2008 年中央研究院「年輕學者研究著作獎」得獎人簡介

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得獎著作名稱：(請以申請時之格式填入)

[1] Daw-Wei Wang, E.G. Mishchenko, and E. Demler, “*Pseudospin ferromagnetism in double-quantum-wire systems*”, Phys. Rev. Lett. **95**, 086802 (2005).

[2] Daw-Wei Wang, M.D. Lukin and E. Demler, “*Quantum fluids of self-assembled chains of polar molecules*”, Phys. Rev. Lett. **97**,180413 (2006).

[3] Daw-Wei Wang, “*Quantum phase transitions of polar molecules in bilayer systems*”, Phys. Rev. Lett. **98**, 060403 (2007).

得獎著作簡介: (2000 字左右)

最近十餘年來，因著 III-V 族半導體製程技術的突飛猛進，許多先進的物理實驗室已可製造出超高純度的半導體材料。特別是當製作成一維或是二維結構時，那是個非常重要的系統，可以研究在低維度時電子的強相關聯交互作用。在過去十年中的許多相關的研究中，我個人對雙層半導體系統中的量子霍爾效應最感興趣。實驗與理論的研究發現，只要把磁場調至適當大小，且兩層平行半導體之間的位置夠近時，這兩層半導體就彷彿與一層相同，在總填充密度(filly factor)是整數時產生量子霍爾效應。

這實驗令人驚訝的地方是可以用不同的方法證實電子其實並未在這兩層半導體中流動，也就是說，這兩層半導體是在彼此幾乎絕緣無關的情況下共同合作產生對總電子密度非常敏感的霍爾效應。理論的解釋乃是因為這是由於電子彼此間長程的庫倫作用力所引起的多體物理現象破壞了此系統原有的 U(1)對稱性。

在 2002 年，我個人在完成一些與以上系統相關的研究後，也在思考如何將類似的多體物理現象在其他不同的系統中實現出來。於是在 2004 年我們提出了相似的情形也是可以在兩條平行的一維半導體電子線中看到，並且預測這會造成一些極不尋常的庫倫拖滯力(Coulomb drag force)而使得一些傳輸現象與現今的

理論預測有很大的不同(見[1])。

2004 年以後，我個人研究的重心開始移向極冷原子與分子的多體物理性質。我發現上述在多分量低維度的半導體系統中的多體物理現象其實更容易在冷分子的系統內達成。原因是冷分子間的偶極作用力可以同時有排斥力與吸引力，且因作用力的主角可以為費米子或玻色子，這使得我們可以有更寬廣的空間來研究一些多體物理的基本性質。所以在 2006 我個人也主導地將此想法在論文[2]表達出來。我們主要的發現是：如果考慮一系列多層的二維結構，這些冷分子是可以排成長鍊狀的流體，造成一種以前只有在軟物質物理或化學反應裡看到的「極性流體」(dipolar liquid)。但與軟物體或化學裡不同的是我們第一次發現這樣的長鏈結購是如何同時擁有溫度與量子效應。這使得一種與軟物質物理相連繫的量子多體物理成為可能。

另外，我個人也更深入研究在雙層系統中，低能量的多體物理系統如何會受到極性分子的空間非對稱偶極力所影響。在[3]中，我們證明因著不同層之間的束縛態的形成，我們是有可能發現一種新的參數空間，使得不同層之間的低能量交互作用大於同一層分子間的交互作用。這樣的情形是一般的固態物理系統裡所不可能產生的。這也意味我們可能在這樣的系統裡找到過去所無法發現的新的物理。我們在[3]中得到的結果發現，我們有可能在這系統裡預備出一種巨觀的量子糾纏態。我們也證明這種量子狀態可以藉由一個古典的二階相變達到，也可以輕易的由對冷分子的干涉實驗而觀察出來。

由於極冷分子是一個最近幾年才開始發展的領域，目前尚有一些實驗技術上的困難待克服。目前世界上已有幾個重要實驗室(包括哈佛、耶魯、JILA 等)在投入研究，而國內也有中研院陳應誠教授的研究群在努力之中。我們相信目前所提出的理論預測應很快可以在實驗室量測出來，也為進一步在多體物理或量子計算上的應用而奠下基礎。

最後我要感謝清華大學物理系與國家理論中心的支持，使我可以在回國幾年之中與許多國內一流的凝態物理和原子分子物理的同仁一同討論研究。也使我有足夠的經費支持得以與國外幾個研究團隊保持密切合作。希望可以為台灣在世界最前沿的物理研究領域上佔有一席地位。

評審簡評：

王道維博士近年來的研究，乃針對物理領域之 Quantum Many-body Physics of Low Dimensional Multi-component Systems 相關問題，進行一系列深入探討，並已成功地獲得許多深具原創性以及前瞻性的研究成果。王博士在 Polar Molecules 的研究，提出了的創新的研究方法，建立了重要的理論基礎，已吸引到國際物理學界的重視以及迴響。王博士的三篇代表作均發表於 Physical Review Letters，這是物理學界最權威且最具影響力的國際期刊。王博士在國際學術交流方面，表現非常積極。除了多次到國際著名研究單位發表專題演講外，他並已和 Harvard University 之國際頂尖研究團隊建立密切的合作關係，表現突出。王博士的傑出研究表現，廣受國際物理學界的重視與肯定，堪稱國內年輕一輩理論物理學家中之佼佼者。

2008 Academia Sinica Research Award for Junior Research Investigators

Name：Daw-Wei Wang	Education:
	1995-2000: Ph.D in Physics, University of Maryland, College Park, MD, USA 1991-1995: B.S. in Physics, National Tsing Hua University, Hsinchu, Taiwan Employer(s)/Job Title(s): 2005-present, Associate Professor, Department of Physics, National Tsing Hua University, Hsinchu, Taiwan 2004-2005, Visiting Scholar, Physics Division, National Center for Theoretical Sciences, Hsinchu, Taiwan 2002-2004, Postdoctoral Fellow, Physics Department, Harvard University, Cambridge, MA, USA 2000-2002, Postdoctoral Researcher Associate, Theoretical Physics, University of Maryland, College Park, MD, USA

Award publications：

[1] Daw-Wei Wang, E.G. Mishchenko, and E. Demler, "*Pseudospin ferromagnetism in double-quantum-wire systems*", Phys. Rev. Lett. **95**, 086802 (2005).

[2] Daw-Wei Wang, M.D. Lukin and E. Demler, "*Quantum fluids of self-assembled chains of polar molecules*", Phys. Rev. Lett. **97**,180413 (2006).

[3] Daw-Wei Wang, "*Quantum phase transitions of polar molecules in bilayer systems*", Phys. Rev. Lett. **98**, 060403 (2007).

Summary of the Award publications（around 2000 words）：

In recent years, due to the progress of the state-of-art experimental technology, there has been more and more attention on the many-body effects in the spatially separated multi-component systems. One of the most important example is the pseudo-spin ferromagnetism in the double layer quantum Hall systems, where both theorists and experimentalists have found that the inter-layer single particle tunneling can be strongly enhanced by Coulomb interaction of electrons in the two layer when the external magnetic field is tuned closed to integer filling and when the layer separation is small enough. Such many-body effects indicates a break down of U(1) symmetry in low dimensional system due to many-body effects, and has drawn a lot of attention recently.

Inspired by our earlier work in the quantum Hall ferromagnetism of double quantum well systems (work with Prof. S. Das Sarma, Prof. E. Demler and Prof. B. I.

Halperin, published in 2002-2003), we started to study the inter-component correlation in other multi-component systems since 2004. The three papers [1-3] listed here (for the application of the AS award) are the representative landmarks that we published in the recent three years (2005-2007).

In [1], we first introduce the idea of inter-wire correlation, or pseudo-spin ferromagnetism, into the system of double quantum wire. We argue that when the external magnetic field is strong enough, the kinetic energy of 1D electronic system can be quenched so that thee system become inter-wire correlated due to the strong interaction. We show that the drag resistance of the double wire systems can have non-monotonic behavior when changing inter-wire distance and/or electron density continuously, due to the predicted novel quantum phase transition.

We further extended our study about inter-component correlation to the systems of cold polar molecules with anisotropic interaction. In [2] we propose that one may load the polar molecules into a one-dimensional optical lattice, which separates the molecules into a stack of 2D pancake layers. When a strong electric field is applied perpendicular to the plane, the dipole interaction between molecules leads to the formation of extended chains, analogously to the chaining phenomenon in classical rheological electro- and magneto-fluids. We derive the thermo-dynamical equations for such dipolar chain liquid and show that only the longest chains can undergo Bose-Einstein condensation. Our results, therefore, for the first time shows a close connection between soft-matter physics at room temperature and the quantum many-body theory at zero temperature.

In [3] I myself study polar molecules in a double layer system, where there is a zero-energy resonance in the s-wave scattering channel for molecules in the two layers. As a result, the inter-layer effective interaction strength diverges as the dipole moment is near a critical value (due to the formation of an inter-layer bound state), leading to a stronger inter-layer interaction compared to the intra-layer one, which is totally impossible in the traditional condensed matter systems. I further show that there could be a second order quantum phase transition between a correlated superfluid phase and a Schrodinger’s cat state, which can be applied to the study of quantum information science.

Finally I would like to acknowledge the great support from National Center for Theoretical Science and National Tsing-Hua University for my research during my first three years in Taiwan (2004-2007). Their support helps me to keep connected with the most frontier research in the world and make some pioneering contribution to the international community. I believe that there will be stronger impact and more following-up works in the many-body physics of multi-component systems recently, especially when the experimental results become more available in the next few years.