Ruling the Waves

Think about coherent systems, and odds are that the first example to cross your mind will be a laser: a device that emits monochromatic light homogenized so that the photons propagate with their phase in lockstep. The well-defined wavefront of the laser beam makes it possible to focus the light to spot sizes on the order of the wavelength of the light without the aberrations usually observed with the random wavefront of incoherent light. The well-defined phase also provides a medium capable of storing and carrying information more efficiently than the intensity-modulated signals typical of incoherent sources. These useful properties of coherence have made lasers almost ubiquitous in science and technology, and that "almost" is shrinking by the day.

In general, coherence comes about when individual components of a system act in unison, either in phase or with a fixed phase difference between the components. More accurately, the system can be described as a local oscillator whose wavefunction contains phase and amplitude terms that define how the system evolves in space and time. The collection of articles in this special issue describes the recent progress and developments of coherence in optical, atomic, and semiconductor systems, and how manipulating that coherence may lead to useful applications and to experimental systems for studying the elements of quantum mechanics.

Since the first demonstration of the laser in 1960, progress in improving the extent of the spatial and temporal coherence of laser light has been steady. Psaltis (p. 1359) reviews developments in optical coherence and highlights examples of the key role coherence has played in applications in imaging, communication, and information processing and storage. Just as lasers revolutionized the field of optics, many researchers have high expectations that other coherent systems will provide similar advances in their respective fields. Exploiting the fundamental tenet of quantum mechanics whereby particles have the properties of waves, Kasevich (p. 1363) reviews coherence effects in collections of cold atoms and describes how the shorter wavelengths associated with atoms and the recent accessibility of bright coherent atom sources may lead to precision measurements beyond anything currently available to the optical regime. For integration and potential applications, the ideal system would be based in semiconductors. Snoke (p. 1368) describes recent work toward the formation of coherent semiconductor systems.

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With coherence in the atomic and optical systems generally comprising macroscopic systems, Mabuchi and Doherty (p. 1372) look at coherence effects at the quantum limit, probing the interactions between single atoms and single photons confined to high-quality cavities. In addition to providing invaluable information on the limits of quantum mechanics, such effects might also shed new light on information science in the quantum regime.

The section opens with a pair of News features by staff writers Charles Seife and Robert Service. Seife presents a smattering of common applications that scientists and engineers have found for coherent waves, whether in light, sound, or subatomic particles. Service describes efforts to create new coherent sources of the type of radiation known as "hard" x-rays—a long-sought range of high frequencies with enormous potential for scientific research, technology, and medicine.

—IAN OSBORNE AND ROBERT COONTZ

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Manipulating Coherence

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