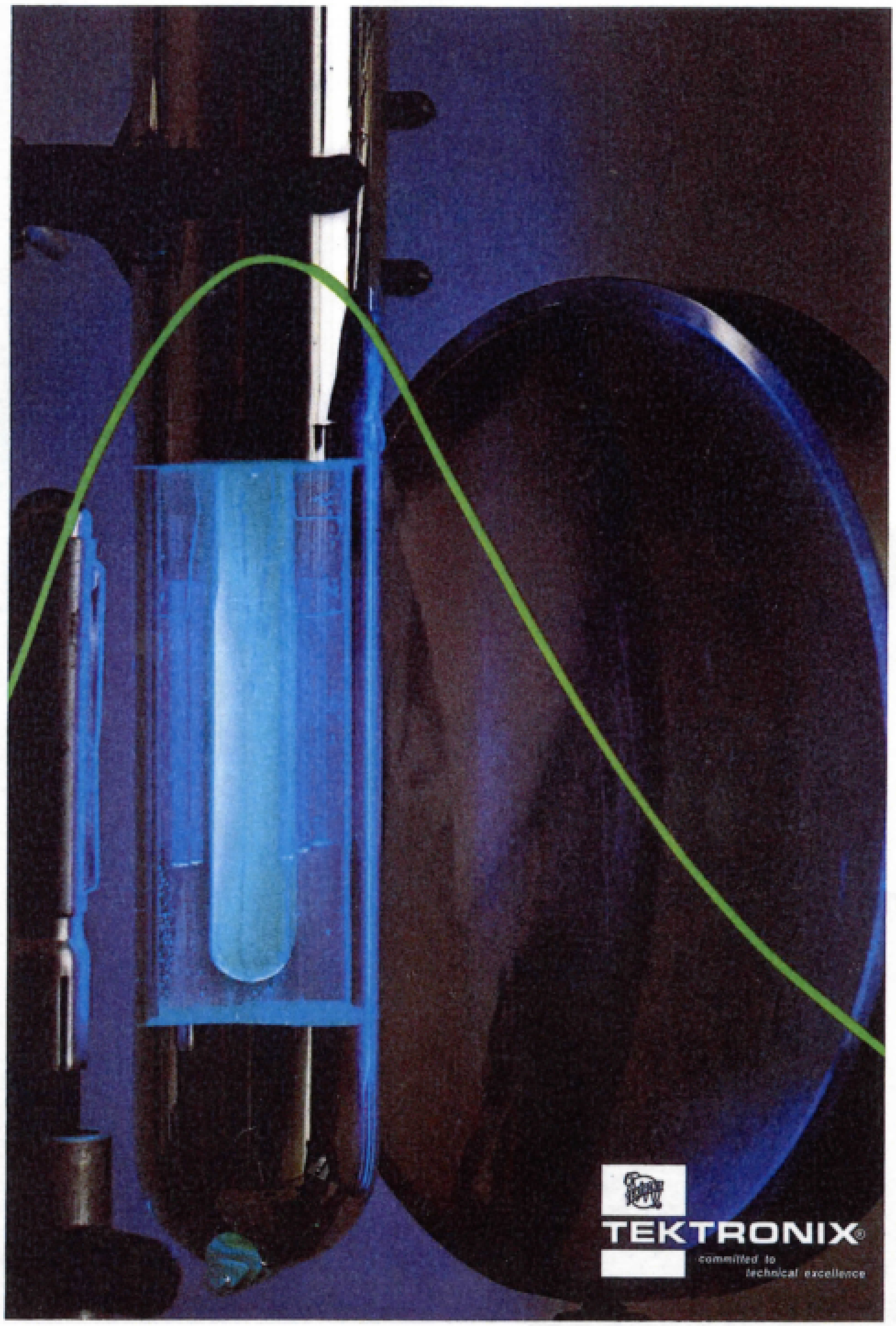
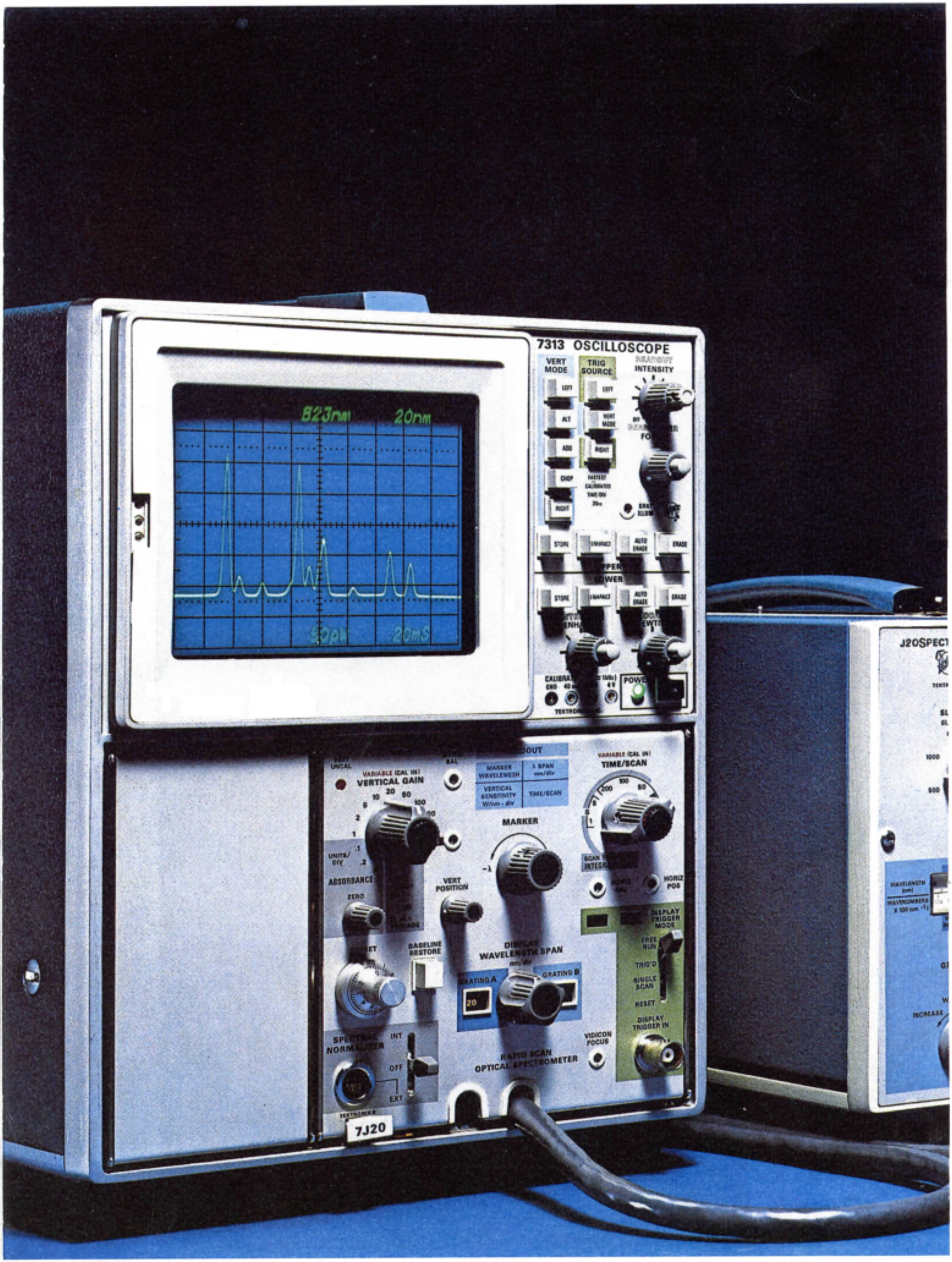
TEKTRONIX RAPID SCAN SPECTROMETER




7313 OSCILLOSCOPE
VERT MODE
TRIG SOURCE
INTENSITY
823nm
20nm
STORE
ERASE
VERTICAL GAIN
TIME/SCAN
MARKER
ABSORBANCE
VERT POSITION
BASELINE RESTORE
DISPLAY WAVELENGTH SPAN
GRATING A
GRATING B
DISPLAY TRIGGER MODE
FREE RUN
SINGLE SCAN
RESET
DISPLAY TRIGGER IN
VIDICON FOCUS
SPECTRAL NORMALIZER
RAPID SCAN OPTICAL SPECTROMETER
7J20

A NEW CONCEPT IN REAL-TIME SPECTROSCOPY

Rapid scan spectroscopy is concerned with the observation and measurement of dynamic optical events. To measure such an event, one must be able to follow and record spectra that are evolving rapidly with time.

The TEKTRONIX Rapid Scan Spectrometer (RSS) offers this capability in a new, versatile, and convenient form.

The RSS can measure and record spectral information of dynamic events with millisecond durations. But performance does not stop there. Spectral information can be gathered over a wide range—400 nm scanned as rapidly as 100 times a second—and displayed instantly for convenient examination.

A spectral range from 250 to 1100 nm permits observations extending from UV to the near infrared region. Radiometric calibration allows measurement of radiant power as a function of wavelength. Spectral absorption may be measured in terms of transmittance or absorbance.

The RSS is a compact, lightweight, rugged instrument consisting of a spectrometer, an oscilloscope, and an oscilloscope plug-in. The system requires a surprisingly small amount of bench space and may be moved about the laboratory or in the field without need for recalibration.

The high performance and versatility of the RSS result from the application of a unique silicon vidicon detector in the spectrometer. Light, dispersed by a Czerny-Turner monochromator, is focused onto the vidicon target, which gathers spectral data at all wavelengths simultaneously. The spectral information is then electronically scanned from the target, and the resultant signal (intensity-wavelength data) displayed on the cathode ray tube of the oscilloscope.

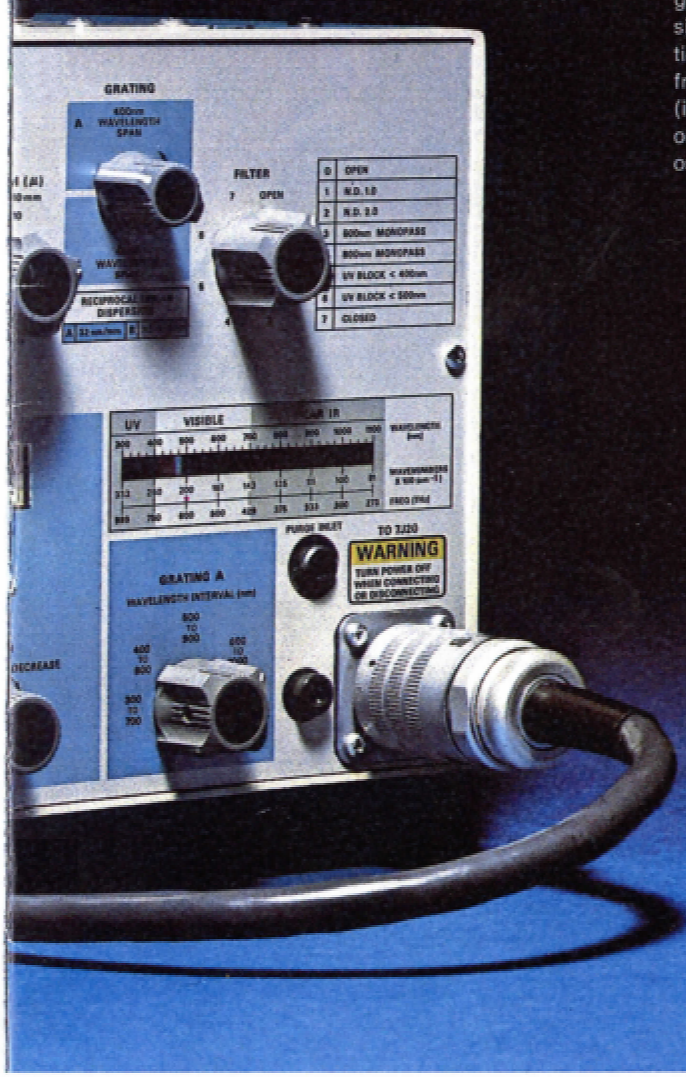
This method of electronic scanning and display provides the RSS with true variable rapid-scanning capability without mechanical movement to effect the scanning. Two modes of scanning (normal repetitive and integrate mode) are provided which fully realize the potential of the silicon vidicon as a spectral detector, offering the user a selectable trade-off between time-resolution and sensitivity.

The electronic plug-in provides an interface between the spectrometer and any TEKTRONIX 7000-Series Oscilloscope. The plug-in contains circuitry for signal processing and amplification for display on the oscilloscope CRT.

Use of a TEKTRONIX 7000-Series Storage Oscilloscope contributes benefits unique to the RSS. Spectral waveforms are displayed instantly on the CRT screen and retained until no longer needed.

Spectral areas of interest are quickly and accurately identified with a unique movable wavelength marker spot. The corresponding wavelength and primary instrument settings appear in digital form on the oscilloscope screen. This information is automatically recorded, along with the spectral curve, by means of a TEKTRONIX Oscilloscope Camera.

Computer treatment of spectral data is provided by the TEKTRONIX 7000-Series Digital Processing Oscilloscope, which can be made an integral part of the RSS system.



MEASURE IN REAL-TIME

The TEKTRONIX Rapid Scan Spectrometer is truly a versatile and powerful research tool in chemistry, physics, biology, and electro-optics.

Several factors combine to produce such versatility. The RSS offers a trade-off between time-resolution and sensitivity, allowing measurement of rapidly changing spectral events (chemical kinetics) or sensitive detection of weak sources (molecular luminescence). Such a trade-off is not possible with any kind of non-integrating detector, and is not available on any other instrument.

The balancing of sensitivity and time resolution is achieved by means of a unique selection of scan modes of the vidicon, taking full advantage of the signal-storage property of the target and the ability to scan the target rapidly.

In many instances, the RSS offers the great convenience of monitoring a spectrum for on-line inspections or screening experiments without the need for reams of chart paper or hard copy of any kind. A working window of 400 nm over the 300 to 1100 nm spectral range provides essentially continuous information over a large spectral region. The sensitivity of the vidicon to light in the near infrared (800 to 1100 nm) opens up opportunities for research in these areas. The detectors commonly used in this region are either cooled photomultipliers or sensitized spectrographic plates, all requiring careful and time-consuming technique. The RSS is equally easy to use in all of its spectral regions. The 1000 nm line of mercury is easily detected.

A detector system sensitive over a wide dynamic light range allows measurement of sources with the intensity from that of lasers and electric arcs to the glow of phosphors.

The cover of this brochure depicts the use of the RSS for measurement of molecular luminescence. An organic compound contained in a quartz sample tube was excited by UV light. Subsequent relaxation to ground state emitted radiation in the form of phosphorescence (long-lived luminescence). The spectral curve has been superimposed over the picture of the sample.

Most phosphorescent decays can be followed by the RSS for analysis of lifetimes if they are in the millisecond range. The spectra of fluorescences can be easily recorded, but their decay is too fast for dynamic studies. The observation of molecular luminescence is useful in chemical spectroscopy as well as quantitative analysis.

The RSS is ideally suited for use in stopped-flow kinetics as a method of following the course of a chemical reaction optically. The photo to the right shows an example of spectral information gained during observations of a chemical reaction. A family of curves (stored on the CRT screen) has resulted from repetitive scanning of the mixture of chemical reactants. A fiber optic bundle was employed to convey the transmitted light to the entrance slit of the spectrometer.

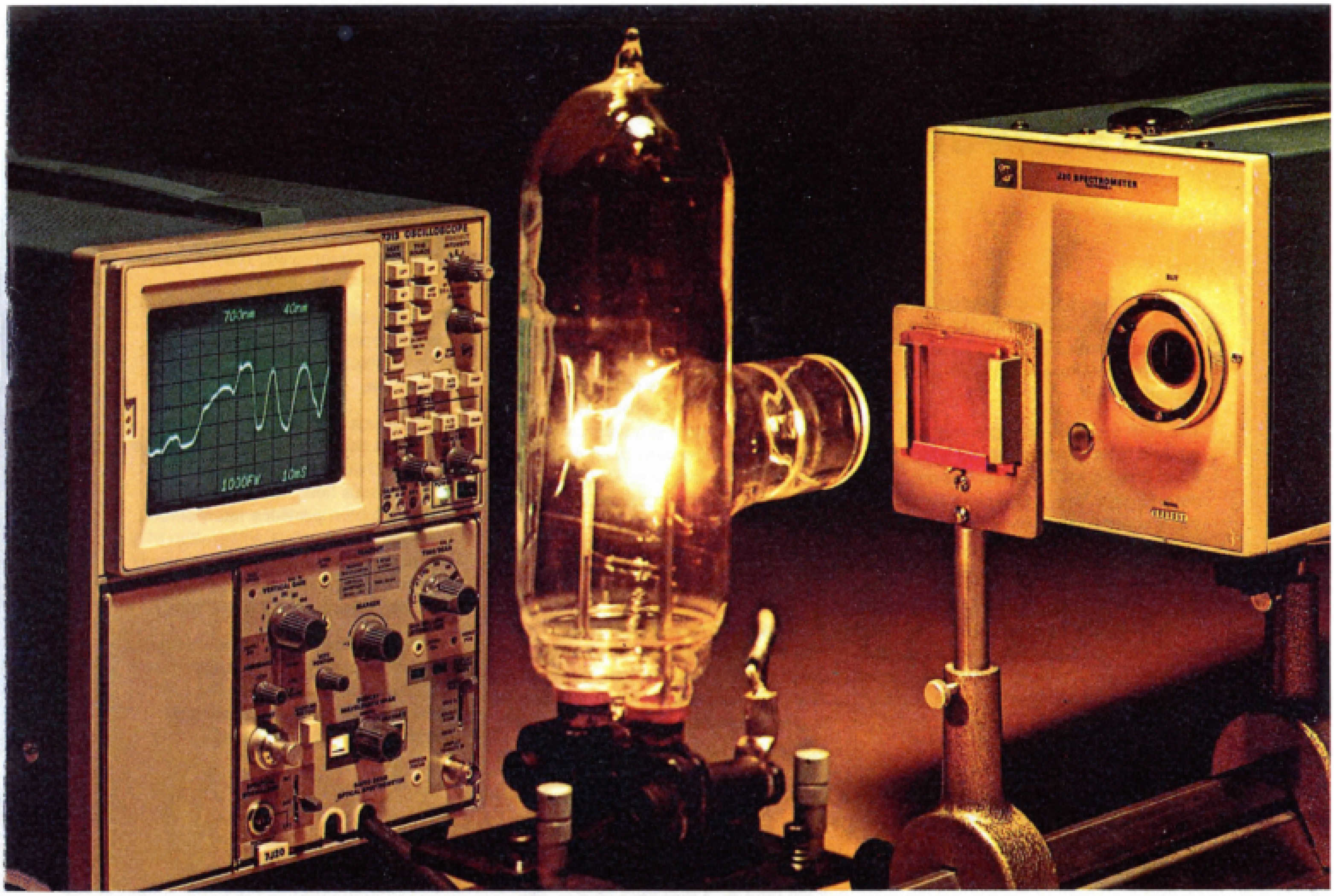
An external spectral correction accessory can be used with the RSS to adjust the shape or response of the displayed spectral range, such that the spectrum of a continuous light source (quartz-iodine) is a flat line. The spectral window is divided into 20 segments by 19 controls, which allows the user to make the necessary adjustments. Such a flat display makes measurements of transmittance much easier by making the "%T per division" constant across the screen.

With the RSS, changes in transmittance over a broad wavelength range can be determined in one experiment. This greatly enhances the ability to observe spectral shifts or intermediate absorptions that would be missed when following a chemical reaction at a fixed wavelength.

Although optimized for high-speed kinetic studies, the RSS performs very well as a general-purpose laboratory instrument.

Broad spectral measurements can be made rapidly and conveniently for rapid screening of multiple sample studies in the laboratory—along with conventional absorption and emission measurement.

Other applications include comparison and sorting of products such as phosphors, lamps, light emitting diodes, and optical filters (pictured to the right). The fast response of the instrument opens up the possibility of automated on-line examination and acceptance or rejection of any number of light-emitting, absorbing, or reflecting components.



...AND THEN ADD A COMPUTER

Combine the speed and accuracy of computer processing with the measurement capabilities of the TEKTRONIX RSS, and you have a truly powerful analytical tool.

The RSS provides an extremely fast method for acquiring spectra which are often times quite complex. It is only natural, then, that a complete analytical system should not only acquire spectral information, but should also process that information into a usable form—answers.

Such a system is possible with the TEKTRONIX Digital Processing Oscilloscope. The major point relevant to the Digital Processing Oscilloscope is this: any waveform which can be displayed on the CRT can be digitized for processing. In addition, any digital information ordinarily displayed by the CRT Readout is automatically known to the computer.

The marriage of RSS and computer is accomplished by the TEKTRONIX P7001 Processor. This unit becomes an integral part of the TEKTRONIX 7704A Oscilloscope, and is located between the Display Module containing the CRT screen and the Acquisition Module containing the 7J20 Plug-In. The computer is a Digital Equipment Corporation PDP-11-05. Measurement software optimized for waveform processing completes the system.

In order to permit use of the full capabilities of the Digital Processing Oscilloscope, new software programming capabilities have been developed. The computer language BASIC was chosen as the starting point because it is a simple, easily learned, general purpose programming language that uses statements closely resembling simple English and Algebra.

Spectral data may be computer processed at the press of a button using your own tailored programs. The range of possible measurements is almost unlimited.

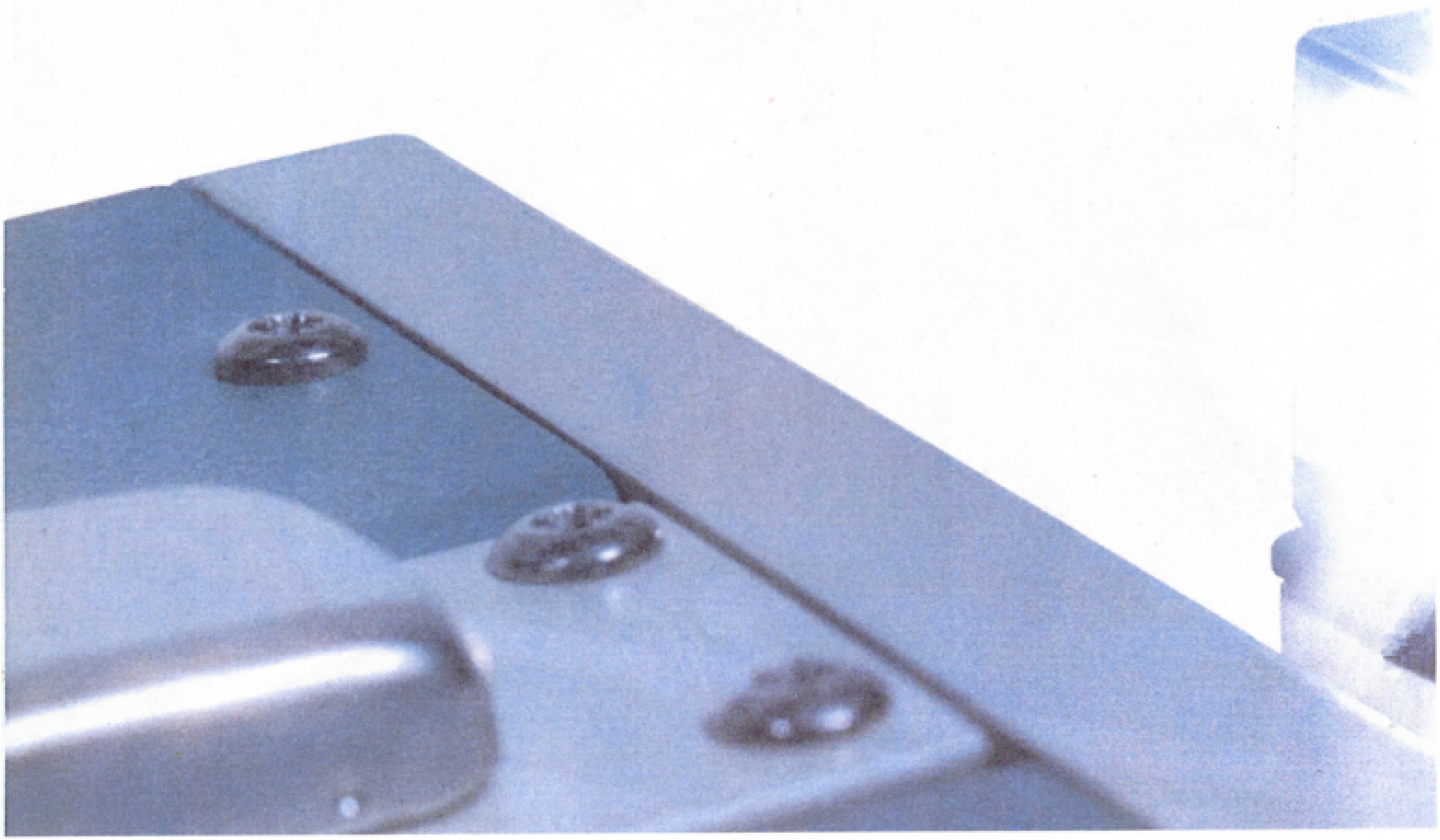
The application depicted here pertains to the analysis of the spectral output from a photographic flash cube. The instrumentation consists of the J20 Spectrometer, the 7704A Digital Processing Oscilloscope containing the 7J20 Plug-In, a timebase plug-in, the PDP-11 Computer, and the TEKTRONIX 4010-1 Computer Terminal.

Assume you wish to know the change of spectral intensity at particular wavelengths with respect to time. In our example, the waveforms consist of 10 successive spectra of light output from the flash cube. The spectra are displayed along the CRT horizontal axis at 5 millisecond intervals. The RSS signal is processed as follows:

The composite 50 ms waveform is stored, representing 10 scans of power versus wavelength from 400 to 800 nm.

At the touch of a front panel button, 400 nm is selected from each of the 10 scans and displayed as 10 points of power versus time. The touch of another button provides interpolation between the 10 points. Integration of the signal then provides a graph of energy versus time at 400 nm. These operations can then be repeated every 10 nm.

All displays are stored in the computer. This information can be displayed in digital or graphical form on the CRT of the Computer Terminal using a simple keyboard instruction.



RSS IN PRINCIPLE

Light, from the source under investigation, passes through the entrance slit and is dispersed by a Czerny-Turner monochromator with two interchangeable gratings. A grating reflects and disperses each wavelength of light at a different angle and directs the array to a second mirror, which focuses the spectrum onto the target of a silicon vidicon. This spectrum is composed of adjacent images of the entrance slit.

Depending upon the grating used, either 40 or 400 nanometers of the spectrum are focused onto the vidicon. The precise region of the spectrum observed can be varied by moving the gratings.

The vidicon has a specially designed target consisting of an array of photo diodes. The diodes in the array have the ability to store positive charges as the result of an optical signal. The target contains enough resolution elements to permit simultaneous observation of all wavelengths in a reasonably large portion of the spectrum. As light hits the target, an electric charge proportioned to the incident intensity is stored locally. The resultant pattern of electric charges (analogous to the incident optical spectrum) is stored across the face of the target area. To recover this information, a focused electron beam scans across the back of the vidicon target.

As the electron beam passes over a diode and discharges it, the resulting signal represents the integration of all optical signals that have impinged upon that diode since the last sweep of the electron beam.

The silicon vidicon, therefore, has an integrating property whereby "scanning off" of the charge may be delayed until light from a weak spectral source has had sufficient time to produce adequate charge for a usable signal. The target current is monitored, amplified, and transmitted by means of an inter-connecting cable to the oscilloscope plug-in.

The silicon vidicon offers advantages as a detector for the RSS. Since the entire spectrum to be scanned is imaged on the vidicon and is scanned by an electron beam, there are no moving parts to affect the scanning. The problems associated with mechanical inertia are eliminated. Problems of nonreproducible baselines, brought about by multiple mirror reflectance mismatch and differential aging, are eliminated. With the storage property of the target, it is possible to record spectral events occurring on a time scale that is short with respect to the fastest scan time. The time resolution of the spectrum for a picosecond flash could not be followed, but no spectral information would be lost.

RSS IN FACT

The TEKTRONIX Rapid Scan Spectrometer consists of three parts: (1) the J20 Spectrometer, (2) a TEKTRONIX 7000-Series Oscilloscope, and (3) a 7J20 Oscilloscope Plug-In. The following pages describe the optics and electronics that make the system work.

J20 SPECTROMETER

The J20 Spectrometer is a compact unit containing the Czerny-Turner monochromator, silicon vidicon, and circuitry necessary to transform a selectable portion of the spectrum into an electronic signal. This signal is subsequently amplified, further processed, and displayed on the CRT of the oscilloscope. The controls located on the spectrometer provide convenient and precise selection of optical settings.

SLIT WIDTH—Eight interchangeable, fixed slit widths are provided, allowing the user to optimize between resolution and sensitivity.

FILTER—An 8-position switchable filter wheel is included in the optical path, containing filters that permit high light level applications, eliminate second order UV spectra, and provide ability to rapidly check wavelength calibration.

GRATINGS—Two switchable gratings allow the user to select a 400 nm or 40 nm window to be focused on the vidicon.

GRATING A—Selects a low dispersion grating, giving a 400 nm window switchable in five steps from 300 to 1100 nm.

GRATING B—Selects a high dispersion grating, giving a 40 nm window, which is continuously variable throughout the spectral range of the instrument.

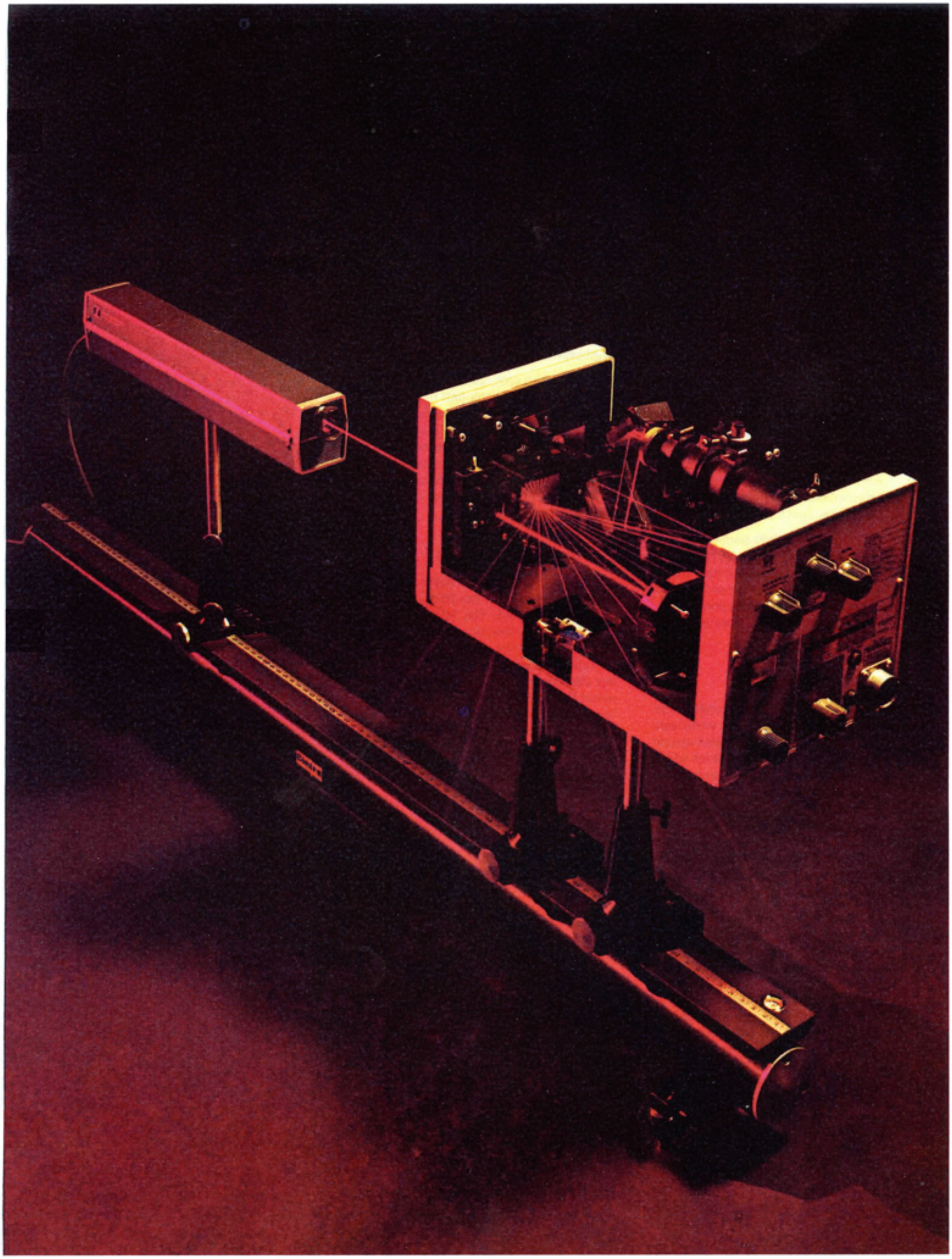
7J20 PLUG-IN

The 7J20 Oscilloscope Plug-In is designed to operate in the TEKTRONIX 7000-Series family of oscilloscopes. It functions as an electronic signal-processor between the J20 Spectrometer and the 7000-Series Oscilloscope Mainframe. Here the signal from the spectrometer is further amplified, filtered, and processed to provide vertical deflection (spectral intensity) on the vertical axis of the oscilloscope CRT. As the horizontal scan of the vidicon is a wavelength scan, the horizontal axis of the oscilloscope display represents wavelength. Primary operations here control presentation of spectral data on the CRT.

VERTICAL GAIN—Sensitivity of the instrument can be varied over a wide range to accommodate wide variations in input energy. Three types of vertical deflection are provided: (1) linear, (2) logarithmic, and (3) inverse logarithmic (absorbance).

TIME/SCAN—The mode (normal or integrate) and time of scanning the vidicon target in the spectrometer. In the normal mode, the vidicon is scanned by successive sweeps, with no delay between scans. Integrate mode provides a selectable delay time between scans for increased sensitivity.

MARKER—An intensified spot on the CRT can be moved horizontally along the trace. The wavelength corresponding to the spot is displayed digitally at the top center of the screen.



DISPLAY WAVELENGTH SPAN—Once a spectral region of interest has been selected using the marker, electronic expansion allows display of a narrow window (as low as 4 nm) for detailed examination.

DISPLAY TRIGGER MODE—Four modes of display triggering are provided: **Free Run**—display is continuously provided. **Triggered**—continuous display is initiated by an external signal, such as a pulse from an experiment. This signal is fed in via the "Display Trigger Mode" connector. **Single Scan**—only one scan is presented. **Reset**—rearms the system for single scan sweep.

SPECTRAL NORMALIZER—Selection is between normalized and unnormalized operation. Internal normalization means the system is radiometrically calibrated. The use of an external normalizer accessory allows tailoring of the wavelength responses of the RSS to allow for spectral characteristics of external filters and light sources, as in absorption spectroscopy.

All TEKTRONIX 7000-Series Oscilloscopes are compatible with the 7J20 plug-in, and will provide a display of the optical information gathered by the spectrometer. The discussion here deals primarily with the use of the 7313 Storage Oscilloscope.

7313 OSCILLOSCOPE

The 7313 offers the best combination of performance and value, when considering the RSS as a system capable of a wide range of applications with high performance and convenience of operation. The 7313 offers adequate vertical amplifier bandpass to ensure optimum spectrometer performance, and CRT READOUT to take advantage of spectrometer operational features such as the wavelength MARKER control.

Because spectral data is displayed instantly on the oscilloscope screen, you may quickly adjust instrument settings until the spectrum is displayed in optimum form. For example, it would take only a few seconds to initially scan 400 nm of the spectrum, define a specific area of interest, increase resolution via a grating change to observe a 40 nm window, make further sensitivity, time scan, horizontal scale adjustments until the spectral presentation meets your needs, and then, take a photo of the CRT with the spectrum and primary instrument parameters recorded on one Polaroid print.

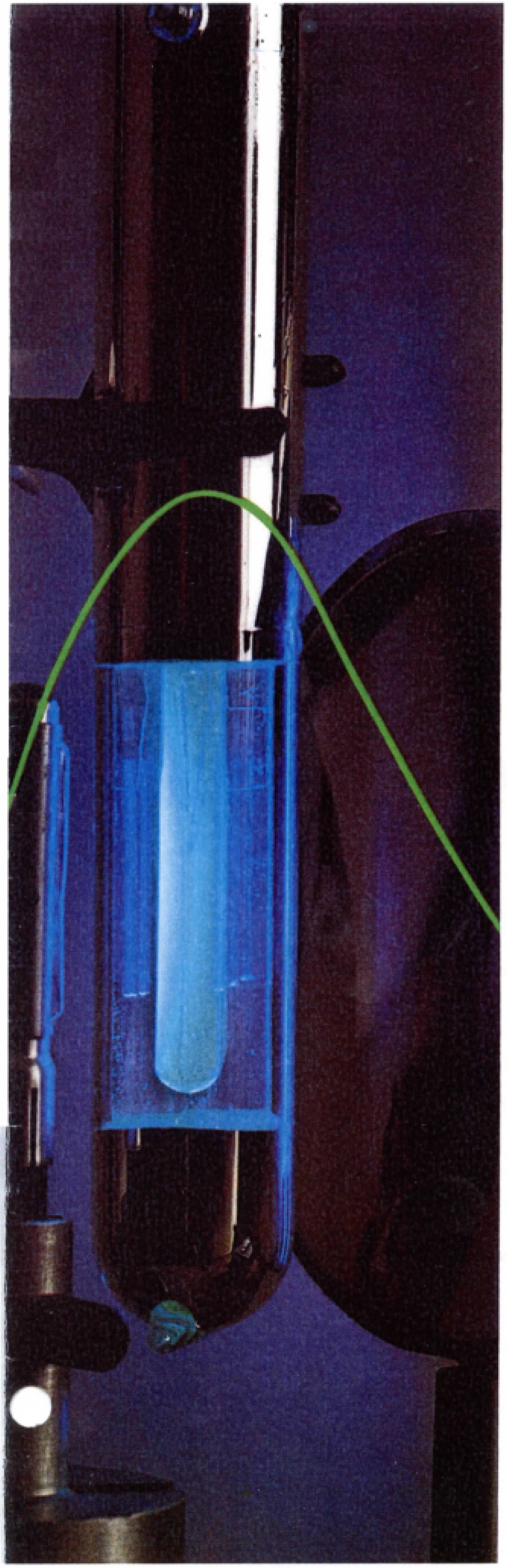
Such "composing" of spectra provides you with permanent records of desired information only. No need to be burdened with nonproductive curves required for the same result. Also, many experiments will not wait.

The 7313 is a storage oscilloscope. Storage CRT's have the ability to retain and display the image of an electric waveform on the tube face after the waveform-causing event has passed. This means the ability to retain the waveform produced by a rapidly changing nonrepetitive event whose image would flash across the CRT. Or, a family of curves can be produced on the CRT when the RSS is in repetitive scan, for example, when following the progress of a chemical reaction or phosphorescence decay.

The 7313 has a split-screen viewing area which allows each half to be used individually for storage displays. A reference waveform may be stored and kept available for ready comparison with waveforms obtained on the non-store portion of the screen. When a desired waveform is observed, it may also be stored.

TWO INSTRUMENTS IN ONE

When your oscilloscope is not performing as display for the RSS, it can be put to good use. The TEKTRONIX 7000-Series Oscilloscopes provide a degree of flexibility, versatility, and operating convenience not available in any other oscilloscope system. You may select from more than 30 plug-ins to "customize" your oscilloscope to specific measurement requirements.



MAJOR SPECIFICATIONS

Two rapid scan systems have been described in this brochure.

The TEKTRONIX RSS combines with the 7313 Storage Oscilloscope to produce an extremely versatile laboratory instrument with high performance and convenience of operation.

The RSS/Digital Processing Oscilloscope combination offers computer processing of the spectral data gathered by the RSS.

Additional RSS/7000-Series Oscilloscope combinations are available offering a wide range of capabilities to meet your measurement requirements.

To learn more about the RSS, please contact your local Tektronix Field Office or call collect to Jere Marrs, (503) 644-0161, extension 6654, or write: Tektronix, Inc., P.O. Box 500, Beaverton, Oregon 97005.

	GRATING A (150 lines/mm)	**GRATING B** (1200 lines/mm)
Total Spectral Range	300-1100 nm (1st order) $\geq$ 250 nm (2nd order)	300-1100 nm (1st order) $\geq$ 250 nm (2nd order)
Scan Range	300-700 nm 400-800 nm, 500-900 nm, 600-1000 nm, 700-1100 nm	40 nm window continuously variable (300-1100 nm)
Resolution	4.0 nm	0.4 nm
Noise Equivalent Power 20 μm slit	20 pW/nm	200 pW/nm
Calibrated Sensitivity/Range	400 fW/nm/div to 2 μW/nm/div	4 pW/nm/div to 20 μW/nm/div
Long Term Accuracy		
Wavelength Marker	±10 nm (at 25°C)	±3 nm (at 25°C)
Power (Radiant)	±20% (370-600 nm) ±12% (600-965 nm)	±12% (370-600 nm) ±11% (600-900 nm)
Short Term Repeatability (after setup and stabilization)		
Wavelength	±1 nm	±0.5 nm
Power (Radiant)	±2%	±2%
Short Term Mechanical Repeatability		
Wavelength Marker	±5 nm	±1.5 nm

Photometric Accuracy—±1% Transmission. (normalizer off)

Stray Light—$\leq$1% at 600 nm

Radiometric Dynamic Range—1:250
Uncorrected Dynamic Range—1:1000

Scan Times (Rapid Scan Range)—10 ms, 20 ms, calibrated; 4 ms to 20 ms uncalibrated

Integrate Times (20 ms scan)—50, 100, 200, 500, 1000 ms

Slit—Interchangeable fixed calibrated slit widths of 10, 20, 50, 100, 200, 500, 1000 μm; slit height is 7 mm

Equivalent f-number—f/6.0 non-vignetting

Filters—switchable filters; open, neutral density 1.0; neutral density 2.0; 500 nm monopass; 800 nm monopass; UV Block <400 nm; UV Block <500 nm; UV pass 250-330 nm

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