51040691(49)$ **MeV**.

*Mass of bound neutral pion: $\pi^o{}_{bound} = 134.9661$ **MeV**.

*Mass of the electrically charged core of proton: $H^+ = 727.4387$ **MeV**.

*Mass of the fundamental spacetime condensate created due to the electroweak interactions in the core of baryons: $M_{Con} = 2\pi\, m_{FGL} - Y = 0.27230$ **MeV**.

We need also the four-object symmetry [1].

2. Dependence of critical temperature on coherence length

From experimental data for the chemical elements at atmospheric pressure, we obtain our best fit dependence of critical temperature, $T_{c,SST}$ [K], on coherence length ξ_{SST} [nm]

$$T_{c,SST} = a / \xi_{SST}{}^{b}, \qquad (1)$$

where $a = 73.7$, and $b = 0.561$.

For Al is $\xi_{o,Al,Exp.} = 1600$ **nm** [2] so from (1) we obtain $T_{c,SST,Al} = 1.175$ **K** – it is consistent with experimental data [3].

For Sn is $\xi_{o,Sn,Exp.} = 230$ **nm** [2] so from (1) we obtain $T_{c,SST,Sn} = 3.49$ **K** – the experimental value is $T_{c,Sn,Exp.} = 3.72$ **K** [2].

For Nb is $\xi_{o,Nb,Exp.} = 40$ **nm** [2] so from (1) we obtain $T_{c,SST,Nb} = 9.30$ **K** – the experimental value is $T_{c,Nb,Exp.} = 9.25$ **K** [2].

But notice that there are some theoretical values which differ significantly from experimental data. It suggests that sometimes untypical changes in intrinsic pressure in some materials change significantly the phonon-electron coupling.

We will apply formula (1) to all types of superconductors to investigate a global behaviour of superconductors.

The relationship between the critical temperature and the coherence length (i.e. formula (1)) is the most important and requires further research. We can rewrite formula (1) as follows

$$T_{c,SST} = \mathbf{Constant_1} / \xi_{SST}^{\mathbf{0.561}} . \quad (2)$$

On the other hand, the Coulomb law looks as follows

$$F = \mathbf{Constant_2} / R^{\mathbf{2}} . \quad (3)$$

The $R^{\mathbf{2}}$ says that the Coulomb field has spherical symmetry, i.e. the electromagnetic interactions of the elementary electric charge have spherical symmetry at distances much bigger than sizes of the tori/electric-charges. On the other hand, the $\xi_{SST}^{\mathbf{0.561}}$ suggests that the phonon field between electrons in Cooper pairs has not spherical symmetry. For directional interactions (in an approximation, the nuclear weak interactions are directional/axial in direction of the spin), the acting force does not depend on distance so there should be the $r^{\mathbf{0}}$. We can calculate value of the b parameter for the nuclear electroweak interactions from following formula

$$b = 0 \cdot \alpha_{w(p)} / (\alpha_{w(p)} + \alpha_{em}) + 2 \cdot \alpha_{em} / (\alpha_{w(p)} + \alpha_{em}) = 0.561 , \quad (4)$$

i.e. the weak part ($\alpha_{w(p)} / (\alpha_{w(p)} + \alpha_{em})$) is directional (0) while the electromagnetic part ($\alpha_{em} / (\alpha_{w(p)} + \alpha_{em})$) is spherical (2).

It suggests that in protons dominate the axial weak interactions,

$$100\% \ \alpha_{w(p)} / (\alpha_{w(p)} + \alpha_{em}) = 72\%,$$

so electroweak interactions cannot have a spherical symmetry – it is consistent with the SST because in both protons and electrons there is the spin-1/2 torus/electric-charge with central condensate so it has also axial symmetry.

Now, from dynamics of the core of baryons, we can calculate value of the a parameter.

By applying the Wien's displacement law

$$T_{Peak} \lambda = 2.898 \cdot 10^{-3} \ \mathbf{[K\ m]} \quad (5)$$

We can calculate temperature of the fundamental gluon loop T_{FGL}

$$T_{FGL} = 2.898 \cdot 10^{-3} \ \mathbf{[K\ m]} / (2 \pi R_{FGL}) = 0.99198 \cdot 10^{12} \ \mathbf{K} . \quad (6)$$

At temperature of the FGL, there is an increase of mass of the proton condensate from Y to mass of the charged core of protons H^+ (it is a virtual process). It forces similar transformation of the condensates in the electron-positron pairs created by protons. We know that at higher critical temperatures, the coherence length is smaller. Assume that at the T_{FGL}, the coherence length, ξ_e, is equal to the radius of the enlarged electron condensate (density of all spacetime condensates is invariant [1])

$$\xi_e = r_{C(e)} (H^+ / Y)^{1/3} = 0.88031 \cdot 10^{-18} \ \mathbf{m} . \quad (7)$$

It means that value of the a parameter is

$$a = T_{FGL}\, \xi_e^{0.561} = 73.7 \,. \tag{8}$$

3. Energy of SST-As condensate from FGL and its range/coherence-length

SST shows that the transition (collapse) from the radial vibrations in the FGL to the circular motions in a spacetime condensate ($R \rightarrow R/(2\pi)$) increases energy 2π times. But the internal dynamics of the core of baryons shows that the final mass of the central spacetime condensate is Y [1]. It leads to conclusion that there is emitted a spacetime condensate carrying following energy

$$M_{Con} = 2\,\pi\, m_{FGL} - Y = 0.27230 \text{ } \mathbf{MeV} \,. \tag{9}$$

Range/coherence-length of such condensate is equal to the radius of the FGL divided by 2π

$$\xi_{o,Con} = R_{FGL} / (2\,\pi) = A/(3\,\pi) = 7.4001 \cdot 10^{-17} \text{ } \mathbf{m} \,. \tag{10}$$

In the next calculations, there will appear a product, F_{Con}, of M_{Con} and $\xi_{o,Con}$

$$F_{Con} = M_{Con}\, \xi_{o,Con} = 0.020151 \text{ } \mathbf{[eV \cdot nm]} \,. \tag{11}$$

4. Superconductivity via the third phonon field at atmospheric pressure

In SST, when an interaction of a mass M is defined by a coupling constant α_i then an exchanged virtual energy, E, is $E = \alpha_i M$. A generalization for a few coupling constants looks as follows

$$E = \Pi_i\, \alpha_i\, M = \alpha_{Total}\, M \,, \tag{12}$$

where Π denotes a product.

Here, for the electroweak proton-electron interactions we have

$$\alpha_{Total} = \Pi_i\, \alpha_i = \alpha_{em}\, \alpha_{w(p)}\, \alpha_{w(e)} = 1.2995 \cdot 10^{-10} \,. \tag{13}$$

The lower limit for phonon energy in the third phonon field (Phonon-III) produced by the electron-positron pairs is

$$E_{Phonon\text{-}III,lower} = \alpha_{Total}\, 2\, m_e = 1.3281 \cdot 10^{-4} \text{ } \mathbf{eV} \,. \tag{14}$$

Coherence length is inversely proportional to energy so by applying formula (11) we obtain

$$\xi_{o,Phonon\text{-}III,upper} = F_{Con} / E_{Phonon\text{-}III,lower} = 151.73 \text{ } \mathbf{nm} \,. \tag{15}$$

By applying formula (1) we can calculate the lower limit for critical temperature for the Type II superconductors at atmospheric pressure

$$T_{c,SST,Phonon\text{-}III,lower} = a / \xi_{o,Phonon\text{-}III,,upper}^{\;b} = 4.4 \text{ } \mathbf{K} \,. \tag{16}$$

In the nuclear strong interactions, range of four bound neutral pions is equal to the equatorial radius A of the core of the baryons [1] so such quanta should define the upper limit for critical temperature for the Type II superconductors at atmospheric pressure.

The upper energy for phonon is

$$E_{Phonon\text{-}III,upper} = 4\,\alpha_{Total}\,\pi^{o}_{bound} = 7.0155\cdot10^{-2}\ \mathbf{eV}\ . \qquad (17)$$

The lower limit for coherence length of the Type II superconductors at atmospheric pressure is

$$\xi_{o,Phonon\text{-}III,lower} = F_{Con} / E_{Phonon\text{-}III,upper} = 0.28723\ \mathbf{nm}\ . \qquad (18)$$

By applying formula (1) we can calculate the upper limit for critical temperature for the Type II superconductors at atmospheric pressure

$$T_{c,SST,Phonon\text{-}III,upper} = a / \xi_{o,Phonon\text{-}III,lower}{}^{b} = 148\ \mathbf{K}\ . \qquad (19)$$

Our results are consistent with experimental data so we can assume that, generally, in the Type II superconductors dominates the third phonon field, i.e. phonons are created due to the electroweak interactions of the masses of the electron-positron pairs.

5. Type II superconductors at extreme pressure

Due to the four-particle symmetry, maximum energy of an object that can interact due to electroweak interactions is 4Y. But emphasize that such energies can exist only at extreme pressure. The energy of phonon is

$$E_{Phonon,pressure} = 4\,\alpha_{Total}\,Y = 0.22046\ \mathbf{eV}\ . \qquad (20)$$

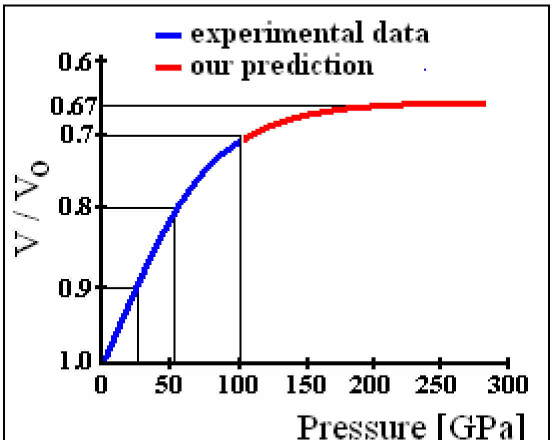

Fig.1
Relative volume versus pressure.

It relates to following coherence length

$$\xi_{o,Phonon,pressure} = F_{Con} / E_{Phonon,pressure} = 0.091405\ \mathbf{nm}\ . \qquad (21)$$

We can calculate the critical temperature

$$T_{c,SST,pressure} = a / \xi_{o,Phonon,pressure}{}^{b} = 282 \ \mathbf{K} . \qquad (22)$$

But extreme pressure changes volume of the superconductors. For relative volume equal to $V/V_o = 0.67$, by applying formulae (21) and (22), we obtain that critical temperature is $T_{c,SST,pressure} = 304$ **K**. For the carbonaceous sulphur hydride at 267 ± 10 **GPa**, there is $T_c = 287.7 \pm 1.2$ **K** [4].

Available experimental data of volume versus pressure up to 100 **GPa** we can find in [5]. We predict that for pressures higher than about 200 **GPa**, for a function describing dependence of volume on pressure (Fig.1), we should observe a plateau (or so).

6. Lower limits for critical temperature for Type I superconductors

The lowest energy of a phonon in the second phonon field (Phonon-II) is

$$E_{Phonon\text{-}II,lower} = \alpha_{Total} \left(m_e - m_{e,bare}\right) = 7.6917 \cdot 10^{-8} \ \mathbf{eV} . \qquad (23)$$

Coherence length of such elementary phonon is

$$\xi_{o,Phonon\text{-}elementary} = F_{Con} / E_{Phonon\text{-}II,lower} = 2.6198 \cdot 10^{5} \ \mathbf{nm} . \qquad (24)$$

From (1) we obtain the lowest critical temperature for critical field composed of such elementary phonons

$$T_{c,Phonon\text{-}II,SST} = a / \xi_{o,Phonon\text{-}elementary}{}^{b} = 0.067 \ \mathbf{K} . \qquad (25)$$

Notice that at higher intrinsic pressure (it depends on structure of the lattice) or at higher intrinsic pressure plus external pressure, there are created the composite phonons composed of the elementary phonons so critical temperature increases.

In the Type I superconductors, there can be also phonons created by oscillations of the electron-positron pairs (Phonon-I) so the lower limit for critical temperature of the Type I superconductors is defined by

$$T_{c,Phonon\text{-}I,SST} > 0 \ \mathbf{K} . \qquad (26)$$

There are only three Type I superconductors with critical temperatures defined by following interval

$$0 \ \mathbf{K} < T_c \le 0.067 \ \mathbf{K} , \qquad (27)$$

so, generally, in the Type I superconductors dominates the second phonon field produced in electroweak interactions of the radiation masses of the electron-positron pairs.

7. Summary

Here we have tried to capture the global features of superconductors and we believe that the effects are definitely better than the complexity and multiplicity of phenomena would imply.

The technological benefits of producing a good room-temperature superconductor operating at atmospheric pressure would be enormous, so in recent decades a huge amount of financial resources has been invested and many research teams worked to produce such a superconductor. So I don't think that the current thresholds for the different types of superconductors that result from experimental data, i.e. for the Type I chemical elements is

$$0\ \mathbf{K} < T_c \leq 4.47\ \mathbf{K} \text{ or } 7.193\ \mathbf{K}\,, \tag{28}$$

for the Type II superconductors is

$$4.47\ \mathbf{K} \text{ or } 7.193\ \mathbf{K} \leq T_c \leq 139\ \mathbf{K} \text{ or so}\,, \tag{29}$$

and the present-day upper limit for superconductor at extreme pressure (267 GPa) is

$$T_c = 288\ \mathbf{K}\,, \tag{30}$$

will change radically in the future. On the other hand, our theoretical results are consistent with experimental data so it validates our very simple model for superconductivity.

For the Type II superconductors we obtained

$$4.4\ \mathbf{K} \leq T_c \leq 148\ \mathbf{K}\,. \tag{31}$$

For the Type I superconductors we obtained two thresholds

$$T_c > 0\ \mathbf{K} \text{ and } T_c \geq 0.067\ \mathbf{K}\,. \tag{32}$$

For the Type II superconductors at extreme pressure (~300 GPa), for relative volume 0.67, we obtained

$$T_c = 304\ \mathbf{K}\,. \tag{33}$$

The global features for superconductivity are as follows.

*Here we showed that superconductivity follows from the dynamics of the core of baryons and concerns the electroweak interactions of the electron-positron pairs.

*There are three sources of the phonon fields: oscillations, radiation masses and masses of the electron-positron pairs. In the three phonon fields, masses/energies of the elementary phonons are different. When we neglect the phonons from the oscillations then mass-energy of elementary phonons in Type I is $7.6917 \cdot 10^{-8}$ **eV** while in Type II is $1.3281 \cdot 10^{-4}$ **eV**. But emphasize that energy of the composite phonons can be much higher, for example, for the critical temperature 148 **K** we have $7.0155 \cdot 10^{-2}$ **eV**. A geometrical mean energy of upper and lower limits for phonons in Type II superconductors at atmospheric pressure is $\sim 3 \cdot 10^{-3}$ **eV** (it is the mean binding energy of the Cooper pairs) – it relates to coherence length equal to ~6.7 **nm**.

*We derived a global relationship between critical temperature and coherence length.

*We calculated the thresholds for critical temperatures for different types of superconductors.

*At critical temperature, there can be a resonance between the electroweak energy of the electron-positron pairs (produced in protons) and the vibrational energy of the ions in lattice of the superconductors – it validates the BCS theory.

*The electroweak structure of the Cooper pairs has both axial symmetry (from weak interactions) and spherical symmetry (from electromagnetic interactions).

* Intrinsic and external pressure decreases coherence length so increases critical temperature.

*A mixture of the three phonon fields and dependence of critical temperature on intrinsic pressure in superconductors (it depends on number density of the electron-positron pairs, on structure of the atomic nuclei, and on structure of the lattice as a whole) cause that sometimes formula (1) gives results that differ from the experimental data.

*The Cooper pairs are some analogs to the spin-0 neutral pions which consist of two spin-1 fundamental gluon loops with the same internal helicity [1]. In the nuclear strong interactions, the spin-1 loops behave as electrons in atoms, i.e. to both we can apply the Hund's rule [1]. The neutral pions are created on the circular axis inside the core of baryons so to conserve the spin-1/2 of the torus/electric-charge, there are created the neutral pions with antiparallel spins of the FGLs – it looks as the s-states in atoms. But in the baryonic resonances (i.e. for very short time $\sim 10^{-23}$ **s**), outside their core, spins of the FGLs can be parallel [1]. It suggests that in strong intrinsic magnetic fields, there can be a spin flip of one of the two FGLs – we can say that there is a fluctuation from spin-0 state to spin-2 state, and vice versa. Notice also that there is the spin flip in the cold hydrogen. Both electrons in the Cooper pairs are internally right-handed [1] so, similar to the neutral pions, the resultant spin of the Cooper pairs is zero. But in ferromagnetic superconductors, there are allowed the fluctuations from the spin-singlet state of the Cooper pairs to the spin-triplet state, and vice versa. It leads to conclusion that, because of the fluctuations, superconductivity and ferromagnetism can coexist.

*The composite phonons cause that there is created a boson condensate composed of the Cooper pairs.

*We showed that it is impossible to make a material that is a superconductor at room-temperature and atmospheric pressure.

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