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NASA TECH BRIEF

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Developments in Spectrophotometry I: An Instrument for High-Resolution Measurements of Optical Intensity and Polarization

Spectroscopy is the study of the interaction of light or other electromagnetic radiations with matter. By measuring the properties of light passing through a sample, information may be obtained about the chemical and physical properties of the sample. Spectrophotometers are used for this purpose by researchers in most all scientific fields, and they have applications in environmental studies such as pollution analysis and meteorology.

This is one of four NASA Tech Briefs describing new developments that extend the accuracy and capabilities of optical spectrophotometers for studying the composition and properties of gases, liquids or solids, in the laboratory or remotely as is often required for pollution studies. These developments should be of interest not only to researchers and engineers but also, because of their wide-ranging applications, to manufacturers in many industries.

This Tech Brief describes a high-resolution spectrophotometer/polarimeter that has the resolution required to analyze the polarization of the spectra of unknown gases, liquids, or solids (or a mixture of these phases). Such resolution has not been available in conventional instruments (photopolarimeters).

The two mechanisms that influence the characteristics of radiation emerging from a sample are absorption of the radiation in the sample and scattering of the radiation. The relative importance of these two mechanisms depends on the particular sample, but for both mechanisms the characteristics of the emerging light vary with frequency. If the measurement resolution is high enough, an examination of the integrated polarization within a spectral line and the polarization at other frequencies can yield valuable information about the composition, structure, and properties of the sample.

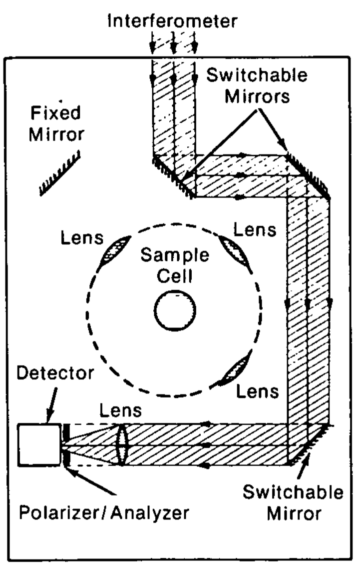

Figure 1. Reference-Beam Path

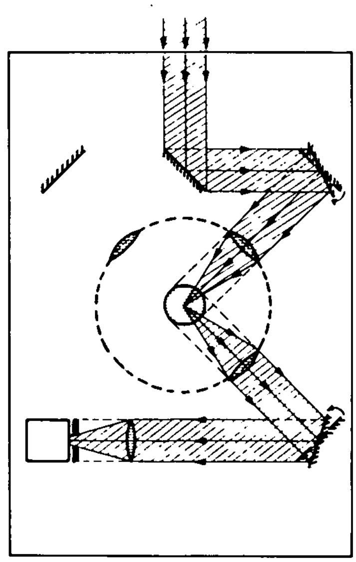

Figure 2. Reflection-Beam Path

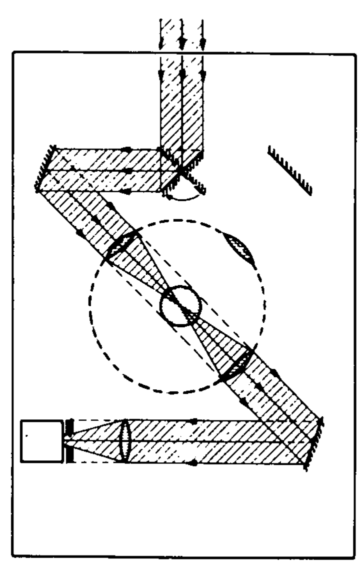

Figure 3. Transmission-Beam Path

(continued overleaf)

The version of the spectrophotometer/polarimeter described here was developed for use in the laboratory and can measure optical intensity and the complete polarization state (degree of polarization, orientation of the plane of polarization, and ellipticity of the polarization ellipse). The high resolution is achieved by basing the instrument on a Fourier interferometer that is optically coupled to a vacuum chamber containing a radiation detector, a linear polarizer/analyzer, a sample cell, and a system of lenses and moveable mirrors for directing the path of the output beam of the interferometer (see figures).

One of the key features of this instrument is the minimal number of components used, including the symmetrical arrangement of paired mirrors to eliminate, by compensation, polarization effects that occur when a beam is obliquely reflected from a planar surface. The intensity and state of polarization of a beam are measured before and after being reflected and transmitted by the sample. This is done by taking a series of nine interferograms: one at each orientation of the polarizer/analyzer (0°, 45°, and 90°) for each of three beam paths (reference, transmission, and reflection).

The different paths are obtained by switching the mirrors as shown in the figures. The Fourier interferometer is a standard two-beam amplitude-division instrument such as a Michelson interferometer. The light source can be polarized or unpolarized, and the sample cell is a transparent cylinder with its vertical axis passing through the common focal point of the three lenses. In front of the detector is a single, linear, polarizer/analyzer that has been adapted so that its transmission axis azimuth can be oriented at angles of 0°, 45°, and 90° to the incoming beam.

Notes:

1. Further discussion may be found in:
   a. "An Interferometric Approach to the Measurement of Optical Polarization," by A. L. Fymat and K. D. Abhyankar, Applied Optics vol. 9, May 1970, p. 1075
   b. "Interferometer-Polarimeter," by A. L. Fymat and K. D. Abhyankar, U. S. Patent No. 3,700,334, 24 October 1972
   c. "Interferometric Spectropolarimetry: Alternate Experimental Methods," by A. L. Fymat, Applied Optics, vol. II, November 1972, p. 2255
   d. "Astronomical Fourier Spectropolarimetry," by F. F. Forbes and A. L. Fymat, in Planets, Stars and Nebulae Studied with Photopolarimetry, ed. T. Gehrels, University of Arizona Press, January 1974, p. 637
2. Other recent developments in spectrophotometry that may be of interest to readers of this Tech Brief are found in:
   a. NASA Tech Brief B75-10333, Developments in Spectrophotometry II: A Multiple-Frequency Particle-Size Spectrometer
   b. NASA Tech Brief B75-10335, Developments in Spectrophotometry III: Multiple-Field-of-View Spectrometer To Determine Particle-Size Distribution and Refractive Index
   c. NASA Tech Brief B75-10338, Minimization Search Method For Data Inversion
3. Requests for further information may be directed to:

   Technology Utilization Officer
   NASA Pasadena Office
   4800 Oak Grove Drive
   Pasadena, California 91103
   Reference: TSP75-10332

Patent status:

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its development should be addressed to:

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Categories: 03 (Physical Sciences)
04 (Materials)