SONOLUMINESCENCE AS CRITICAL PHENOMENON-SINGULARITY BEHAVIOUR OF TRANSPORT PROPERTY

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Sonoluminescence is interpreted as second order phase transition and critical phenomenon. It was recently discovered that transport property of second order phase transition has singularity behaviour at the critical point of phase transition. The tremendous increase of the heat capacity, a transport property during sonoluminescence is an example of the singularity behaviour of transport property. The transport theory is used to interpret phase transition. This leads to a second characteristics of second order phase transition. That is the singularity behaviour of the transport properties at the critical point of phase transition. This is also known as the singularities approach. The first characteristics being the spontaneous symmetry breaking of Landau’s theory of second order phase transition. An Ising model for sonoluminescence is developed with the acoustical Poynting vectors replacing the spins of magnetization. An introduction to solving the Ising model to obtain the partition function and hence the critical temperature is given.
Keywords: singularity, Ising model, partition function.

1. Introduction

In a previous paper[1] sonoluminescence was interpreted as second order phase transition from the heat phase to the light phase with spontaneous symmetry breaking(SSB). The concept of second order phase transition which has the property of SSB is due to Landau[2]. This is phenomenology and a meanfield theory which approximates a many body problem by a one body problem and so will not be able to explain the region near the critical point or critical temperature. In one of my previous papers[3], the renormalization group(RG) method of Ken Wilson[4] was used to study the divergence problem of the correlation length at the critical point. There is a recent discovery of the singularity behaviour of the transport properties at the critical point during second order phase transition[5]. This is the second characteristics of second order phase transition besides SSB.

2. What is critical phenomenon

The fluctuations of the transport property near the critical point of second order phase transition is known as the critical phenomenon. This fluctuation is due to the singularity behaviour of the transport property at the critical point of phase transition. Landau’s theory of second order phase transition[2] which describes the spontaneous symmetry breaking(SSB) during second order phase transition is unable to describe the critical phenomenon. This is because it is phenomenology and is a meanfield theory which is a one body approximation and hence ignores the interaction between the atoms. Several theories have been proposed to explain the critical phenomenon. One is the Ken
Wilson’s renormalization group (RG) method [4] which is meant for solving the problem of the divergence of the correlation length near the critical point and Ising model of magnetization which is used to explain interaction between spins during magnetization.

3. **Sonoluminescence as second order phase transition**

Sonoluminescence is an outcome of cavitation when the bubble breaks up and emits tremendous heat. There is spontaneous energy focusing from all acoustical Poynting vectors pointing in one direction and phase transition with the transduction of the heat phase of matter to light phase of matter. Free electrons from the ionized noble gas within the bubble interact with other neutral atoms causes light emission. Sonoluminescence is a paradigm of transdiscipline physics. Low amplitude sound energy entering a fluid spontaneously focussed by 12 orders of magnitude to create a flash of light and a new phase of matter. The interaction of free electrons with ionized atoms is governed by the nonlinear interaction term in the Hamiltonian of the system which in this case is the interaction between the acoustical Poynting vectors. Here one extends the Poynting vector from first order effect to second order effect to take account of the interaction of the free electrons with ionized atoms. This nonlinear interaction gives rise to the broken symmetry of the ground state of the Hamiltonian. Broken symmetry enables the Poynting vector to be lining up in one direction resulting in the spontaneous focusing of heat. Thus one explains that the broken symmetry combines the spontaneous focusing of heat to produce spontaneous symmetry breaking (SSB). Usually spontaneous focusing also gives rise to SSB.

4. **Discovery of singularity behaviour of transport properties at critical point of second order phase transition**

G.M.Mayer [6] in her statistical mechanics book mentioned about the singularity behaviour during second order phase transition. Recently W.S.Gan [5] discovered that second order phase transition has the characteristics that the transport property of the phase transition process has singularity behaviour at the critical point. This can be shown by the examples of the zero value of the viscosity or infinite Reynolds’ number at the critical point of turbulence, the singularity behaviour of the partition function during magnetization, the infinite value of conductivity during superconductivity and the zero value of viscosity of superfluid. The study of the singularity behaviour of transport properties during second order phase transition will enable a deeper understanding of the phase transition and in obtaining the value of the critical temperature of the phase transition. The discovery of the singularity behaviour of transport properties at the critical point of phase transition is the discovery of a second characteristics of the second order phase transition besides spontaneous symmetry breaking (SSB).

5. **Singularity and resonance**

Resonance is a common phenomenon in physics. The common examples of resonance are a simple harmonic resonator, forced vibration and local resonance in acoustic metamaterials. It is important to note that there is a relation between resonance and singularity as both show tendency towards infinity. In most works on resonance, it is only pointed out that there is a sudden tremendous increase in the magnitude of certain parameters such as the amplitude of vibration at the resonance frequency without mentioning that it is in fact towards infinity at the resonance frequency. This can be illustrated by the following example of a simple harmonic oscillator.
In the above figure, the resonance transmissibility is in fact towards infinity.

6. Transport theory approach to second order phase transition

The transport theory approach to second order phase transition is a new approach and a new theory compared with Landau’s theory of second order phase transition[2]. Landau’s theory gives rise to spontaneous symmetry breaking (SSB) during second order phase transition, the first characteristics of second order phase transition. The transport theory on the other hand gives rise to the second characteristics of second order phase transition, the singularity behaviour of the transport properties at the critical point of phase transition. In 1966, W.S.Gan[7] first introduced transport theory into condensed matter physics. Before that, transport theory was known as neutron transport theory applied to the design of nuclear reactors. W.S.Gan[7] used transport theory to study topological phase transition from metal to semiconductor. Transport theory is the theory of transport properties, which are the ingredients of a phase of matter. Examples of transport properties are conductivity, viscosity, specific heat, dielectric constant, permeability, bulk modulus, mass density etc. Hence transport theory is intimately related to phase transition. It is to be noted that solids state physics changed name to condensed matter physics in 1967 to reflect the important role of phase transition. Philip Anderson and and Volker Heine changed the name of solid state theory to condensed matter theory at the Cavendish Lab, Cambridge University in 1967.. In this paper there is the application of transport theory to second order phase transition in particular to study the region near the critical point of phase transition. This is statistical mechanics approach and will enable the study of partition function and the critical temperature.
7. **Ising model of sonoluminescence**

To have a detailed study of the region around the critical temperature of phase transition, the Ising model of sonoluminescence is introduced. Ising model is meant for magnetization and the Hamiltonian of Ising model involves spins interaction and the lining up of spins in one direction during magnetization. Here, for sonoluminescence, instead of spins, one has the lining up of acoustical Poynting vectors focusing in one direction, resulting in the spontaneous focussing of all the Poynting vectors in one direction. In the Ising model for sonoluminescence, one will replace the spins by the acoustical Poynting vectors and the magnetic moment and the external magnetic field will be zero. Hence the expression for the Hamiltonian for the Ising model will be:

\[ H = \sum_{i,j} J_{i,j} S_i S_j \]  

(1)

where J represents the interaction strength between the Poynting vectors and S the acoustical Poynting vector.

The solution of the Ising model will be to solve for the partition function and the formula for the critical temperature of phase transition. This will be the contents of a future paper.

8. **Conclusions**

This paper introduces a new approach to second order phase transition. This is the transport theory approach or the singularities approach in oppose to the Landau’s spontaneous symmetry breaking (SSB) approach. This gives rise to a second characteristics of second order phase transition. That is the singularities behaviour of the transport properties during the critical point of phase transition. The first characteristics being spontaneous symmetry breaking (SSB). This singularities approach is then applied to second order phase transition of sonoluminescence.

**REFERENCES**