

# A Quantum Leap in Next-Gen Optical Atomic Clocks

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QuantX Labs, an Australian deep technology company, has achieved a groundbreaking advancement with its cryogenic sapphire oscillator, the Cryoclock. Operating at microwave frequencies, it offers unparalleled signal purity and stability, attracting interest from defense and commercial markets while also spearheading the development of advanced quantum technology for space applications.

QuantX Labs, a 100% Australian-owned deep-technology company based in Lot Fourteen, Australia's innovation precinct in Adelaide, South Australia, has achieved significant advancements with its groundbreaking cryogenic sapphire oscillator, operating at a microwave frequency of approximately 10 GHz and offering unparalleled signal purity, outperforming any competing commercial technology by 1,000-10,000 times near the carrier frequency. With short-term (one second) fractional frequency stability of order  $10^{-16}$ , the Cryoclock effectively loses or gains only one second every 40 million years. Even after one day of averaging, the long-term frequency stability remains exceptional (about  $10^{-15}$ ), moving to  $10^{-14}$  after one month of operation.

The innovative Cryoclock technology is composed of a 5 cm cylinder-shaped sapphire crystal, cooled to approximately 6 K. This extreme temperature allows the sapphire crystal to display the lowest microwave energy losses of any known substance on Earth. The oscillator's core principle is based on the Whispering Gallery phenomenon, discovered by Lord Rayleigh in 1878. Within the resonator, microwaves injected into the sapphire crystal propagate along its circumference, generating a stable resonant frequency. This single-frequency, spectrally pure source proves ideal for applications that demand exceptional timing precision, such as very long baseline interferometry radio astronomy, quantum computing development and radar technology. To achieve its extraordinary performance, the Cryoclock



**The Cryoclock is a revolutionary cryogenic sapphire oscillator, offering unmatched signal purity and stability at microwave frequencies.** Credit: QuantX Labs

actively maintains the sapphire temperature within 10 microkelvins of the set point, while meticulously controlling the amplitude and phase of the microwave signal entering the crystal. Probes detect the resonant microwave frequency Whispering Gallery mode, which is then amplified to produce a highly pure frequency.

Cryoclock's journey began in 1989 when Professor Andre Luiten created the first version while working toward his Ph.D. at the University of Western Australia. Professor John Hartnett further improved the technology between 2004 and 2012. Initially, the device required regular liquid helium refilling, but with the introduction of a cryogenic refrigerator and a specially designed ultralow-vibration cryostat, it became autonomous, facilitating deployment to remote locations for extended periods.

In 2021, the Australian government awarded QuantX Labs, through BAE Systems, a contract to develop the cryoclock system for inclusion in Australia's nationwide surveillance system, the Jindalee Operational Radar Network (JORN), which is the Australian Defense Force's key

surveillance system. Consisting of three connected remote, over-the-horizon radars located around Australia, JORN monitors Australia's northern approaches and beyond, critical to the nation's defense posture. The integration of Cryoclock technology will significantly enhance the network's detection capabilities and sensitivity, where improved spectral purity enables this radar system to detect slow-moving (low Doppler shift) and small targets (weak reflected signals).

The developed Cryoclock system, which recently passed through full acceptance testing, is self-contained and features multiple inbuilt redundancy measures and monitoring software to maintain system health levels. Servicing is required only once every two years, streamlining its maintenance. With the inclusion of this advanced technology, Australia's defense force solidifies its commitment to the JORN surveillance system, propelling the nation's worldwide reputation.

The Cryoclock technology is just the start of the innovative products being developed at QuantX Labs. QuantX Labs is now considering options to scale down the size of the Cryoclock system by reducing the size of the cryostat system and integrating strip-line electronics, making the technology more compact and attractive to commercial markets and expanded export opportunities. Additionally, the Australian Space Agency has recently announced AUS\$4M in funding to QuantX Labs to develop its next-generation optical atomic clock, to be launched into space as early as 2025. This project will showcase some of the most advanced quantum technology ever launched into space. This high-performance clock delivers capability that can be utilized for numerous high value objectives. Examples include enhanced autonomy and navigation in deep space or acting as an alternate source of network time synchronization for defense and commercial assets vulnerable to GPS-denied scenarios. [www.quantxlabs.com](http://www.quantxlabs.com)