

## Infrared Technology—Part 2

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IR systems drive IR technology development: We want to build more powerful IR instruments that detect fainter signals and resolve smaller details. The IR portion of the electromagnetic spectrum covers a wide wavelength band: from about 1 to 1000  $\mu\text{m}$ . This region is limited at the shorter wavelength end by the response of the human visual system. At the longer wavelength end, it is defined by the detection process. The far-IR region is referred to as the microwave region when microwave techniques of signal guiding and mixing are used in the detection process.

An IR system is generically very similar to any other optical system. IR technology was developed to address the component and material needs specific to imaging and detection in the IR. Figure 1 shows a representative IR instrument and its block diagram. Its basic components include an optical system for light collection and, often, imaging; a detector that functions as a transducer of IR energy into an electrical signal; signal-conditioning electronics that often reconstruct the signal to increase the SNR; an image processing module that improves the image; and finally a display that presents the detected and enhanced image in a form suitable for human decision making.

The potential sources of IR photons are also illustrated in Fig. 1. The illumination source shines light on the object and the ever-present background, both in the field of view of the optical system. The intervening medium, often an atmo-

sphere, generates its own signature and attenuates the signal traveling through it. Other sources of IR photons are the physical components comprising the instrument itself. They emit IR radiation because they are at a finite temperature. Additional electrons are generated in the detector and in the signal-conditioning electronics due to their finite temperature. We choose to define the signal as that portion of the detected radiation that comes from the object of interest and is imaged according to the imaging criteria defined in advance; everything else is noise. We often design IR systems and instruments to maximize the SNR.

Significant progress in detector technology in the last few years has resulted in the detection of sources emitting just a few IR photons. Although this may be good news to the scientist interested in photon counting, it is not good news to the IR system designer. Sensitive detectors detect not only very faint signals, but also very faint noise in the form of stray light from the off-axis sources outside and inside the instrument. Stavroudis and Foo apply their thorough knowledge of geometrical optics to design a complicated and, what looks like, perfect baffle system to prevent a ray of stray light from falling on the detector. Thermal emission from the instrument parts represents a noise that may be decreased with a careful baffle design for all instrument components except those seen directly by the detector. For a standard telescope, such as that used in an IR observatory facility, Scholl points out that the

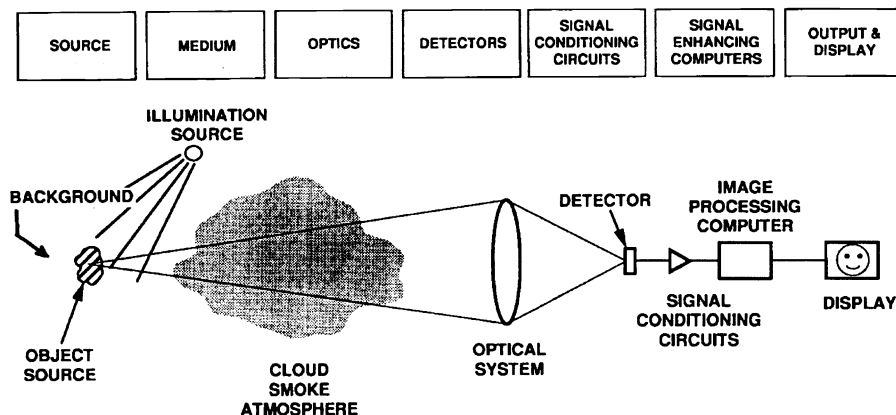


Fig. 1 A representative IR system and its block diagram.

most critical thermal emitter is the secondary mirror assembly. Its temperature and temperature stability are determined by the magnitude of the faintest signal to be detected.

The visible wavelength region remains a benchmark for us because we are locked in the visible world: we see the diffraction pattern as formed by the visible light, and we specify the quality of optical surfaces in terms of (the number of waves of) visible light. Parks shares with us some of his insights on the fabrication of IR components. The surface finish in terms of absolute height may indeed not be as critical in the IR region as it is in the visible; however, materials that transmit at longer wavelengths have different mechanical and physical characteristics requiring unique fabrication and polishing techniques. Physical phenomena prominent at longer wavelengths differ from those observed in the visible range. Wang and Scholl investigate diffraction patterns produced by apertures of wavelength dimensions. They find that the traditional scalar Fresnel/Fraunhofer and the geometrical theory of diffraction fail to explain the measured intensity patterns.

Progress in detector technology development is reported by three groups of investigators. High-temperature superconductivity, the most exciting new discovery in physics in the last few years, led to the development of a new field of superconducting detectors. Their detection concept and potential are described by Bluzer and Forrester. Kozlowski et al. report that traditional HgCdTe detectors continue to play an important role in the detection of IR radiation. The performance objective for these established detectors has changed: good responsivity is obtained even at elevated temperatures (up to 180 K). Lin et al. summarize their research on SiGe/Si heterojunction internal photoemission IR detectors.

The emergence of 2-D IR imaging arrays spurred the development of techniques to test their performance and to present their output in a format suitable for human processing. Varela and Boreman present a scanned-fringe, spatial-harmonic-distortion test to assess detector nonlinearity. Lettington and Hong incorporate an image processing scheme into a detector data processing system so that it also functions as an interpolator for IR images.

The detection of IR signals has often relied on postprocessing. Signal reconstruction can be rather simple, as when phase-sensitive detection is used for chopped radiation, or more complicated, as when reticles are designed to enhance a specific image feature. Olsson describes a sophisticated image processing scheme to deconvolve images of an optical system incorporating special-purpose reticles.

SNR may be improved by using detectors with increased sensitivity and by increasing the signal integration time. Therefore, the limiting performance of an instrument depends to a high degree on our ability to keep its platform still during the exposure time. Theoretical work by Bayard and Boussalis on the dithering of the control gains in a periodic fashion leads to a method for deadbeat control that holds the instrument platform perfectly still.

Improved performance of IR systems is the ultimate test of the state of the art in IR technology. Successful design and development of an IR instrument results in deployment to collect data more accurately, compare measured data with the model predictions, and hopefully develop better models to

describe the physical universe. Devir et al. report on the results of experimental investigation on the water continuum in the near-IR region to assess the presence of water molecule clusters in dimers.

Imaging cameras remain the primary instruments for surveying the IR skies. Multispectral coverage is possible by introducing transmission filters to delineate different wavelength bands. Cesarsky et al. describe the IR imaging camera to be used on the Infrared Space Observatory (ISO). This IR observatory facility is scheduled for launch in 1995.

A good practice in instrument design is to incorporate component testing prior to assembly, and system calibration and testing after assembly. Perault et al. describe the calibration facility and preflight characterization for the imaging camera on the ISO. Steimle and Wang describe the design and performance of an interferometer adapted for use in the near-visible IR.

While data are being collected with instruments incorporating old technology, next-generation instruments are being designed incorporating the advancing state of the art in IR technology. Aumann and Pagano exploit detector technology to design a high-spectral-resolution IR spectrometer to determine temperature and humidity distribution in the Earth's atmosphere. Lamarre describes a next-generation IR observatory facility concept. This IR telescope facility, planned for launch early in the 21st century, will be ready to incorporate recent technology developments in IR and cryogenic temperature control to detect the faintest and most distant IR sources.

The quality of a refereed journal depends on both the authors and the reviewers. The authors receive deserved recognition when their manuscripts are published. Referees are responsible for maintaining the journal standards by providing critical feedback to the authors. It is, once again, my pleasure to thank the scientists and engineers who served as anonymous referees. This is an incomplete list; most of the authors in this special section also served as reviewers, sometimes for several manuscripts.

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I wish to conclude with a reflection on my favorite renaissance man: His achievements in engineering, building machines of war, architecture, sculpture, and painting are so numerous that his skills as an optical scientist are usually left unmentioned. Yet, his ability to observe the world in dynamic motion, to assess the distance of the hills by the shades of their greens and blues, required a knowledge of optics that he was not willing to share. Leonardo Da Vinci even chose to employ optical science to encode his secret diaries.

His diaries demonstrate an intuitive knowledge and a deep understanding of the physical world based on his relentless observations. It is often said that this man for all seasons was centuries ahead of his time. It has even been claimed that Leonardo described the phenomenon of diffraction, one among many subjects on which he briefly focused his perceptive eyes. However, he chose not to publish it.

So, five centuries later, we look at his diaries and drawings that seem just like the drawings of other great men of optical science, and we wonder whether we should rewrite the books to give Leonardo more of the deserved credit. He gave us great art: he recorded an enigmatic, indescribable smile, and he captured the tense situation of an impending, unavoidable betrayal. However, if he indeed had the knowledge, he did not

share it with the rest of humanity. He had his own good reasons for being miserly. He made a decision not to add to the body of scientific knowledge. He allowed us to toil through the labor of repeating his work and the pleasure of rediscovering the beauty of optics.

Unlike the rest of us, Leonardo cannot claim that his scientific discoveries went unpublished because the reviewers did not understand.

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**Marija S. Scholl** completed high school in 1969. She earned the BS and MS degrees in physics in 1972 and 1974, respectively. Initially, she performed research on magnetic lenses. Dr. Scholl received the MS and PhD degrees in optical sciences from the University of Arizona, specializing in IR. She also earned a MS degree in engineering from the University of California at Los Angeles. As an engineering manager for

Rockwell International, Dr. Scholl was responsible for optics technology issues and diagnostics for high-energy IR lasers. While a staff scientist for the Sperry Corporation, she developed a 1500-pixel  $\times$  1500-line color projection display system for digital maps and path planning. As a senior scientist at the Jet Propulsion Laboratory, Dr. Scholl worked on novel concepts for autonomous planetary exploration. She applied optical processing techniques to autonomous navigation, landing, and vision functions. She also developed a star-field identification technique to allow an intelligent camera to determine its orientation in inertial space for autonomous optical navigation. Additionally, she taught undergraduate optics at the University of Southern California and radiometry and IR system design at the University of LaVerne. Currently, Dr. Scholl is a senior scientist at Alenka Associates. She is also serving as a topical editor for *Applied Optics* for IR optics. Dr. Scholl is a member of SPIE, the Optical Society of America, the American Association for the Advancement of Science, and Sigma Xi, and a former member of IEEE, the Electro-Chemical Society, and the American Physical Society.