then

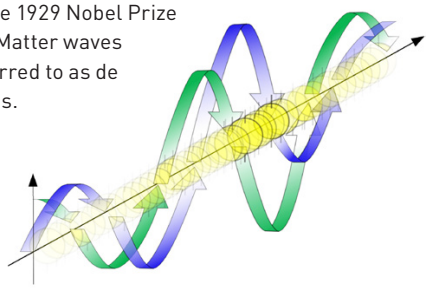
Making Atoms Interfere

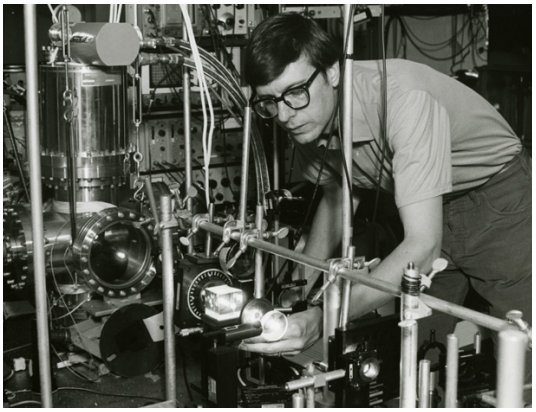
The concept of "matter waves" was coined in the 1920s. Seven decades later, scientists had leveraged the principle to create ultra-precise atom interferometers.

Louis-Victor de Broglie / Illustration of de Broglie wave [Wikimedia Commons]

1920s: Wave–particle duality

In the 1920s, the French physicist Louis-Victor de Broglie hypothesized that electrons have a wave-like nature—a hypothesis soon confirmed by the experimental observation of electron diffraction. The idea that all matter exhibits properties of both particles and waves became a central tenet of quantum mechanics, and it earned de Broglie the 1929 Nobel Prize for Physics. Matter waves are also referred to as de Broglie waves.

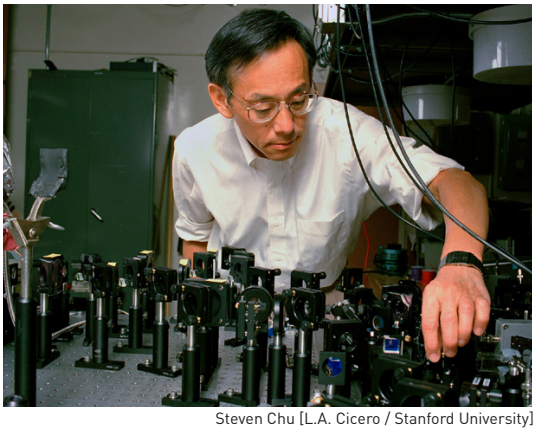




William Phillips [NIST Digital Archives]

1970s/80s: Cool down, slow down

It took decades to directly observe the wave-like nature of matter. Atoms were too hot and moved too fast; their tiny de Broglie wavelengths made observation practically impossible. That is, until scientists such as Nobel laureates Steven Chu, Claude Cohen-Tannoudji and William Phillips began to use laser light to trap and cool atomic gases to near absolute zero in "optical molasses," opening the door to atom interferometry.



Steven Chu [L.A. Cicero / Stanford University]

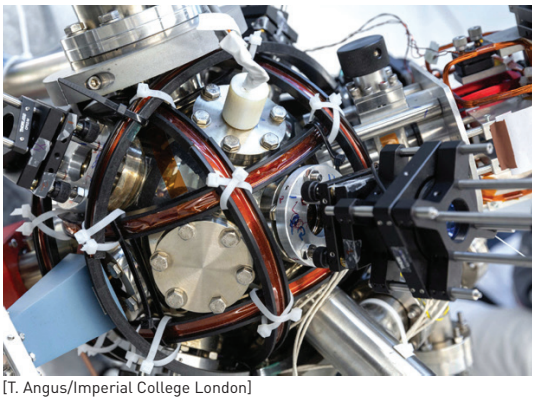
1991: Toward atom interferometers

In 1991, Chu and Mark Kasevich demonstrated a cold-atom-based interferometer, a device that measures the phase difference between atom waves traveling along different paths. The scientists used stimulated Raman transitions on laser-cooled sodium atoms to create their matter-wave interferometer. The resulting device was so sensitive to atomic movement that they could use it as an inertial sensor to measure acceleration.

now

Precision Quantum Sensing

Atom interferometry underlies a myriad modern quantum sensors that accomplish everything from measuring gravitational changes to probing fundamental science.



[T. Angus/Imperial College London]

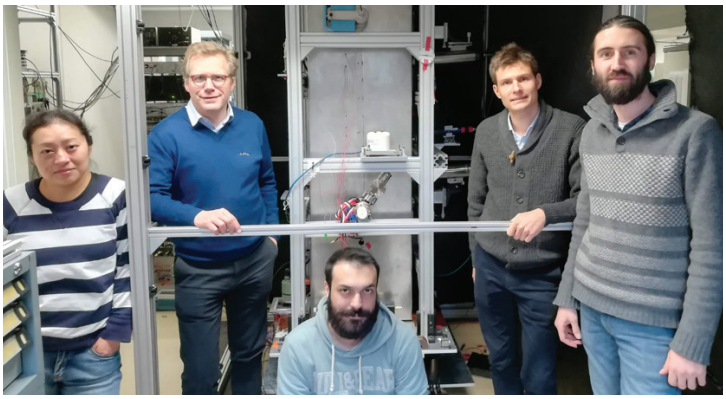
2018: Building a quantum compass

A U.K. team has demonstrated a portable, stand-alone quantum accelerometer for navigation. The device can measure an object's velocity changes so well that, given a known starting point, it can precisely track changes in the object's position without tapping an external GPS signal. The current system is designed for large vehicle navigation, but the academic–industrial team is also working on basic-research applications.

[Getty Images]

2018: Satellite-based gravimetry

NASA has teamed up with AOSense Inc., USA, to create a quantum sensor capable of obtaining highly sensitive gravity measurements. The prototype employs atom interferometry to map Earth's time-varying gravitational field, measuring small changes in Earth's water mass that affect mass distribution and thus gravity. The sensor could be a stepping stone toward next-generation climate-monitoring missions in space.



The experimental set-up and the Paris Observatory SYRTE team. [R. Geiger / SYRTE]

2018: Interleaved atom interferometry

Using cold-atom inertial sensors to measure time-varying signals, for problems like detecting dark matter, has been challenging. French researchers have created a precise cold-atom gyroscope based on "interleaved" interferometry—interrogating multiple atom clouds simultaneously in a single experiment. The team believes this work validates interleaving as a key concept for future atom-interferometry sensors probing time-varying signals.

Scratching the quantum surface

These examples peel back only the first few layers of the current, rich work in quantum sensing. As the field evolves, researchers envision sensors that steer autonomous vehicles on land or underwater, that sniff out volcanic eruptions before the top blows or earthquakes before the first dish breaks, and that measure fundamental constants of nature.

For references and resources, go online: www.osa-opn.org/then-now/atom-interferometry.