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A new prospect on Bose- Einstein Condensation

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Abstract

This project is based on the discussion of the mean field theory for the dilute base gas then there is derivation of the Gross- pitaeskii equation for the order parameter and we have used it to calculate the ground state energy of the system , then we discuss Bogoliubov model , it is a theory beyond mean field and takes in to account the flucturiton of order parameter . We introduce BogoLiubov effective Hamiltonion , discuss its diagonal – ization by means of bogoliubov transformation and calculate the correction of the ground state energy arising from the quantum flutuition then we discuss within the bogolivbov model the effects of weak external random potential we have also studied the behavior of the one body density matrix

Keywords : The non- interacting Bose gas, Condensed Phase , Normal Phase, The Gross pita evskil equation , The thomas Fermi approximation, Dilute Bose gas, Gross- pitaevskil equation, Ground state energy .

Introduction

The first experimental realization of Bose Sinstein condensation in dilute atomic gases happens in 1995 .

1.1 A Bose condensate (BEC) a state of matter in which separate atoms on sub atomic particle , cooled to near absolute Zero (OK-273.15^{0}c or – 459.67^{o}F, K = kelvin), coalesce in to a single quantum mechanical entity. BEC's most intriguing property is , it can

Slow down light. In 1998 lene Hau of Harvard university and group , Slowed light travelling through a BEC from its speed in the vaccum of 3 X 108 m/sec to a mere of 17 m/s , or up to 38 mile/hour. Lenevestergard Hau and group have completely stored and halted a light pulse within Bose einstein consasate , later releasing the light uncharged or sending it to the second BEC . There manipulation hold promise for newer light based telecommunication type , quantum computing and optical storage of data through the low temperature requirement of BEC's offer practical difficulties .

Lene Hau does not only know how to stop light but also manipulate it and save its imprints for later use .

We can hold on to the light move it around or even save it for later we can actualry manipulate it .Lecture of Hau at sauthern Den Mark

In those regard the speed of light takes on a new meaning . The light became compressed.

We are trying to unify Einsteins theory of relativity with quantum mechanics to find out how the univase came in to existence

According to photonics media in 1998, Hau slowed light which travelles in free space at speed of 1 86000 m/sec to just 38 mile/sec in a cloud of ultra cold atoms Einstein and others have theorized that the speed of light in free speed does not changed . Two years after hav and group stoped light completly in similar cloud , then restarted it without charging its characteristics.

The Bose Einstein condensates are very important to this work because within these clouds atoms become phase – locked , losing their individually and independence.

2.1 The non-interacting Bose gas

The Bose distribution function

$F^0(Ev) = \frac{1}{\frac{ev-\mu}{kt}-1}$ .... (1)

WhereEv is the energy of the single particle state for the particular trapping potential under consideration, μ is chemical potential

By Boltzmann distribution

$F^0(Ev) = e\frac{-(ev-\mu)}{kt}$ ....(2)

At highttempretureμ>>Emin $e\frac{\mu-ev}{kt}$<<1 ....(3)

The higest temperature at which the condensate exits is called Bose Eonstein temperature (T_c)

Were as Tc>>1 The number of the particle is excited states is given by

Nex $= \int_0^\infty d\epsilon g(\epsilon)\, f^0(\epsilon)$ ....(4) ϵ

This a achieves its greatest value $\mu = 0$

$N = Nex(Tc,\mu = 0) = \int_0^\infty d\epsilon g(\epsilon) \frac{1}{e^{\frac{\epsilon}{ktc}}-1}$ .... (5)

Let a dimensionless variable $x = \frac{e}{K\tau_c}$

$N = C_\propto (ktc)^\propto \int_0^\propto dx\, x^{\epsilon 1}/\, e^{x-1} = c_\propto\{\tau(\propto)\xi\} \propto (ktc)^\propto$

$\Rightarrow KT_c = \frac{N^{\frac{1}{\alpha}}}{c\,[\propto\gamma(\propto)\xi(\propto)]^{\frac{1}{\alpha}}}$ .... (6)

For 3D harmonic – oscillator potential $\propto = 3$

$KT_c = \frac{\bar{h}\,\bar{\omega}N^{\frac{1}{3}}}{[\xi(3)].^{\frac{1}{3}}} \approx 0.99\bar{h}\,\overline{\omega}N^{\frac{1}{3}}$ ....(7)

$\omega \approx (\omega_x\omega_y\omega_z)^{1/3}$

⇒Tc ≈ 4.5 (f/100HZ) $N^{1/3}$nk ………………………………(8)

For uniform Bose gas in a 3- dimension box of volume V the index ∝ = 3/2

K Tc = $\frac{2\pi}{\{\xi(3/2)\}6^{\frac{2}{3}}}\frac{\bar{h}^2 h^{\frac{2}{3}}}{m} \approx \frac{\bar{h}^2 h^{\frac{2}{3}}}{m}$ ……………………………..(9)

W = n$(\frac{2\pi\bar{h}^2}{mkt})^{3/2}$ ………………………………(10)

This majority of occupied states have energies of order KT or less , Hence the number of the states per unit volume that are occupied significantly is of the order of the total number of the state per unit volume with energy less then KT

After Solving the transition temperature Nex of particle in exited state

Nex (T) = $c_\propto \int_0^\propto d \in \varepsilon^{\propto-1} \frac{1}{e^{\frac{\epsilon}{RT}}-1}$ ……………………………..(11)

We get N_o = N $[1-(T/TC)^3]$ ……………………………..(12)

For 3-D harmonic oscillator∝= 3

2.2 Density profile and velocity distribution

As BEC state is typically formed when a gas of bosons at law densities is cooled to temperature very close to absolute zero Also the distribution of the particle after a cloud is allowed to expend depends not only on the initial density distribution but also on the initial velocity distribution. In momentum space wave function become Fourier transform

$\frac{-p^2x}{e_2c^2x}\frac{-p^2y}{e_2c^2y}\frac{-p^2z}{e_2c^2z}$ ……………………………(13)

φ_0(p) = $\frac{1}{\pi^{3/4}(c_xc_yc_z)^{1/2}}$ ……………………………(14)

Which gives n(p) = $\frac{N}{\pi^{\frac{3}{4}}(c_xc_yc_z)}\frac{-p^2x}{e_2c^2x}\frac{-p^2y}{e_2c^2y}\frac{-p^2z}{e_2c^2z}$ ……………………………(15)

2.3 In thermo dynamics quantities we have condensed phase

The energy of the micro scopically occupied state is taken to zero, there for only excited state contribute to the total energy of the system. Internal energy is E = $\int_0^\propto dEg$ (E) $\frac{1}{e^{\frac{\epsilon}{RT}}-1}$

⇒ E = $C_o\,\Gamma(\propto +1)\,\delta\,(\propto +1)(KT)^{\propto+1}$ ……………………….(16)

2.4 we are familiar with Normal phase and theory of condensed state we get time – in dependent gross – pita evaskiz equation after solving

$\varphi(r_1,r_2,r_3....r_n)\, \mathbb{I}^N \varphi(r_i)$ e = 1 …………………….(17)

As Hamiltonian of the system is given by

$\hat{H} = \sum_{i=1}^{N}(\frac{pi^2}{2m}+v_{ext}(ri) + ½ \sum_{i=1}^{N}.\sum_{j=1}^{N} V(|\gamma_\xi - r_j|)$ ………………….(18)

We have

$\frac{-\bar{h}^2}{2m}\Delta^2\varphi(r)+V_{ext}(r)\varphi(r) + N\frac{4\pi\bar{h}^2}{m} \propto |\varphi(r)|^2\varphi(r) = \mu\varphi(r)$ ………………..(19)

2.5 the ground state for trapped bosons.

A variational calculation is

$E(b_x,b_y,b_z) = N\sum \bar{h}\, w_i(\frac{ai^2}{4bj^2}+\frac{bi^2}{4qj^2}) + \frac{N^2\mu o}{2(2\pi)^{\frac{3}{2}}} b_xb_yb_z$ ……………………………(20)

Now we came on the Thomas Fermi approxi matron the ground state energy of the system,

$\frac{-h^2}{2m}\Delta^2\varphi(r) + V(r)\varphi(r) + U_o|\varphi(r)|^2\varphi(r) = \mu\varphi(r)$ …………….(21)

At boundary of cloud v(r) = μ ....(22)

E = v(r) + n (r) U_o ....(23)

But v(r) = μ

2 μ = $mRi^2\ wi^2$ and $Ri^2 = \frac{2\mu}{mwi^2}$ ....(24)

Number of partrcies N. For harmonic trap is

N= $\frac{8\pi}{15}\left(\frac{2\pi}{m\overline{w}}\right)^{3/2}\frac{\mu}{U_o}$ ....(25)

Length $\overline{\propto} = \sqrt{\frac{h}{m\overline{w}}}$ ....(26)

$\mu = \frac{15^{2/5}}{2}\left(\frac{Na}{\overline{a}}\right)^{2/3}\overline{h}\overline{w}$ ....(27)

$\overline{R} = (R_1, R_2, R_3)^{1/3}$ ....(28)

R = $15^{\ 1/5}\left(\frac{Na}{\overline{a}}\right)^{1/5}\overline{a}$ ....(29)

Since $\mu = \frac{\delta E}{\delta N}$ and $\mu \propto N^{2/5}$ ....(30)

$\Rightarrow \frac{E}{N} = \frac{5}{7}\mu$ ....(31)

This is the leading contribution to the energy at large N.

Which is our result.

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