Charles Hard Townes (1915–2015)

C H Townes shared the Nobel Prize in 1964 for the concept of the laser and the earlier realization of the concept at microwave frequencies, called the maser. He passed away in January of this year, six months short of his hundredth birthday. A cursory look at the archives shows a paper as late as 2011 – 'The Dust Distribution Immediately Surrounding V Hydrae', a contribution to infrared astronomy. To get a feel for the range in time and field, his 1936 masters thesis was based on repairing a non-functional van de Graaf accelerator at Duke University in 1936!

For his PhD at the California Institute of Technology, he measured the spin of the nucleus of carbon-13 using isotope separation and high resolution spectroscopy. Smythe, his thesis supervisor was writing a comprehensive text on electromagnetism, and Townes solved every problem in it – it must have stood him in good stead in what followed. In 1939, even a star student like him did not get an academic job. The industrial job he took set him on his lifetime course. This was at the legendary Bell Telephone Laboratories, the research wing of AT&T, the company which set up and ran the first – and then the best – telephone system in the world. He was initially given a lot of freedom to work with different research groups. During the Second World War, he worked in a group developing a radar based system for guiding bombs. But his goal was always physics research. After the War, Bell Labs, somewhat reluctantly, let him pursue microwave spectroscopy, on the basis of a technical report he wrote suggesting that molecules might serve as circuit elements at high frequencies which were important for communication.

At a conference in 1950, Rabi, the Nobel Prize winning physicist and head of the Columbia University physics department, made very critical comments after Townes' talk which he did his best to deal with. To Townes' surprise, he received a job offer on the beach from Rabi later during the same meeting! Clearly, he had passed his test. Microwave spectroscopy flourished in his group at Columbia University, which included his postdoctoral fellow (and future brother-in-law), Arthur Schawlow – their book on the subject is still a classic. One important measurement was the inversion of ammonia, NH_3. One can visualise this as an oscillation taking the nitrogen above and below the plane defined by the three hydrogen atoms. Quantum theory describes this process by two energy levels, separated by an energy corresponding to a wavelength of 1.25 cm. Importantly for what followed, these two states respond oppositely to an electric field gradient. The ground state is pulled towards stronger fields, and the excited state away from them. The laboratory in Columbia was already famous for separating different states of beams of atoms and molecules in this way. By Townes' own account, the defining moment came when he was sitting on a park bench in Washington in 1951, while waiting for a government committee meeting (see picture). The idea that material not in thermal equilibrium – for example mostly in the excited state – would show negative absorption, was not new. Einstein had proposed it in 1917, but Townes was uniquely positioned to view it in engineering terms as a negative resistance which could be made the basis for an oscillator when coupled to a resonant circuit. This consists of inductance and capacitance at low frequencies, but at 1.35 cm/22 GHz, it is a metal box. It took two years for this flash of inspiration to become a working device producing coherent radiation at the ammonia frequency of 24 GHz. Apparently, the last crucial step was when his student, Gordon, took off the end walls of the box into which the excited ammonia molecules were being fed! A few months before this, his senior colleagues, Rabi and Kusch, had told him that he was wasting time and money and he should stop the project. Even after the device was built, Neils Bohr and John von Neumann expressed concerns that such a narrow spectral line was inconsistent with the energy – time uncertainty principle, because the atoms spent so little time in the cavity. (The answer to this paradox was later given by his Columbia colleague, Willis Lamb). This was the birth of the maser – Microwave Amplification by Stimulated Emission of Radiation. Replace M by L for light and you have the laser which is commonplace today. This extension by four orders of magnitude in frequency was not easy or immediate. The concept was proposed by Townes and Schawlow, and by Basov and Prokhorov in the Soviet Union, but neither could actually build a laser. That distinction went to T H Maiman of the Hughes aircraft company which, like the Bell Telephone company, supported basic research which they thought was interesting. The crucial step for both the maser and laser was feedback. In electronic oscillators, this is achieved by connecting a part of the output to the input. For radio or light waves, it is done with mirrors. This merging of ideas from circuits and microwaves, mainly the province of engineers, and the quantum physics of atoms and molecules proved tremendously fruitful over the coming decades. The name 'quantum electronics' is now in wide use to describe this synthesis.

Townes' home town of Greenville commemorated the son of its soil by a statue placed on the original bench where he had his moment of inspiration. Visitors are also invited to occupy the vacant space.
Courtesy:www.greenvillejournal.com/ /index.php?page=3&item=2441

Many scientists face a serious crisis after their greatest work. But reading about Townes' career gives no such indication. He had another ace up his sleeve – spectroscopy of interstellar molecules. Already in the early 1950's, he had felt that astronomy with radio waves would reveal new information. Eminent astronomers dissuaded him. In 1967, he moved across the US to the University of California, Berkeley, and started the search for interstellar molecules, in which he became a pioneer. At a seminar in Bengaluru, he recalled his student calling him up from the observatory with the news that it was raining in Orion! They were looking for a weak signal from the water molecule H_2O at a wavelength of 1.35 cm. What they saw was far stronger than expected. Not only had they discovered water molecules in the space between the stars, but the fact that there was stimulated emission. Not strictly a maser, since there was no feedback, but the name 'water maser' (now accompanied by OH maser, SiO maser, methanol maser, and many more) has stuck. And when the field of molecular astronomy was mature, Townes moved to the infrared, taking up the challenge of extending the microwave techniques he had perfected to a frequency of 28 THz (close to a thousand times more than his work with ammonia at 24 GHz)! As always, he had a scientific goal. It was to achieve the highest possible angular and frequency resolution in the study of the environments of stars – the paper cited at the beginning of this article is an example.

What makes such a person tick? One gains some insight from the Wikipedia article and the extensive interviews that he gave for an oral history project (https://en.wikipedia.org/wiki/Charles_H._Townes, http://content.cdlib.org/view?docId=kt3199 n627&brand=calisphere&doc.view=entire_text). He was brought up in the small town of Greenville in the southern state of South Carolina in the US, with strong religious, ethical, family, and academic values and a strong work culture. His early fascination was with Nature – he even sent a sample of a fish to a museum to see if it was a new species! He was good at making things work. He preferred to stay closer to home for his undergraduate and masters degrees, rather than seek out more famous places, partly because they were costlier.

Townes was rather open about his religious belief and practice, even in academic circles where notions like faith and purpose are hardly fashionable. They sustained his confidence, focus, and energy throughout a long and intense life. In 2005, he was awarded the Templeton Foundation Prize which is for an individual making "an exceptional contribution to affirming life's spiritual dimension, whether through insight, discovery, or practical works". All this might give the impression of a one-dimensional life. Far from it – he could wrestle, hike, sing, play music. Unusually for someone so productive, he firmly resolved not to work or even (consciously!) think of work on Sundays, which were reserved for church and family!

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