理學院通訊 Newsletter

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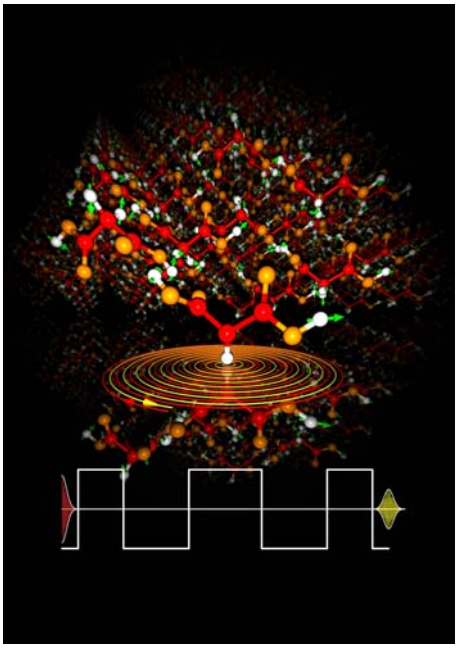
Groundbreaking Discovery in Quantum Research
延長量子態壽命　朝量子計算邁步

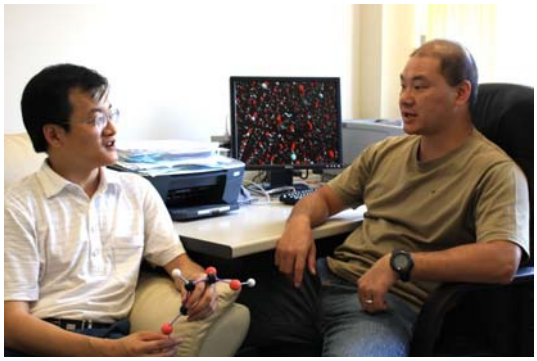


Professor Liu breaks new ground in quantum computing research by significantly prolonging the coherence lifetime of electron spins.

Professor LIU Renbao (劉仁保 教授) of the Physics Department has achieved a significant breakthrough by prolonging the lifespan of the state of quantum superposition from less than 0.04 microseconds to 30 microseconds in his joint research with the University of Science and Technology of China (USTC). Widely recognized as a great leap in quantum computing, the research is published in the latest edition of the prestigious international science journal *Nature*.

It is believed that the mastery of quantum information will make possible the creation of quantum computers capable of processing massive and complex data, and provide solutions for weather forecast, optimal design, identification of genes and engineering decoding, which are considered tough tasks for present day computers.

Superposition and state collapse are two unique features of a quantum object. Superposition means that an object can stay simultaneously in multiple states. For example, an electron spin, similar to a tiny magnetic needle, can simultaneously point up and down. State collapse occurs when a quantum object turns either up or down randomly and unpredictably, thus losing quantum information. This problem is especially severe for electron spins in solid-state systems at room temperature.



Prof. Liu Renbao (right) of the Department of Physics, CUHK, and Prof. Du Jiangfeng of USTC

To protect the state of quantum superposition, the research team led by Professor Liu tactfully applied microwave pulses to electron spins in a solid-state material called malonic acid crystal. It was discovered that the lifespan of spin superposition state was greatly prolonged from less than 40

billionth seconds to about 30 millionth seconds, which is sufficiently long for quantum computer. The team also proved that the method works well event at room temperature, laying the foundation of household quantum computers.

The research also bears significance to the improvement of magnetometry which is useful in the field of biomedical measurement. Professor Liu remarked that the microwave pulse sequences adopted in the research could extend the resonance period in magnetic resonance imaging, hence yielding higher precision in frequency measurement.

Professor Liu Renbao

二十一世紀是資訊的年代。我們每個人都離不開互聯網。不論收發電郵，還是瀏覽網頁，都已成爲了每個人每日的工作和休閒活動的重要部分。互聯網的骨幹是中大前校長高錕教授發明的光纖，光纖內的亮度，上下起伏，最多可以按每秒萬億次或以上的速度變化，傳遞一連串的「0」和 「1」位元，把訊息從世界的一角帶到另一角。由於這項發明，高錕教授今年獲頒諾貝爾獎，報導已經很多，不必冗述。

資訊科技方面，最近又有兩項重要發展，對香港中文大學而言，都是重大的喜訊。其一是由訊息工程學系楊偉豪教授等率領的網絡編碼研究，獲得教資會撥款，成爲卓越學科領域(AoE)。這項研究已經分別報導。其二是物理系**劉仁保教授**及其合作者的工作，爲處理量子訊息帶來重大突破。這項工作已在本年 10 月 29 日第 461 期的權威學術期刊《自然》(*Nature*)中發表。

雖然計算科技一日千里，計算機的速度不斷提高，今天幾千元的筆記本電腦，能力已超過幾十年前的所謂超級電腦。然而還有許多計算問題，須處理龐大資訊。以目前電腦的運算能力，要解決這些問題還是遙不可及。這十多年來，物理學家和計算科學家發現，如果我們能夠操縱微小的量子系統，以量子位元來體現計算，這一切在今天束手無策的問題，就迎刃而解了。比方說，現在認爲不能破解的密碼，屆時要破解也就變得輕鬆平常了。這是科學家的夢想，在這十多年來有不少的進展。到了今天，人們已經可以控制大約 10 個量子位元。

量子位元不單是微小，它和經典位元更有本質上的差異。每個量子位元好像手錶上的時針，有它的長度，也有它的指向。正如時針一樣，它的指向（嚴格來說還是各個位元之間的相對指向）極爲重要。其實，量子位元更像不限於平面，而是可以在立體空間隨意指向的時針。這些時針的指向，稱爲波函數的相位，而相位是量子訊息的靈魂。

問題在於這些時針的指向非常敏感，只要受到些微干擾，便發生變化，有關訊息就會消失。換句話說，量子態的壽命極短，不足以有效使用。如果能找出延年益壽的配方，使量子態能夠經歷更長久的穩定時期，就足以克服障礙，向量子計算邁進。

量子位元用電子自旋實現。最近在《自然》發表的文章裡，中大物理系劉仁保教授和他在合肥中國科技大學的合作夥伴，設計並實現了一套方案，利用巧妙的微波技術，把處於一種固體材料中的電子自旋的量子相位維持了 30 微秒，使本來 0.04 微秒的壽命延長了近千倍，朝著量子計算的實現邁開了一大步。尤其可貴的是，儘管固體材料裏面的擾動異常複雜，但他們的研究證明在常溫下延長量子態的壽命是可行的。這使我們可以

憧憬有朝一日，我們可能像現在擁有筆記本電腦一樣，擁有一台小巧的量子電腦，在家居溫度下工作。

把相位穩定下來的辦法，原則上並不困難。相位的漂移，是源於環境所造成的（不可知的）局部磁場。科學家們利用脈沖微波，把電子自旋幾經反轉，反轉之後磁場效應變成相反，磁場的影響便很大程度上抵銷了。要把這個方案實現起來，當然毫不簡單，劉仁保教授及其夥伴的工作，就是通過精細的分析和小心的實驗，證明了這個方案是可行的。

量子訊息，真是妙不可言。如果以光纖所傳達的光線亮度而言，量子訊息的算術規則是這樣的：$1+1\neq 2$，$Q\times P\neq P\times Q$。

(1) 以亮度而言，1+1 不一定等於 2，可以等於 0 至 4 之間的任何數字。

(2) 兩個量 Q 與 P 的積，要視乎次序，$Q\times P$ 不一定等於 $P\times Q$，其實，如果 Q 與 P 是「天造地設」的一對的話，

$$Q\times P-P\times Q=\sqrt{-1}\,h/2\pi$$

其中 h 是量子力學裏最基本的布朗克常數，以一般公制單位表示，微乎其微，在小數點後第 34 位出現一個 6 字，而以上公式又居然涉及負數的開方根。

這兩條奇妙的規則背後，有以下的意義：

加法如此奇妙，因爲如上所述，每一個物理量子位元好像手錶的時針，有它的長度，也有它的指向。兩個物理量子位元相加的時候，是要把兩枝時針首尾相接，疊加起來（這就是中學生也學過的矢量和），而亮度就是疊加總和的「時針」的長度平方。如果兩枝時針方向相反（比方一枝指向 3 時，一枝指向 9 時），加起來是 0。如果兩枝同向的話（比方兩枝都指向 3 時），加起來就是 2，其平方就是 4。

而且，$Q\times P-P\times Q\neq 0$ 的奇怪乘法，表示要量度一個系統，就必須干擾它。所以量度 Q 與 P 的次序，會出現不同的結果。這個原理是量子物理的核心，亦是量子世界與古典世界的分野。在量子位元的問題上，它有以下的體現：如果位元的相位模糊了，訊息並不是真正消失，只不過跑到了環境裏去，使位元和環境「糾纏」起來。量子態的糾纏，是愛恩斯坦等人（Einstein, Podolsky, Rosen）提出的深奧問題，而與之有關的一些概念，是量子力學裏最基本、最玄妙，但又最未能明白的詮釋和波函數塌縮問題。量子態相位所受到的擾動，本質上就是波函數因爲量子位元和環境糾纏所導致的塌縮。劉仁保等教授的工作，一方面可以說是把波函數塌縮前的壽命延長了千倍，保衛了訊息，不讓量子位元和環境糾纏；另一方面，長遠來說還會幫助我們對量子力學的最基本問題增加認識，解釋愛恩斯坦等人提出而未能解答的問題。

5th Lau Oi Wah Memorial Science Lecture Series

The above event will be held on Saturday 7 November 2009 from 9:30a.m. to 1:00p.m. in Sir Run Run Shaw Hall. The programme itinerary is as follows:

TIME 時間	PROGRAMME 程序表	SPEAKER 講者
09:30 – 09:45	Registration	
09:45 – 10:00	Opening Ceremony 開幕禮	
10:00 – 10:40	Chinese Medicine: The Science of Disease Prevention and Healing 中醫：預防與治療疾病的科學	*Professor LEUNG Wing Nang Albert* School of Chinese Medicine（中醫學院）
10:40 – 11:20	Doing Chemistry with Computers 計算化學	*Professor LI Wai Kee* Emeritus Professor of Chemistry Department of Chemistry （化學系）
11:20 – 11:40	Break 小休	
11:40 – 12:20	Introduction to Game Theory 博弈論初探	*Dr. LAU Chi Hin* Department of Mathematics （數學系）
12:20 – 13:00	Green Fluorescent Proteins in Life Sciences Research 綠色熒光蛋白與生命科學研究	*Professor JIANG Liwen* Department of Biology （生物系）

Dean's Honour List 2008/09 and Faculty Exemplary Teaching Award 2009 Ceremony

The above ceremony will be held on Saturday 16 January 2010 in L1, SC. The Faculty Office will send out invitations to Dean's List honorees towards the end of the month.

Application Deadlines

1. Research Fellowship Scheme

The Research Committee has allocated over $1M to support the above scheme. Applications should be submitted to the Science Panel, c/o Science Faculty Office by Friday 20 November, 2009.

2. Knowledge Transfer Project Fund

Knowledge Transfer as defined by the UGC refers to "The systems and processes by which knowledge, including technology, know-how, expertise and skills are transferred between higher education

institutions and society, leading to innovative, profitable or economic or social improvements."

The University has established a Knowledge Transfer Project Fund of $3M in total and is now inviting applications. Applications should be sent to Ms. Sharon Tam, Manager, Knowledge Transfer, via email: sharontam@cuhk.edu.hk.

3. 2010 State Science and Technology Awards 「國家科學技術獎」

(1) State Technological Invention Award (STIA) 「國家技術發明獎」 and (2) State Scientific and Technological Progress Award (SSTPA) 「國家科學技術進步獎」are inviting nominations. Deadline for application to the Research Committee via the Research Administration Office is 10 November 2009.

GE Lunch Seminar:

Science Education Through General Education

Date: 13 November, 2009 (Friday)
Time: 12:30 p.m. to 2:15 p.m.
Venue: G3, Fung King Hey Building
Speakers: Dr. Chiu Chi Ming Lawrence (Department of Biology, CUHK)
Dr. Pang Kam Moon (Department of Physics, CUHK)
Language: Cantonese
Light lunch provided

Dr. Chiu Chi Ming and Dr. Pang Kam Moon are both experienced University GE (UGE) teachers. They have been teaching UGE science courses since 2002. In this seminar, they will share their experience in teaching large classes. It is generally agreed that a UGE science course should lead students to, with a scientific attitude, appraise and evaluate human's role in being part of nature and the impact of science and technology on today's life. However, most teachers also find it difficult to achieve this goal in large classes where individual students' science backgrounds are hard to cater for. The speakers will share the difficulties they encountered and suggest some possible solutions, including the design of teaching plans, for discussion.

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