ICV TAnK

Quantum Clock

Market Research Report

March 2023

Introduction

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The clocks and watches that people usually use have an error of about 1 minute per year with high precision, which has no effect on daily life, but more accurate timing tools are needed in demanding production and scientific research.

At present, the quantum clock is the most accurate timekeeping tool in the world, which provides a strong guarantee for astronomy, navigation, and space navigation.

The International System of Units (SI) defines the second as the time, it takes a cesium-133 atom in a precisely defined state to oscillate exactly 9,192,631,770 periods.

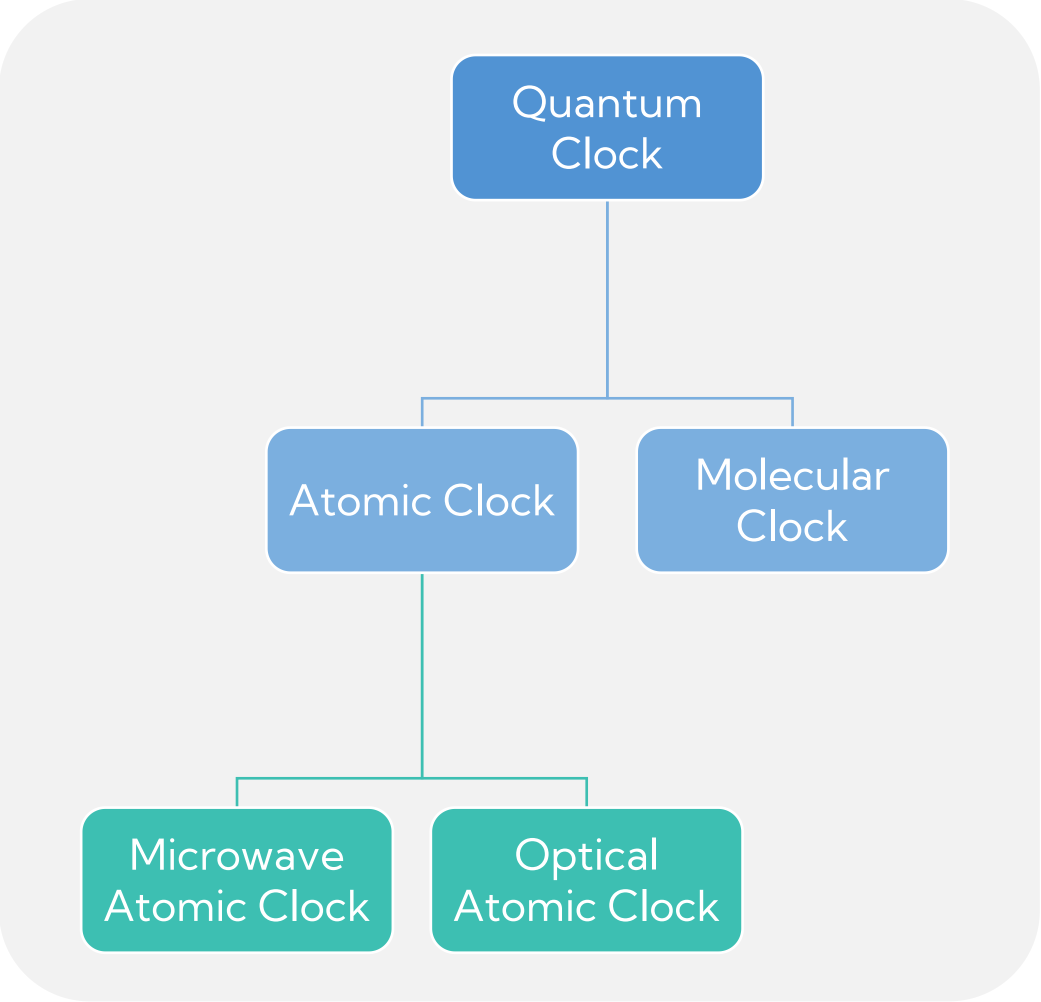
On the time scale, frequency standards worldwide can basically be divided into the following categories:

	Ticker	Counter
Earth's orbit	$yr^{-1} \approx 32$ nHz	Calendar
Pendulum clock	1 Hz	Escapement, gears
Quartz watch	2^{15} Hz	Microchip
Microwave atomic clock	10^{9} Hz	Electronic oscillator
Optical atomic clock	10^{15} Hz	Frequency comb

Categories of Quantum Clocks

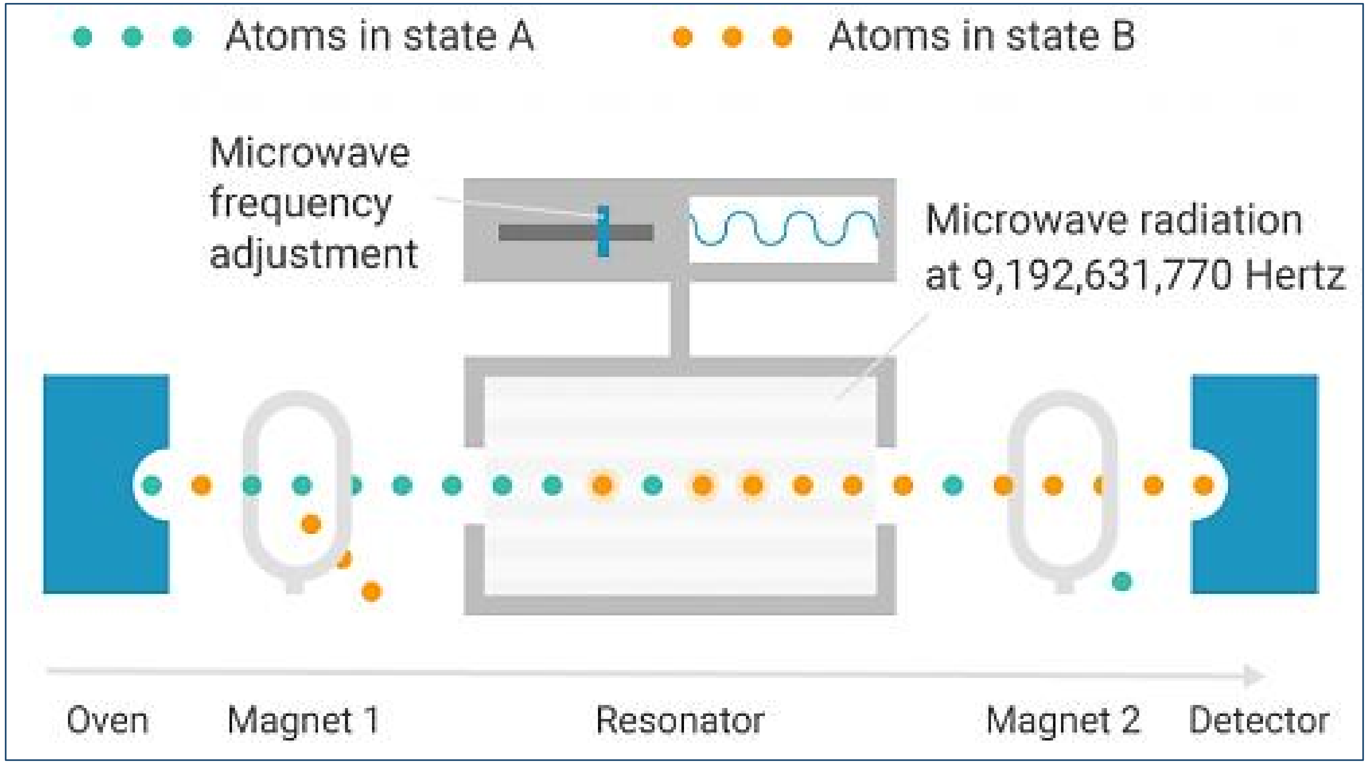
Research on atomic clocks is shifting from the microwave frequency band to the optical frequency band. Because the optical frequency is 4 to 5 orders of magnitude higher than the microwave frequency, the uncertainty accuracy of the optical atomic clock will be better than that of the microwave atomic clock under the condition of the same transition spectral line width. At the same time, chip-scale molecular clocks(CSMC) have also made new research and commercialization progress. Chip-scale atomic clocks(CSAC) are also mature and commercially available.

Microwave atomic clock, optical atomic clock and molecular clock are the three current categories of quantum clocks.



How Quantum Clock Work (1/2)

The principle process of the microwave clock is shown in the figure below:



Sources: The inner workings of an atomic clock, Schematic drawing of an atomic clock at Timeanddate

Optical atomic clocks are similar in structure to microwave atomic clocks, including a wave-emitting shaker, a wave-counting detector, and an atomic control unit for adjusting the oscillator when out of sync.

The frequency of the laser is much higher than that of the microwave, and the biggest difference is that the microwave oscillator is replaced by an ultra-stable laser. The laser oscillation frequency is too fast to be read electrically, so an optical frequency comb is required.

How Quantum Clock Work (2/2)

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There are many different types of atomic clocks, but they generally share the same basic working principle, which is described below:

1 Heat, Bundle, and Sort

First, the atoms are heated in an oven and bundled into a beam. Each atom has one of two possible energy states. They are referred to as hyperfine levels, but let's call them state A and state B.

A magnetic field then removes all atoms in state B from the beam, so only atoms in state A remain.

2 Irradiated and Count

The state-A atoms are sent through a resonator where they are subjected to microwave radiation, which triggers some of the atoms to change to state B.

Behind the resonator, atoms that are still in state A are removed by a second magnetic field. A detector then counts all atoms that have changed to state B.

3 Tune and Measure

The percentage of atoms that change their state while passing through the resonator depends on the frequency of the microwave radiation. The more it is in sync with the inherent oscillation frequency of the atoms, the more atoms change their state.

The goal is to perfectly tune the microwave frequency to the oscillation of the atoms, and then measure it. After exactly 9,192,631,770 oscillations, a second has passed.

Sources: How Does an Atomic Clock Work, Konstantin Bikos , Timeanddate

Market Prediction

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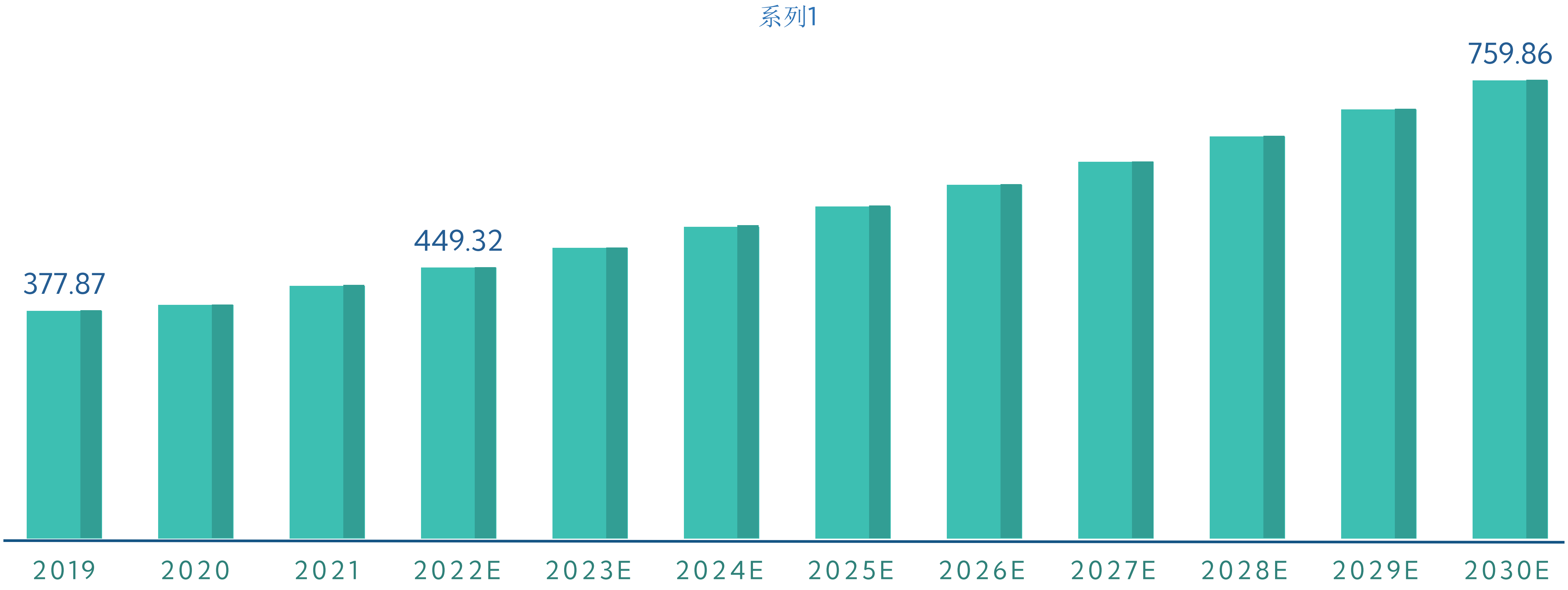
Quantum Clock Market Size（2019-2030E)

(Unit: Million U.S. dollars)



Market Share & Industry Analysis (1/2)

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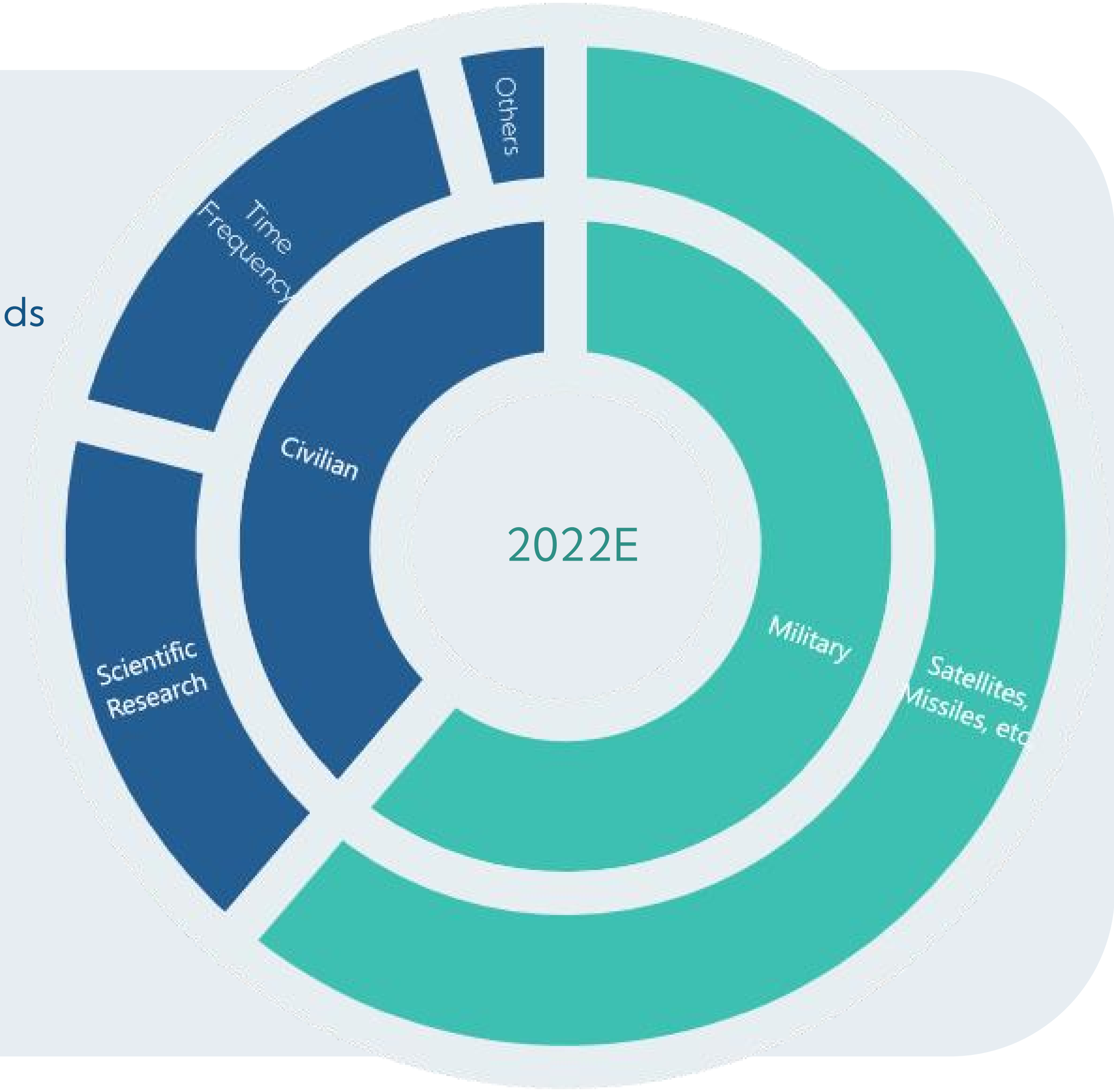
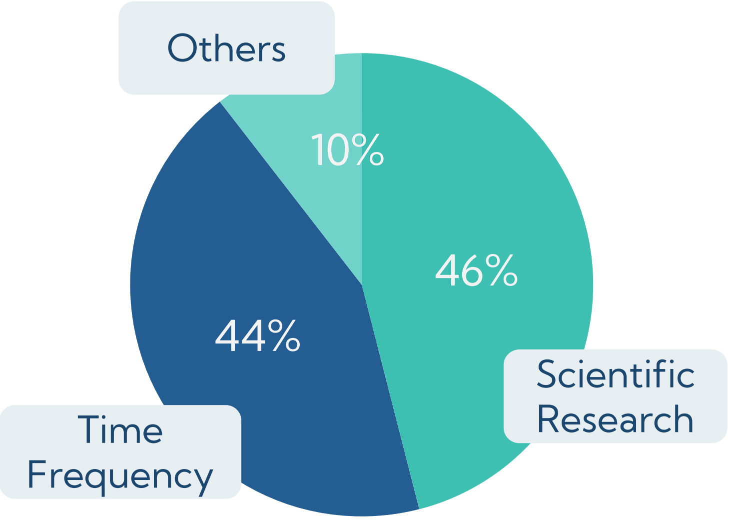
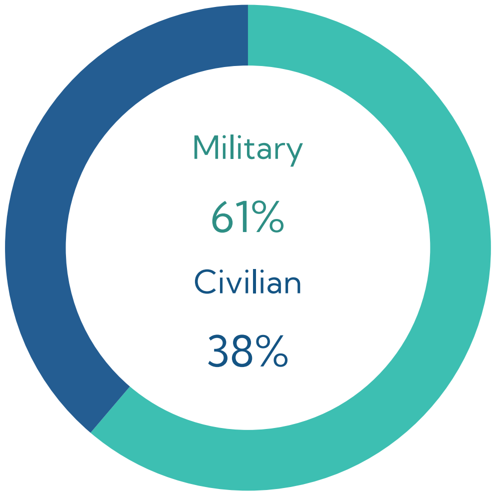
The application fields are classified as:

Military

Civilian







Market Share & Industry Analysis (2/2)

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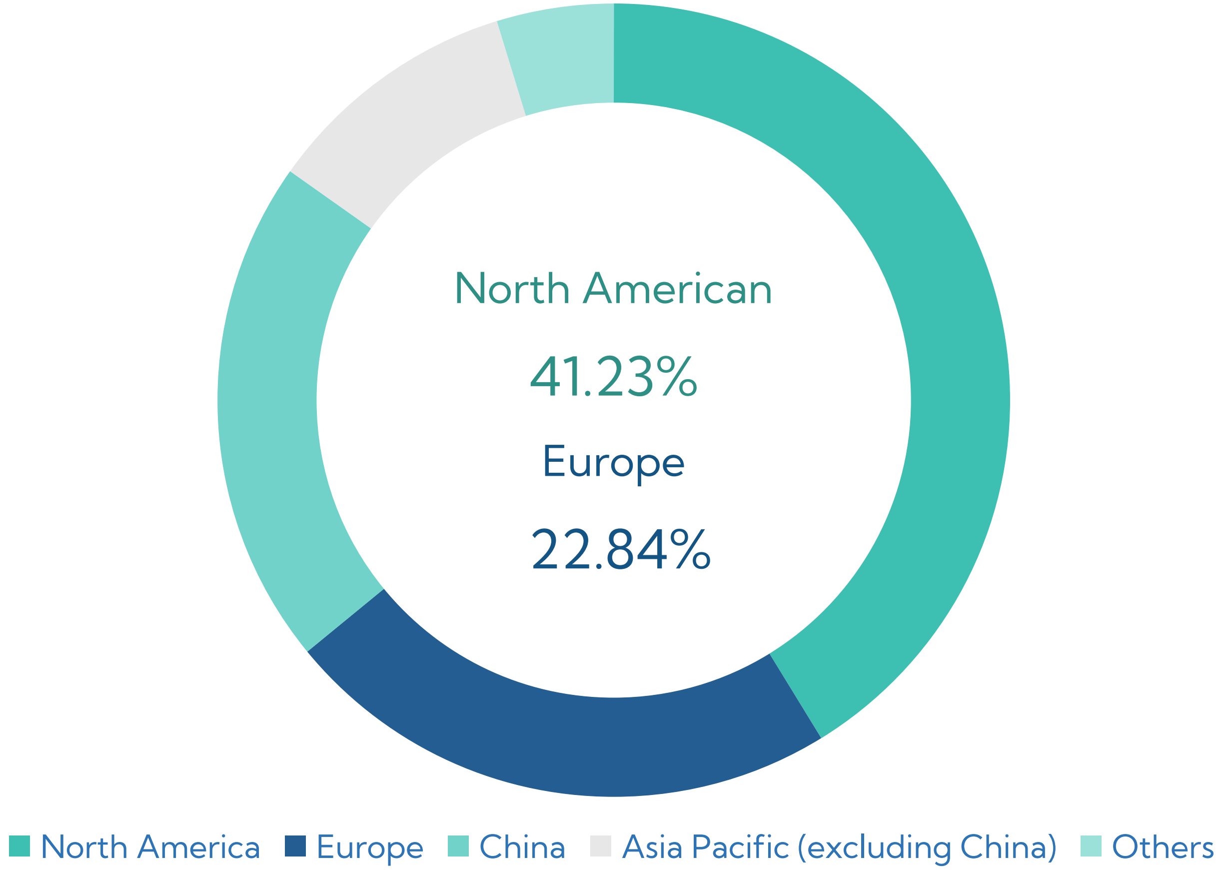
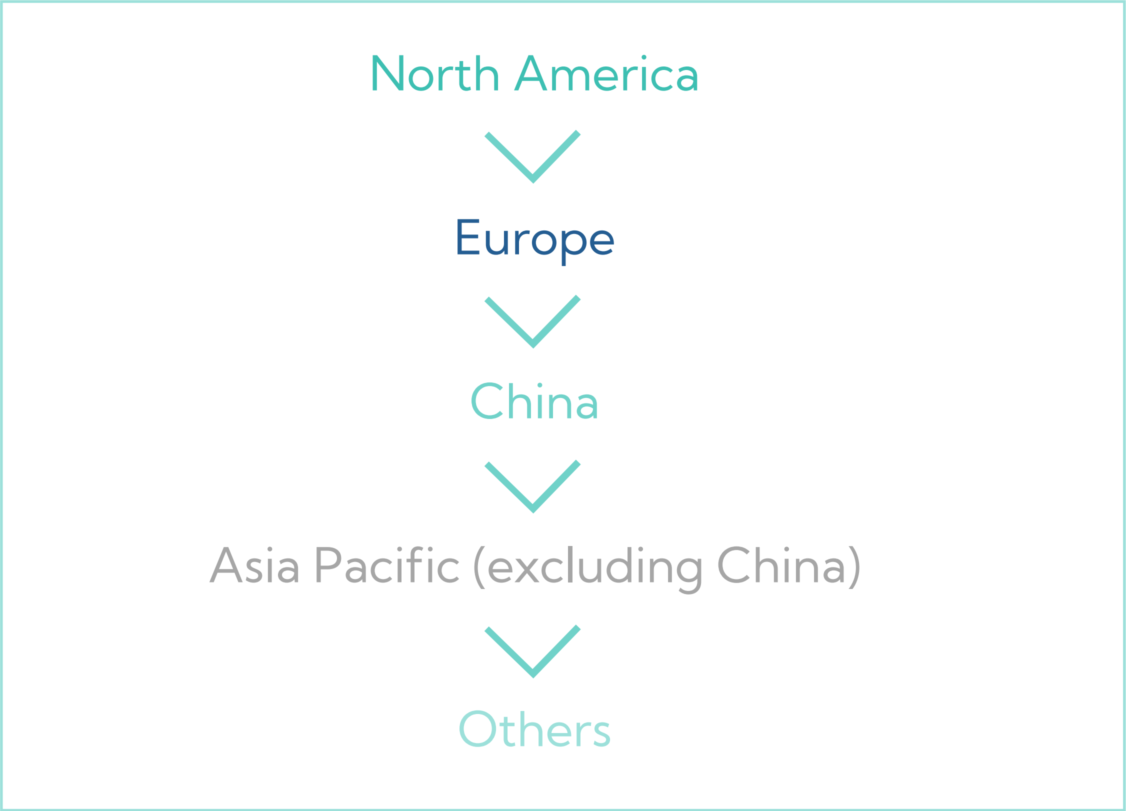
Regions
(2022E)



Regions are divided into North America, Europe, China, Asia Pacific (excluding China) and others.



Key Players

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	Microwave Atomic Clock	Optical Atomic Clock	Molecular Clock
North American	Microsemi (USA) AOSense (USA) Symmetricom (USA) Stanford Research Systems, Inc. (USA) Frequency Electronics, Inc (USA)	NIST (USA) JILA (USA) UA (USA)	-
European	Oscilloquartz SA (Switzerland) KVARZ (Russian) VREMYA-CH (Russian) AccuBeat Ltd (Israel) SpectraTime (Switzerland)	PTB (Germany) Max Planck Institute (Germany) INRiM (Italian) SYRTE (France)	-
Asia Pacific	Elecspan (China) Xhtime (China) Sync-tech (China)	NIM (China) NTSC (China) WIPM (China) SICM (China) KRISS (South Korea) Tokyo University (Japan) NMIJ (Japan) NICT (Japan) UWA (Australia)	Zhongweidaxin (China)

Table of Contents

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We bring together the deepest intelligence across the widest set of capital-intensive industries and markets. By connecting data across variables, our analysts and industry specialists present our customers with a richer, highly integrated view of their world.

That is the benefit of The New Intelligence. We are able to isolate cause and effect, risk andopportunity in new ways that empower our customers to make well-informed decisions with greater confidence.

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