Values of $x$ are typically 0.2 to 0.4. Furthermore, (AlGa)As is unique in that the size of the basic unit in the (AlGa)As crystal lattice is nearly independent of the amount of aluminum, a factor that allows great flexibility in the process of fabrication.

A form of solution growth called liquid phase epitaxy (LPE) has turned out to provide a way to fabricate (AlGa)As heterojunction laser diodes. A molten gallium solution containing the requisite amounts of aluminum, arsenic, and appropriate doping impurities is slowly cooled, and excess (AlGa)As precipitates onto the substrate in a sufficiently orderly manner to build up crystalline layers.

By 1970, scientists had reduced the threshold current for lasing to the neighborhood of 1000 amperes per square centimeter. Since then, interest in making long-lived room-temperature CW laser diodes has become worldwide. The principal subject of this interest has been how to achieve long lifetimes reproducibly. The earliest lasers often failed because of catastrophic destruction of the cleaved mirror faces by the high photon densities in double heterojunction laser diodes (10 milliwatts of laser light corresponds to a power density of up to 1 megawatt per square centimeter). The catastrophic mode of failure has not been a big problem with CW lasers, however, because much less optical power is produced. The problem with CW lasers is that the intensity of the laser light tends to gradually decrease with time. When the light intensity is too low to sustain lasing, the laser shuts off.

*Speaking of Science*

# Weisskopf on the Frontiers and Limits of Science

Victor Weisskopf is a physicist's physicist and something of a Renaissance man. Both of these talents were displayed in a recent talk in which he celebrated the scientific world view and yet raised a humanistic note of caution as to the limits of its applicability. Weisskopf predicted, in effect, that science may eventually explain all observable phenomena and yet remain incomplete, and he criticized exclusively rational views of human experience by comparing them to medieval religious excesses.

Weisskopf's career has spanned two continents, including graduate study in Europe under Wolfgang Pauli and wartime work on the U.S. atomic bomb project. He has been director of the European Center for Nuclear Research (CERN) near Geneva, Switzerland, one of two Americans to have held the post, and was on the faculty of the Massachusetts Institute of Technology from 1945 until his retirement last fall. By avocation he is a pianist of near-professional competence, and he has a broad interest in many aspects of literature, philosophy, and international relations. In retirement, he has continued to write and lecture. The address he gave to the American Academy of Arts and Sciences* reflects his growing concern that science has lost its human anchor, that both its critics and many of its practitioners have lost sight of the relationship in which science properly stands to human affairs.

Man, Weisskopf notes, has been curious about the world since the beginning of culture, but it was only about 500 years ago that a more focused and limited version of that curiosity began to result in what we now call science. According to Weisskopf, it was the renunciation of immediate contact with absolute truth and the investigation of particular phenomena that created a framework for understanding the natural world. The growing discovery that nature is indeed comprehensible led to a world view—what Weisskopf calls "the scientific myth of the universe"—that in its twentieth century version depends heavily on a description of matter derived from quantum mechanics. Thus matter is composed of atoms, and atomic phenomena—encompassing chemistry, biology, geology, and most naturally occurring phenomena on earth—are essentially electric in character. These phenomena exemplify for Weisskopf the internal frontier of science, in which the basic principles (the coulomb force and the quantum mechanical selection rules) are believed known but understanding is limited by the complexity of phenomena. The external frontier, on the other hand, includes subnuclear physics and astronomy, where the fundamental principles are still unknown.

*V. F. Weisskopf, *Bull. Am. Acad. Arts Sci.* **27**, 15 (March 1975).

Weisskopf is hugely optimistic that the frontiers of scientific knowledge will continue to recede. He believes that "it is reasonable to predict that man will eventually understand all of nature scientifically"—all observable phenomena. But he qualifies this sweeping claim by asserting that scientific insights will not cover every aspect of human experience. For example, "one can understand a sunset or the stars in the night sky in a scientific way, but there is something about experiencing these phenomena that lies outside science." Quoting Wittgenstein and the Swiss philosopher Fierz, Weisskopf goes on to develop the point that science does not always illuminate the most important aspects of human experience, that there are limits to the scientific world view. Indeed, he believes that overemphasis on the scientific way of thinking can be dangerous in that it leads to the neglect of other modes of experience, and he draws an analogy to religion in the Middle Ages. "The religious and the scientific emphases have each released creative forces, but as one-sided approaches, both have also produced serious abuses. In the Middle Ages, one can point to the Crusades and to the complete neglect of corporal suffering; in our time there has been overrationality with respect to definitions of the quality of life and political decisions and an excessive concern with the production of material goods."

It is to this overemphasis of the scientific approach and the corresponding neglect of modes of experience captured in art, music, and literature that Weisskopf assigns the blame for much of the current prejudice against science and technology and for the rise of such pseudosciences as astrology and ESP—"perverse" forms that are, he claims, the result of natural urges suppressed because "the scientific approach is considered the only 'serious' way of dealing with human experience."

It is an uncompromisingly humanist manifesto, and one that carries all the more force coming from a scientist of Weisskopf's stature. In an interview, Weisskopf said that he does not wish to be considered a spokesman for Carlos Castaneda, Theodore Roszak, or other antirationalist critics of science. But he did acknowledge that a connection exists between the narrowness and specialization of graduate training and research practice in the sciences today and the problems they, and he, have addressed. "Specialization has made of the rational method a profession and not an avocation," was how he put it. Many "professional" scientists may wish to disagree with Weisskopf's diagnosis, but they might do well not to dismiss it out of hand.—ALLEN L. HAMMOND