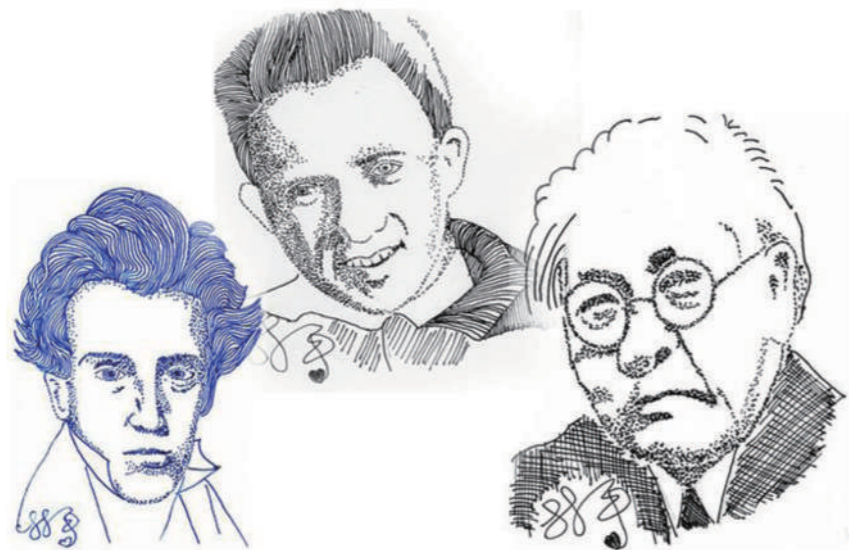


量子計算的源頭 - 波爾叔叔

文／林一平 講座教授



林一平手繪之齊克果、海森堡、仁科芳雄。

量子計算被認為是新一代的計算技術，其理論的源頭可追溯到丹麥人波爾 (Niels Henrik David Bohr)。他被認為是 20 世紀最偉大的科學家之一，好友們都親密的叫他「尼克叔叔」。

波爾早期的思想深受 19 世紀宗教哲學家，也是存在主義哲學之父齊克果 (Soren Kierkegaard) 的影響。齊克果寫了被稱為有史以來最長，也最隱晦難懂的情書《非彼即此》(Either/Or) 給愛人奧森 (Regine Olsen)。結果奧森離他而去，和別人訂婚，而《非彼即此》則變成現代存在主義的聖經。

《非彼即此》和齊克果 1845 出版的書《生命道路各個階段》(Stages on Life's Way) 有相當的關連性。雖然波爾不盡然完全同意齊克果《非彼即此》的看法，他的確熟讀《生命道路各個階段》。這本書敘述一個事件在各個階段有不同的呈現。當我們描述光的物理行為為這個事件時，將波動性與粒子性都納入考量，或許就是「光」這事件在各個階段不同的呈現。

諸位讀者可能不知道，波爾是李國鼎的師兄，2 個人都曾經接受過拉塞福 (Ernest Rutherford) 的指導。基於拉塞福的理論基礎，波爾發展出量子理論 (Quantum Theory)，也因此於 1922 年獲頒諾貝爾獎。他的兒子 Aage Niels

Bohr 也是諾貝爾獎得主，成為物理史父子檔的一段佳話。

波爾最厲害的學生是海森堡 (Werner Heisenberg)，他是建立量子動力學 (Quantum Mechanics) 的最重要人物。1941 年波爾和海森堡討論原子彈的可能性。海森堡後來成為德國納粹原子彈計畫的主持人。日本也於 1941 年開始研製原子彈，計畫的負責人則是接受過波爾訓練的仁科芳雄。仁科芳雄後來指導了日本第一位諾貝爾物理獎得主湯川秀樹 (Hideki Yukawa)。

由於教出懂原子彈理論的德國及日本徒弟，波爾深深憂慮軸心國會發展出威力強大的武器。因此於 1943 年逃到美國後，就參與催生了曼哈頓計畫，在新墨西哥州的羅斯阿拉摩斯實驗室指導美國科學家研製原子彈。為了保密，每個在該實驗室的科學家都必須化名。波爾的化名是尼可拉斯·巴克。不過認識他的好友都叫不習慣，仍然暱稱他為「尼克叔叔」。

波爾死後葬於哥本哈根的公墓，與齊克果及安徒生 (Hans Christian Andersen) 為鄰。化學元素 Bohrium (Bh) 係因為紀念波爾而命名。波爾生前最後一篇論文《Light and Life revisited》(Licht und Leben-noch einmal) 發表於 1963 年 (他去世後一年)。顯然波爾臨死之前對生命仍充滿好奇。

The Origin of Quantum Computing—Uncle Bohr

Quantum computing is considered to be a new generation of computing technology, and the origin of the theory could be traced back to the Danish Scientist, Niels Henrik David Bohr. Bohr is generally regarded as one of the foremost scientists of the 20th century. His friends familiarly called Bohr "Uncle Nick," a nickname referencing Bohr's wartime alias.

It is known that Bohr, in his early years, was deeply influenced by Soren Kierkegaard, a 19th century philosopher of religion and the father of existentialism. Kierkegaard wrote the longest and most obscure love letter *Either/Or* to his beloved Regine Olsen. Orson left him and got engaged to someone else, but *Either/Or* became the Bible of modern existentialism nevertheless.

Either/Or and *Stages on Life's Way*, published by Kierkegaard in 1845, are closely connected. Although Bohr didn't completely agree with Kierkegaard's view in *Either/Or*, he did read *Stages on Life's Way* thoroughly. This book describes how an event is presented differently in various stages. When we describe some event of the physical behavior of light and consider both wave and particle characteristics, it may be the event of "light" that may have different appearances in various stages.

You may not know that Bohr is Kwoh-ting Li's senior fellow. They both had studied under the supervision of Ernest Rutherford. Based on Rutherford's theoretical foundation, Bohr developed Quantum Theory and was awarded the Nobel Prize in 1922. His son, Aage Niels Bohr, is also a Nobel Prize winner, which is broadly eulogized in the history of physics.

The best student of Bohr is Werner Heisenberg, one of the most important pioneers of quantum mechanics. In 1941, Bohr and Heisenberg discussed the feasibility of an atomic bomb. Heisenberg later became the leader of the Nazi atomic bomb program. Japan also started to develop atomic bombs in 1941, and the leading figure in the Japanese Atomic Project was Yoshio Nishina, who had also studied physics under Bohr. Nishina later mentored Hideki Yukawa, Japan's first Nobel Prize winner in physics.

Because his German and Japanese apprentices understood the atomic bomb theory, Bohr was deeply worried about the Axis Alliance's potential to develop devastating weapons. Therefore, after escaping to the United States in 1943, he participated in the birth of the Manhattan Project and instructed American scientists to develop the atomic bomb at Los Alamos National Laboratory in New Mexico. In order to keep the project confidential from others, every scientist in the laboratory must have a pseudonym. Bohr's pseudonym is Nicholas Baker. However, the friends who knew him were not used to it and instead called him "Uncle Nick".

After Bohr died, he was buried in a cemetery in Copenhagen, next to Kierkegaard and Hans Christian Andersen. The chemical element Bohrium (Bh) was named in honor of Bohr. Bohr's last paper "Light and Life Revisited" (*Licht und Leben-noch einmal*) was published in 1963, one year after his death. Obviously, Bohr was still curious about life in his last days.