The industrial academy

IBM's Zurich Research Centre opened its doors 50 years ago, quickly becoming a world-leading research lab. But does it still live up to its illustrious past? **Philip Ball** travels to Switzerland to find out

It is easy to imagine, as you stroll around IBM's research laboratory in the Zurich suburb of Rüschlikon, that you are on a university campus. The place has that laid-back vibe, those poster-decorated corridors and that faintly dishevelled appearance. For many researchers visiting from the nearby Swiss Federal Institute of Technology (ETH), it is almost like an annexe of their own institution. Indeed, countless distinguished scientists – from ETH and elsewhere – have spent time at IBM while seeming scarcely to notice any differences from academia.

That has been the intention since the research centre was constructed some 50 years ago. When Ambros Speiser, the lab's first director, dedicated the centre in May 1963, he noted that the only way it could succeed was "to become part of this [European] scientific community".

Not only did it survive, but it thrived. In the early 1980s scientists at the Rüschlikon lab made a series of breakthroughs. In 1981 Gerd Binnig and Heinrich Rohrer invented the scanning tunnelling microscope (STM) – the first microscope that could resolve the structures of surfaces at atomic resolution. Binnig subsequently collaborated with fellow IBM researcher Christoph Gerber and Stanford University physicist Calvin Quate to devise the atomic force microscope (AFM). These and related scanning probe microscopes have not only revolutionized surface science but also become the iconic tools of nanotechnology, enabling atomic-scale fabrication and manipulation. Binnig and Rohrer's achievement was recognized when they were awarded the 1986 Nobel Prize for Physics.

That year was a high-water mark for IBM Zurich, for it was then that another pair of scientists at the centre, Alex Müller and Georg Bednorz, discovered superconductivity in a class of inorganic materials – lanthanum barium copper oxide – at the unprecedentedly high temperature of 30 K. Their finding triggered a frenzy of research around the world, and within barely a few months other copper-oxide materials had been synthesized that superconducted at temperatures as high as 90 K. The record finally reached 135 K in 1993. Müller and Bednorz won the 1987 Nobel Prize for Physics, making it two years in a row for the IBM lab.

Manfred Richter

Built for success IBM's research campus in the Zurich suburb of Rüschlikon – established 50 years ago – has a rich history of physics breakthroughs.

"Without these Nobel prizes this lab would not be what it is today," says Walter Riess, the laboratory's department manager of science and technology. "In particular, what Binnig and Rohrer did 30 years ago is still impacting us." Indeed, the Rüschlikon lab's new $90m nanotechnology facility, which opened in May 2011 and was built in collaboration with the ETH, is named the Binnig and Rohrer Nanotechnology Center.

With a legacy like that, IBM Zurich might be forgiven for resting on its laurels. But that does not look likely. As well as investing in the new nanotechnology centre, which includes a suite of "noise-free labs" (see box), the laboratory is expanding into fields that could determine the future of the company's core business of information technology, including topics such as spintronics and molecular electronics. It is also branching out into new areas as diverse as bioinformatics, solar cells, battery technology and biomolecular-structure determination.

Mr Watson comes to Europe

IBM's predecessor – the Computing Tabulating Recording Company – was created in the pre-computer era in 1911, when the firm made machines for tabulating data using punched cards. Its founder, Thomas J Watson Sr, rechristened the parent company International Business Machines in 1924, and by the 1930s its tabulators became known as computing machines. As primitive electronic computers began to appear in the 1940s, Watson opened the company's first research laboratory in New York in 1945.

Collaboration with academia was always IBM's style. In the 1950s it cultivated ties with the Massachusetts Institute of Technology and by the time IBM opened its Almaden research laboratory in the nascent Silicon Valley at San Jose, California, in 1952, it was a leading force in US computer science and the emerging field of information science and technology. Despite the travails of the 1990s, when industrial research became increasingly short-termist and application-focused, IBM has managed to re-establish a strong research profile in basic physics.

In 1956 Thomas Watson Jr – the eldest son of Thomas J Watson Sr – decided it was time to tap into Europe's scientific expertise. With most of Europe still piecing itself back together after the war, neutral Switzerland seemed a wise location. Speiser was put in charge of the operation, which was initially very modest and focused on the area of data processing. In 1962 he identified the plot of land in Rüschlikon as the best site for a permanent European lab. Looking out from the campus at Lake Zurich on one side and the alpine pastures on the other, it is not hard to see why.

The future of computing

IBM now has 12 research laboratories around the world, including centres in Australia, India and Japan. But the glory years of the 1980s have given the Zurich lab a glamour that is hard to match. It is keen to capitalize on that success, in particular to maintain a leading profile in nanotechnology. In cultivating basic research, however, the Zurich lab takes a relaxed view of any corporate commercial agenda and is not strongly application-driven. "Ideas come from the bottom up – you try to hire the best people, and they bring ideas that they want to pursue," says the lab's director Matthias Kaiserswerth.

That commitment to science is also a conscious attempt to maintain the respect of the academic community. "We've not followed the model that many companies have where they outsource the basic research to universities," says Kaiserswerth. Echoing Speiser's foundational strategy, he believes that "to be an accepted partner with universities, we need to be able to have an eye-level conversation with them".

Besides, IBM has long known that staying competitive in its core business of information technology requires substantial inputs of basic science. In particular, as the shrinking of microelectronic circuitry starts to approach the physical limits of what silicon can achieve, entirely new approaches, devices and materials will be needed to sustain the trends in computing power.

However, Kaiserswerth says that silicon's life can be extended by working on how the devices are structured, arranged and deployed on chips. One of the problems with current transistor designs is that, as the distance between the source and drain terminals decreases, the gate electrode becomes less able to turn the device off. In other words, it leaks. One option being pursued at Zurich is to make transistors from silicon nanowires, in which the gate is wrapped all around the circumference of the wire, giving better gating control.

Another ruse is to switch from 2D side-by-side packing of devices on chips to 3D stacking. This could cut the distances signals have to travel between devices, which makes integrated circuits slow and power-hungry. With these approaches, silicon microelectronics could keep pace for maybe another 5–10 years.

But what comes after that? No-one knows, and IBM is not trying to guess. What the Zurich lab does recognize is that it is no good developing a replacement from scratch when silicon comes to the end of the road – the exploration of alternatives has to start now. Riess says that there is no obvious leading candidate yet, so IBM is exploring several, among them carbon nanotechnologies (such as nanotubes and graphene), molecular electronics and spintronics, as well as devices such as quantum computers.

New horizons

The pervasive influence of information technology means that any major computer company now has to concern itself with much more than just handling bits. For example, IBM has begun to venture into energy technologies, in part because energy consumption and management is becoming key to the performance of supercomputers. While the power demand of microprocessors is dropping (the number of flops per watt is rising), the miniaturization and massive integration of computer circuits means that supercomputers consume a huge amount of energy, much of which must be dissipated as heat.

IBM researchers have already developed water-cooling technologies to help supercomputers avoid meltdown. But IBM's interests in energy are broader. Researchers at the Zurich lab are, for example, developing solar concentrators for photovoltaic cells, and IBM has launched the Battery 500 project to develop a battery that can power a car for 500 miles without need for recharging. The company's researchers are investing a lot of effort in the lithium-air battery, which captures the chemical energy of the reaction between lithium and oxygen.

"IBM is not in the business of making batteries for electric vehicles," Riess explains, "but its has lots of experience in computational sciences and materials. IBM has partnered with two companies in Japan and hopes someday to bring this technology to the marketplace."

> We mustn't lose sight of who pays the bills – it is IBM's customers. They're not paying us to do basic research, but to solve their problems

Bioinformatics is becoming another focus at the Rüschlikon lab. But if the encroachment of information technology into all areas of science is a boon for IBM, there is also in the end only so much it can follow up. "We're a small lab and can't do everything," says Kaiserswerth. "If you let 1000 flowers bloom like a university, they might all be very interesting but they're not going to have any impact. We mustn't lose sight of who pays the bills – it is IBM's customers. They're not paying us to do basic research, but to solve their problems."

The triumphs of the 1980s have created a hard act for IBM Zurich to follow. But it is not a matter of trying to produce more of the same. The industry has changed since then: there are new pressures and priorities, and new ways of working. "The time horizon from research to market has shrunk," admits Kaiserswerth. The open-source movement has also profoundly affected how a company such as IBM thinks about intellectual property. The question has become "finding the right balance between what's proprietary and what's open".

For basic science, the move towards openness seems to be paying off. Involving a partner such as ETH not only offers a way of spreading the costs of facilities such as the nanotechnology centre, but also invites new ideas, projects and collaborators. In the past few months, IBM Zurich researchers have made headlines with the direct mapping of a spin helix in spintronics, the commercialization of an affordable tool for nanoscale sculpting, and the measurement of charge distribution and bond orders in single molecules with the AFM. If there's no telling where the next Nobel might come from, they are certainly keeping their options open.

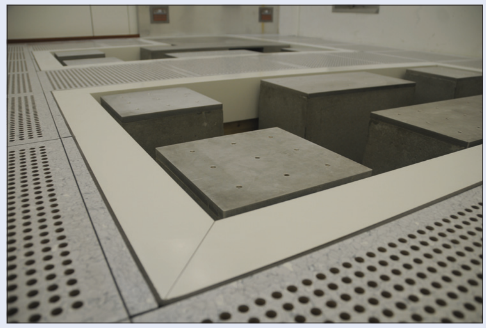
Quiet please!

One of the star attractions of the new Binnig and Rohrer Nanotechnology Center at IBM Zurich is the noise-free lab. Constructed in the basement, it is used for experiments – such as detecting electron spin – that are so sensitive they could be disrupted by the slightest tremor, stray electromagnetic field or fluctuation in temperature.

The Rüschlikon centre is not the place you would ideally choose for such a facility: there are electricity pylons overhead, a train tunnel 175 m away and a truck-laden highway 150 m distant. The train track not only shakes the ground but sends out a powerful 16.7 Hz electromagnetic field. Indeed, when physicist Emanuel Lörtscher set out to design the lab, many people said that his targets were unfeasible.

But not only did he meet the targets, he exceeded them. In the lab's vaults, huge blocks of concrete – weighing as much as 78 tonnes each – supported on air pistons provide a base for mounting experiments that experience vibration-induced speeds of less than 500 nm per second at 1 Hz. Power equipment and workspace are kept separate from the experimental chambers to reduce other sources of vibration. The air conditioning seeps from floor to ceiling to eliminate turbulent flow, and maintains the temperature to within 0.05 °C over a day, with humidity changes of less than 3%.

The entire lab is encased in electromagnetically shielding mu metal, with additional Faraday coils running round the individual rooms to smooth out any hotspots. As a result, the labs experience alternating magnetic fields of less than 2 nT. And the constraints don't interfere with user-friendliness. "We wanted labs that can still be easily accessed and equipped, rather than superior but impractical conditions," Lörtscher says.



Emanuel Lörtscher

Set in stone The noise-free lab IBM Zurich will be used by researchers for experiments that are extremely sensitive to the outside world.