

INFORMATION ON DOCTORAL THESIS

1. Full name: Pham Duy Thanh
2. Sex: Male
3. Date of birth: August 26th, 1999
4. Place of birth: Dien Bien
5. Admission decision number: 2448/QĐ-ĐHSPHN2 dated October 24, 2023
6. Changes in academic process: Change of the doctoral thesis title in accordance with decision number 2659/QĐ-ĐHSPHN2 dated December 13, 2024.
7. Official thesis title: Theoretical study on thermodynamic properties of dilute Bose gases at ultra-low temperatures
8. Major: Theoretical physics and mathematical physics
9. Code: 9440103
10. Supervisors: Assoc. Prof. Dr. Nguyen Van Thu
11. Summary of the new findings of the thesis

- For the two-component dilute Bose gas: The properties of the prewetting phase are thoroughly investigated using the double parabola approximation (DPA) within the Gross–Pitaevskii (GP) theory. Our study shows that, in the prewetting phase, the thickness of the wetting layer increases linearly with the logarithm of the ratio of the chemical potentials as the system approaches the fully wetting phase. During this process, the contact angle decreases from a finite value (partial wetting) to zero (complete wetting). These findings will contribute to the design of experiments aimed at observing the wetting phase transition in BECs.

- For the single-component dilute Bose gas: Our study shows that the Cornwall–Jackiw–Tomboulis (CJT) effective action framework describes very well the thermodynamic properties of dilute Bose gases not only at zero temperature but also at finite temperature. The relative shift of the critical temperature due to interparticle interactions obtained in this work agrees well with the corresponding results from numerical Monte Carlo simulations. The results obtained within the one-loop and two-loop approximations are also found to be in good agreement with each other. The use of the CJT effective action in the improved Hartree–Fock (IHF) approximation yields very good results for the thermodynamic properties of dilute Bose gases, especially the continuous and non-monotonic behavior of the chemical potential near the phase-transition temperature. This resolves the limitation of the standard Hartree–Fock theory, which predicts an unphysical discontinuity in the chemical potential at the transition point.

12. Practical applicability, if any: Although the doctoral thesis does not yet have direct practical applications, its results provide a theoretical framework and analytical methods that can be applied to the future study of Bose–Einstein condensate systems, quantum materials, and low-temperature surface phenomena.

13. Further research directions, if any:

The investigation of the wetting transition presented in this dissertation is carried out within the mean-field GP framework. This means that condensate depletion due to quantum fluctuations and thermal excitations has not been included. Such effects may lead to significant deviations from experimental observations when the system is not sufficiently cold, specifically when the temperature is only moderately below the critical temperature. In addition, the hard-wall boundary condition is an idealized model, and in current experiments it is generally not feasible to construct perfectly rigid boundaries of this type. Building upon the results obtained in this thesis, we propose several potential directions for future research:

- At zero temperature: explore alternative boundary conditions to replace the ideal hard wall, with the aim of experimentally observing the wetting phenomenon in BEC systems.

- At finite temperature: assess the effect of temperature on the surface energy, and consequently examine its impact on the wetting transition in BECs.

14. Thesis-related publications:

[1] Nguyen Van Thu & **Pham Duy Thanh**, (2024). Phenomenological analogy between Gross–Pitaevskii theory for Bose–Einstein and Newton equation for classical mechanics. *VNU Journal of Science: Mathematics – Physics*, 40(2), 100-105.

[2] Nguyen Van Thu & **Pham Duy Thanh**, (2024). Effect of nonzero temperature to non-condensed fraction of a homogeneous dilute weakly interacting Bose gas. *Physics Letters A*, 523, 129787.

[3] **Pham Duy Thanh** & Nguyen Van Thu, (2024). Static properties of prewetting phase in binary mixtures of Bose–Einstein condensates. *International Journal of Theoretical Physics*, 63(12), 315.

[4] **Pham Duy Thanh**, Tran Ky Vi & Nguyen Van Thu, (2025). Phenomenological analogy between Gross–Pitaevskii theory for Bose–Einstein condensate mixtures in infinite space and classical mechanics. *HNUE Journal of Science: Natural Science*, 70(1), 25-35.

[5] **Pham Duy Thanh** & Dang Thanh Hai, (2025). The interface position of a Bose–Einstein condensate mixture restricted by a hard wall in double-parabola approximation. *Dalat University Journal of Science: Natural Sciences and Technology*, 15(3S), 33-43.

[6] Nguyen Van Thu, **Pham Duy Thanh** & Lo Thi Thuy, (2025). Transition temperature and thermodynamic properties of homogeneous weakly interacting Bose gas in self-consistent Popov approximation. *Physica B: Condensed Matter*, 713, 417356.

[7] **Pham Duy Thanh** & Nguyen Van Thu, (2025). The thermodynamic contact angle in prewetting phase of a binary Bose–Einstein condensate mixture. *HNUE Journal of Science: Natural Science*, 70(3), 35-46.

[8] Nguyen Van Thu & **Pham Duy Thanh**, (2026). Thermodynamic properties of repulsive weakly interacting Bose gas at sufficiently low temperature. *International Journal of Modern Physics B*, accepted for publication.

February 27th, 2026

Supervisor

PhD Student

Assocs. Prof. Dr. Nguyen Van Thu

Pham Duy Thanh