PREFACE*

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ONE hundred and fifty-nine years ago, while moving a thermometer through the sun's spectrum, the astronomer Sir William Herschel found that the temperature recorded by the thermometer increased from violet to red and then continued to increase, reaching a maximum in the dark region beyond the red end of the visible spectrum. Thus was discovered the "infra"-red region of the electromagnetic spectrum. For more than one hundred years little use was made of infrared energy, largely because of the lack of a suitable detector. The detection problem can be understood from the fact that a modern wide-range infrared detector, the thermocouple, must often detect radiation which causes a temperature rise of only one-millionth of a degree with a resulting electrical signal of less than one billionth of a volt; the infrared radiation, being incoherent in nature, cannot be amplified through the use of resonant circuits such as are commonly employed with the coherent radiation in the radio portion of the electromagnetic spectrum.

Despite the discovery in 1917 by T. W. Case that thallous sulfide is photosensitive in the infrared, little practical use was found for this radiation outside the laboratory. Then, early in World War II, captured equipment revealed that the Germans were using infrared for secret signalling between infantry groups, for the surveillance of Russian tanks supposedly secure in the darkness, and for the detection of Allied night bombers which confused radars by the use of chaff. This was the turning point in the practical application of infrared to military problems. At about the same time, the American synthetic rubber program required rapid analysis of the C_4 fraction in butadiene production; since this could best be achieved through infrared spectroscopy, commercial infrared spectrophotometers for chemical analysis began to appear in 1943. This was the turning point for the commercial application of infrared. Also at this time, Dr. Robert J. Cashman of Northwestern University developed a design and a sensitizing treatment for thallous sulfide that resulted in a detector which was both simpler and more rugged than previous cells. The practical application of infrared radiation was now assured.

The physical basis for the military interest in infrared is simply that any object at a temperature above absolute zero (and every object is), having an emissivity greater than zero (and every object has), radiates electromagnetic energy, much of which is in the infrared. Thus all objects, ranging from heavenly bodies to jet aircraft to human beings, are natural radiators of invisible infrared energy, and can thereby be detected by means of passive instrumentation which does not reveal the presence of the observer. Add to this the facts that infrared detection is virtually jamproof, as contrasted with radio and radar, that many military targets are copious emitters of infrared, that infrared systems are far smaller, lighter, less complex and less expensive than comparable radar systems, and that the shortness of infrared wavelengths permits resolution far higher than that attainable even with our highest-resolution radars—and the military interest becomes obvious. An example often quoted is that whereas an X-band (3-cm) radar, with a 12-inch-diameter antenna and at a range of 5 miles, can resolve two twin-engine aircraft as separate targets if they are laterally separated by at least 1 mile, at the same range an infrared system working at 2 microns (0.002 mm) and using a 3-inch-diameter scanner can resolve individual engines on each aircraft.

Commercial interest in infrared stems not only from this natural emission, but also from the fact that the spectral absorption bands of most molecules lie in the infrared. Thus the selective absorption of infrared radiation by molecules reveals their presence and structure.

The development in production quantities during the past decade of new photoconductive detectors such as lead sulfide and lead selenide, which are both highly sensitive and fast in response, and of suitable optical materials, has led to an enormous growth in the commercial and military applications of infrared. Several hundred industrial and military organizations now include infrared research, development, and production in their programs. In industry, several thousand infrared spectrophotometers are being employed for the nondestructive and quantitative identification of chemical and biological unknowns, and this application is only in its infancy. Infrared is also being used in the automatic monitoring of chemical and biological processing, in temperature measurement and control in the manufacture of textiles, plastics, and metals, in fire and incipient-explosion detection, and in weather research. Future civilian applications are being developed in navigation, altitude determination, collision-avoidance systems, ground-speed indication, automatic landing systems, and in astronomy and various outer-space projects.

Ever-increasing military use for infrared is being found in surveillance, early warning and detection, photography and aerial mapping, search, acquisition and track, secure communications, missile guidance, fire control, fuzing, decoying, and countermeasures.

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Despite the major current and anticipated activity in the infrared field, there is at present no unclassified American publication which brings together in one place the bulk of the basic information on infrared physics and technology. The PROCEEDINGS OF THE IRE appears to be a highly appropriate journal in which to publish a review of the infrared field, inasmuch as the field is substantially a marriage of optical physics and electronics. An attempt has been made to present here as comprehensive a review of the subject as security restrictions will allow. The material has been prepared under the auspices of the Infrared Information Symposia (IRIS), an organization sponsored by the Office of Naval Research and under joint-service direction. The IRIS organization sponsors a continuing series of classified symposia devoted to the military applications of infrared. The symposia are designed to facilitate the exchange of technical information, on a "need to know" basis, among the many government laboratories and industrial contractors engaged in infrared research, development, and production. The papers presented at the symposia are published in the classified journal entitled *Proceedings of IRIS*, which is distributed to all members of IRIS and to such others as establish the required need to know.

It may be of interest to mention here, as being representative of the difficulties encountered in fields other than infrared, the factors which led to the creation of IRIS. In the years immediately following World War II, the military infrared program was severely handicapped by the inadequate facilities for the exchange of information, such exchange being effected at best only with delay and through the exercise of considerable persistence and inquisitiveness. The flow of information was restricted to such an extent that certain contractors were not even aware of the existence of almost identical efforts being conducted by certain other contractors. These difficulties were not occasioned primarily by the need for military security, but stemmed rather from the lack of rapport between the different cognizant branches of the armed services, institutional rivalries, the desire of commercial concerns to keep secret their own technical procedures, and the absence of unifying meetings and reports. Such needless barriers were a real impediment to the military program, resulting in the duplication of effort from ignorance of parallel efforts, and slowing the advance of science and technology which thrive on the cross-fertilization of ideas.

In an effort to alleviate this situation, the Office of Naval Research, which has the responsibility for the coordination of research and development within the Naval establishment, in 1949 undertook the creation and sponsorship of the IRIS organization. IRIS meetings, now held bimonthly on alternate coasts, are attended by hundreds of scientists and engineers who gather together to discuss freely their problems and achievements in the classified areas of infrared. By publishing in the *Proceedings of IRIS*, these men have the opportunity of presenting their results to a relatively wide audience and of benefiting from the constructive criticism which such publication engenders. In substance, the IRIS organization affords those employed in this classified area the opportunity for discussion and publication which is afforded in unclassified areas by organizations such as the Institute of Radio Engineers and the American Physical Society. As a result, these scientists and engineers, though engaged in classified work which formerly entailed confining procedures and oppressive secrecy, now may again enjoy the feeling of "belonging" to the scientific community, with many of the benefits that society membership provides. The consequent improvement in the attitudes of these scientists and engineers and in the quality of their efforts cannot help being reflected in achievements beneficial to the missions of the military services.

Holding membership in IRIS are all the leading investigators in the field of military infrared; it is for this reason that the material in the following pages, prepared by these men, can be regarded as current and authentic. The difficult task of procuring, reviewing, and coordinating the material submitted by the many authors has been handled with high competence by the various section editors, whose efforts are gratefully acknowledged. Special acknowledgment must be made of the contribution of Dr. Stanley S. Ballard, whose responsibility it was to coordinate the over-all effort.

It is hoped that this presentation of the physics and technology of infrared radiation will furnish engineers with the necessary background for understanding the field, and will provide them with a foundation for further study of this rapidly growing science, which appears to be only on the threshold of its full realization.