The Communications Frontier Between Classical and Quantum Physics

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MAN'S sophisticated art of communications has been built upon his ability to generate and detect coherent electromagnetic waves. This art has been pushed to higher and ever higher frequencies, until now important experimental work is being carried on in the neighborhood of one millimeter wavelength.

At this point, however, we seem to have arrived at a barrier. The physical dimensions of vacuum tubes and diodes have been reduced to the limits of practicality, and there is little hope that further progress can be made with these devices. On the other hand, the field has been greatly stimulated by the advent of new concepts of generating, amplifying, and detecting radiation by maser and mavar[1] processes. These concepts offer promise of extending coherent wave techniques into the infrared and optical ranges. It is too soon to say what uses will be made of this part of the spectrum, but there is little doubt that coherent radiation will prove as powerful a tool at these frequencies as it has at lower frequencies. At the moment, however, we stand at a scientific frontier which challenges us with a number of stimulating questions.

What kind of a frontier is this? It might be called an infrared frontier, but this is only true in a narrow sense. It is also the frontier between coherent and incoherent waves. In the broadest sense, it is the frontier between classical and quantum physics.

In the past, classical physics succeeded well with most of the processes involving man-made, coherent radiation. When dealing with natural radiation produced by the random, incoherent emissions of individual atoms and molecules, the statistical approach of quantum mechanics was necessary. Since the two fields seldom overlapped, the fact that they employed different languages was of no great importance.

The comfortable separation which has existed between these two disciplines in the communication field is now dissolving. Masers use the paramagnetic moments of individual atoms to produce coherent waves, and quantum mechanics is the language used to describe their behavior. Ferrites also can produce coherent waves by means of atomic magnetic moments, but because these moments are strongly coupled so that they operate in a coordinated manner, their behavior is best described classically. The only real distinction between the two processes is the presence of the coupling forces. It is becoming very important, then, to break down the barrier between the languages of classical and quantum physics so that physicists and radio engineers can translate freely.

It might be argued that, in the future, radio engineers should learn more about quantum physics. This is certainly true, but it is not enough. The language of quantum physics involves the mathematical formalism of selection rules and density matrices, but it is lacking in the tangible physical pictures of atomic processes which the radio engineer would like to have. In the development of quantum theory, the demand for physical models of complex atomic processes often has seemed hard to fulfill. Useful results could be obtained by sidestepping the models and relying entirely on abstract mathematical symbolism. By now, it is frequently assumed that because the detailed mechanism of atomic processes cannot be absolutely determined, it is futile to seek physical understanding of them. The writer does not believe this. On the contrary, it is important to develop a physical understanding of quantum theory to the fullest extent possible.

This is necessary in order that the knowledge given to us by quantum theory may be fully exploited. The researcher, interested in ferreting out new facts of nature, may be content when he is able to express nature's processes in compact mathematical form, even though such a description may bring no physical understanding. But mathematics is primarily an analytical tool. It can express quantitative relationships, but it cannot tell how to use them to make something new and useful. This requires an act of creative imagination. And while there may be individuals who can create within a framework of mathematical symbolism, they are rare. Most inventors can create effectively only when they have a "physical feel" for the processes they are conjuring with.

As an illustration, it is not sufficient to know the power and frequency relations between the pump and the signals in a ferrite mavar or a ruby maser in order to build an operative microwave amplifier. It is also necessary to know what polarizations of waves will be absorbed and emitted by the atomic reactors when magnetized and pumped in given directions, and how these polarizations can be coupled to the electromagnetic modes of a cavity or waveguide. Thus, a considerable knowledge of spatial relations is necessary, and these can best be remembered and visualized if a physical model is available.

Finally, the attempt to find a physical interpretation of mathematical results has in many instances produced an improved understanding of basic physics.

Since the merging of quantum techniques and microwave techniques appears to be the coming thing, work in this field is particularly challenging today. The accumulated knowledge of atomic physics can be more quickly put to work in creating new devices for communications if a concerted effort is made to bridge language barriers and improve our physical understanding of quantum processes.

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[1] Also called variable reactance amplification, parametric amplification.