Preface

Since the publication of the first edition of this book in 1998, the realm of optical frequency measurement has opened up with the development of extremely broad band frequency combs extending over a full octave on the frequency scale. This has enabled the direct coherent calibration of the frequency of an optical clock with respect to the microwave Cs standard. This continues at an accelerating pace the revolutionary changes that the field of frequency and time measurement has undergone in recent years, with regard both to its precision and particularly to its extension to include optical frequencies.

What began as the introduction of techniques to cool atoms and ions through interaction with suitable laser beams, coupled with methods of particle suspension in ultra-high vacuum, has been carried forward to an astonishing degree with ultra-sharp resonances being observed at optical frequencies on *individual* ions stored in ultrahigh vacuum for extended periods of time. This brings us to the point of the ideal first expressed by Dehmelt of making observations on isolated atomic particles at rest in space. This was the author’s own motivating principle in the initial experiments on a field-confined mercury ion standard for space applications. The rapid progress in the stabilization and synthesis of optical frequency signals using solid-state sources has brought about unprecedented degrees of long and short term stability, with the prospect of developing a new generation of space-hardened optical clocks. The implementation of a satellite global navigation system, the Global Positioning System (GPS), is the most visible example of the enormous impact that atomic frequency standards have had on the civilian and the military sectors of society. The crucial elements in this system are the spacecraft atomic clocks, without which it could not exist. It has become very much part of our culture permeating many aspects of our life and technology. The cesium and rubidium clocks aboard the satellites maintain submicrosecond synchronization, putting the accuracy of position determination globally in the submeter range!

As with the first edition, the object is to convey a broad understanding of the physical principles underlying the workings of these quantum-based atomic clocks, with introductory chapters placing them in context with the early development of mechanical clocks and the introduction of electronic time-keeping as embodied in the quartz-controlled clocks. While the book makes no pretense at being a history of atomic clocks, it nevertheless takes a historical perspective in its treatment of the subject.

Intended for non-specialists with some knowledge of physics or engineering, *The Quantum Beat* covers a wide range of salient topics relevant to atomic clocks, treated in a broad intuitive manner with a minimum of mathematical formalism. Detailed descriptions are given of the design principles of the rubidium, cesium, hydrogen maser, and mercury ion standards; the revolutionary changes that the advent of the laser has made possible, such as laser cooling, optical pumping, the formation of "optical molasses," the cesium "fountain" standard, as well as topics that bear on the precision and absolute accuracy of standards, such as noise, resonance line shape, and the relativistic Doppler effect. Also included are the time-based global navigation systems: Loran-C and the Global Positioning System, as well as tests of invariance principles and symmetry in fundamental unified theory, such as the constancy of physical "constants" such as the fine structure constant in atomic physics, and tests of Einstein's Equivalence Principle.

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Severna Park, Maryland, USA F.G. Major
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Major, F.G.
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