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A PRECISION FLYING SPOT FILM DIGITIZER

Livermore, California

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Operating Characteristics of the Scanner

This device and its associated data handling system measures locations of images on transparent film by automatically scanning an area on the film with a mechanically generated flying spot of light. These location measurements are directly transmitted to a digital computer for subsequent processing. The digital computer controls and monitors the digitizing equipment operations. Initially, a film to be analyzed is placed manually into the digitizer. If a large volume of a film is to be processed, a computer controlled automatic strip-film transport can be installed.

Scanning Area and Measuring Speeds

The digitizer will scan film fields whose width is 10 cm or less and length is 15 cm or less. Two side-by-side 35-mm, one 70-mm, or a single 4-in. by 5-in. film may be scanned within this maximum field size. Hand-drawn transparencies can also be processed, making this device a graph input device to a digital computer.

A single traversal of the flying-spot scans the width of the field in about 8 msec. Ten percent of the scanning time is lost during a between-scan dark period. The computer can select several scanning pitches.

The scanning element is a flying circular spot of light whose diameter (at the 20% amplitude) is about 20μ. A simple alteration of the equipment can enlarge this scanning element diameter. To a first approximation, an opaque image whose dimension in the direction of the scanning spot motion is 20μ or greater will totally occlude the flying spot producing 100% modulation of the light. Assuming radial symmetry of the light spot, the center of such an

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opaque image can be determined to one-tenth of its width by measuring the location at which the center of area of the modulated light video signal occurred. Such a technique has been employed successfully in locating the centers of bubble chamber track images in the Flying Spot Digitizer.[1]

Description of Equipment

The equipment is shown schematically in Fig. 1. The scanning device and the method of digitizing was originally described in a Brookhaven National Laboratory Applied Mathematics Division Note,[2] and at a Paris Conference on High Energy Physics.[3] Four microscope objectives produce the flying spot. These lenses demagnify an image of an intensely illuminated circular orifice onto the film plane. The objectives are mounted at equally spaced azimuths and at identical radial distances on a rotating wheel. The microscope objectives axes are parallel to the wheel's axis of rotation.

A condensing system images the arc of a high pressure mercury lamp (PECK 109) onto a circular orifice of 200-μ diameter. The orifice is drilled into a heavy heat sink to prevent its burning.

Each of the objectives views the orifice through a periscope. Light passes from the illuminated orifice to the four faces of a 45° first surface prism. This prism is mounted on the exact center of the wheel. A prism face reflects the orifice image into its 45° mirror. This image splitting and path bending creates four 20-μ spots in the film plane. The intensity of the light passing through the objectives remains constant during the wheel rotation. A turn of the wheel generates four sequential scanning lines (segments of an arc) across the film.

A synchronous motor drives the wheel at 1800 rpm. Ten power microscope objectives have been operated on a 12-in. radius wheel at speeds to 4000 rpm without image displacements greater than 2μ (probably wheel distortion) or disaster. The objectives produce an image of about 20μ on the film. The wide aperture objectives (about f 1:1.2) produce a much brighter spot than does the narrow slit scanner in the Hough-Powell machines.[4]

Digitizing the Instantaneous Spot Position

For this device to make precise measurements of images on film the instantaneous location of the flying spot must be known. As the spot of light

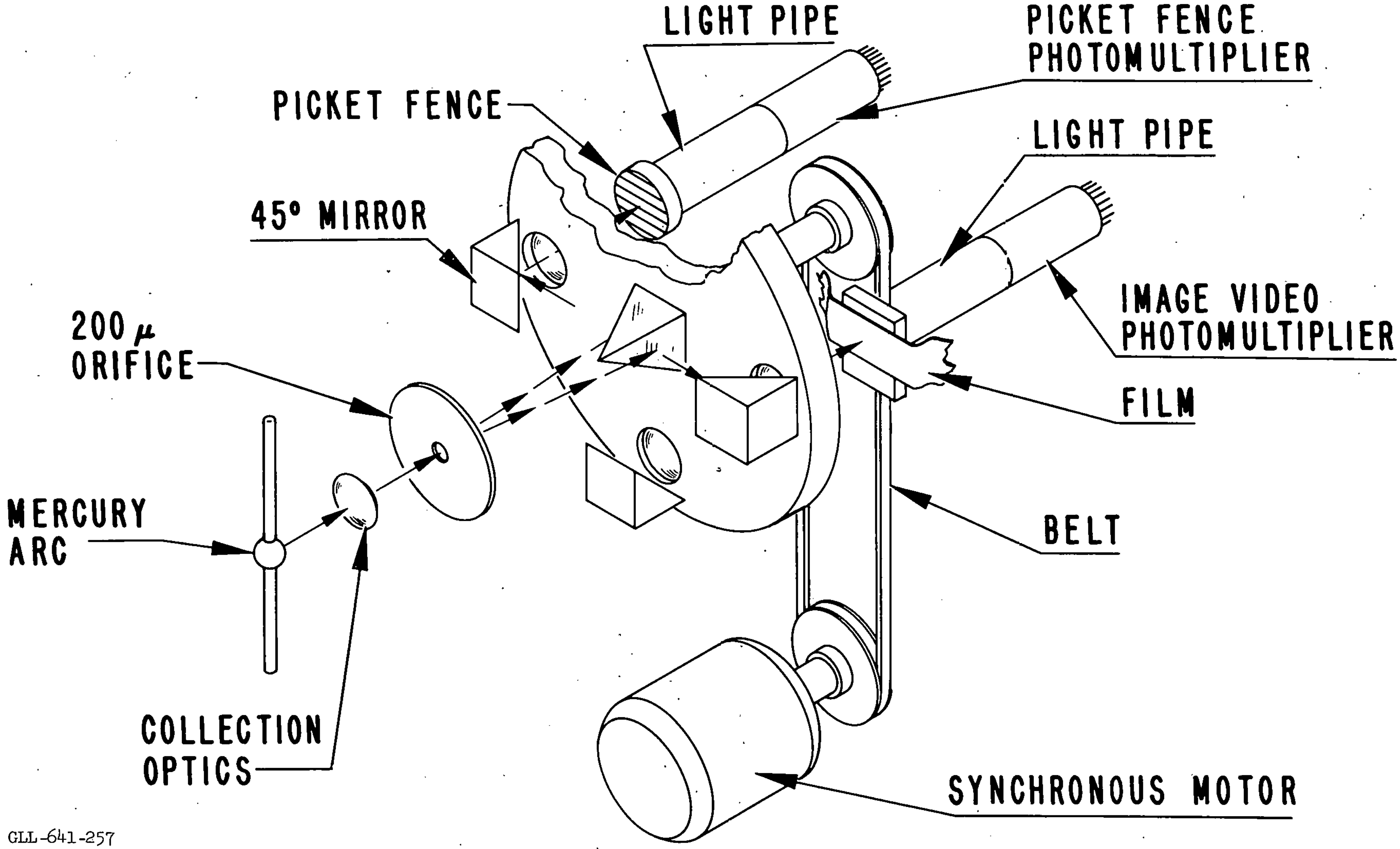

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Fig. 1. Flying spot digitizer optical-mechanical system.

from an objective travels across the film field, the light from the lens on the opposite side of the wheel is passing over a precision picket-fence grating. These gratings are manufactured either by the National Physics Laboratory in England (1/2 mil opaque followed by 1/2 mil clear and repeated for about 75 mm) or by Bausch and Lomb (16-μ pitch). A photomultiplier receives the modulated light as the spot crosses the grating. The electrical signal from the photomultiplier creates pulses which are counted by an electronic scaler. The instantaneous state of the scaler indicates the measuring spot image position along the scan path to a least count of 12.5μ. As the velocity of the wheel is uniform, a time interpolation between picket passings permits a least-count resolution to about 10% of a picket width, plus or minus 1.2μ. System noise, including wheel bearing jitter make 2-μ measurements feasible.

The Film Stage

While being scanned, the film is mounted on a vacuum platen to insure its flatness. This mounting is necessary as microscope objective field depths are but a few microns. The platen is mounted on a traveling measuring stage. Platens of several sizes may be fitted to the stage so that several format sizes can be scanned. As the stage moves, its instantaneous location is measured by a moire fringe-scaler system (least count ±2.5μ). The states of the scanning-line scaler and the moire fringe stage scaler represent the location of the flying spot with respect to the measuring device. A velocity servo control system drives the stage at one of several speeds. The computer selects scanning pitch by choosing a stage speed. Limit switches prevent damage from stage over travel. These switches inform the computer when the stage is ready to scan a frame.

Light Collection and Photodetectors

There are three light collection systems in the digitizer: a film density measurement light pipe and photomultiplier; the picket fence modulation light receiver; and the beginning-of-a-scan-line detector.

Immediately behind the glass film holding vacuum platen is a Lucite light pipe for collecting the light from the flying-spot which passes through the film. It is the modulation of this light which generates a video signal from which film density measurements are extracted. The Lucite light pipe is attached to a photomultiplier.

A similar light pipe, immediately behind the picket fence, collects and transmits the picket-fence modulated light to its photomultiplier. Neither of the collection systems nor the spot generation system moves. The wheel and the film carrying stage are in motion during the scanning of a field.

The picket-fence photomultiplier starts generating a pulse train before the measuring spot enters the film field. A gate prevents this pulse train from incrementing the line digitizing scaler until the spot of light at the film measuring side of the wheel has passed the beginning-of-line-marker. This marker is a narrow slit, mounted to intercept the measuring spot immediately before the spot enters the measuring field. A glass fiber transmits the light passing through the slit to a third photomultiplier. This photomultiplier signal opens the digitizer scaler input gate to the picket fence pulses.

The Data Handling System

Electronics

The electronic system (see Fig. 2) includes:

- Photomultiplier preamplifiers.
- Film image video signal processor (line center generator or analog density digitizer).
- Scan-line digitizing scaler and gates.
- Beginning-of-scan-line marker signal generator.
- Stage location measurement (moire fringe system and scaler).
- Data buffer store.
- Computer interface.
- Stage motor control and velocity servo.
- Sequence controllor and command registers.

Operation

When the image signal video processor detects an image, the instantaneous states of the stage position and line digitizer scalers are transferred to the buffer store. The size of this buffer depends upon the speed at which the computer can accept measurements. The computer, sensing that information exists in the buffer can read the measurements into its own data registers.

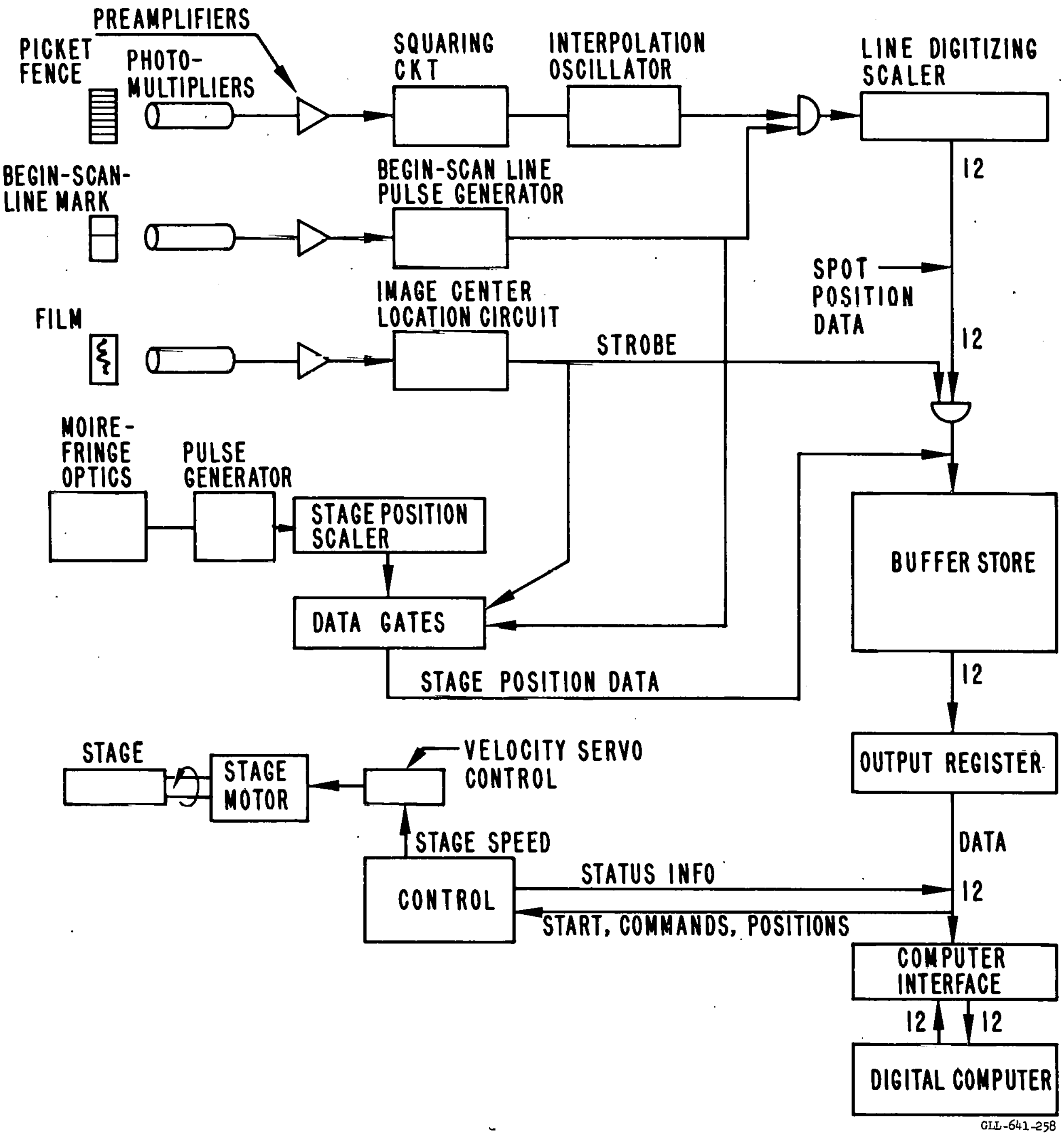

Fig. 2. Digitizer electronics.

To initiate a scanning raster, the computer transmits, the stage velocity information and the move-stage command to the digitizer. The command to start the stage moving is initiated in the computer after detecting that the digitizer is ready for operation. By commanding a starting stage position other than zero, the computer causes the digitizer to begin its scanning at a predetermined location. This mode might be useful for seeking detailed measurements of particular areas after a rough scan has been analyzed and interesting areas defined.

For processing curves, whose lines widths are close to the spot diameter a line image center detection circuit can strobe the scaler information into the digitizer buffer. For wider features, another detector can store the coordinates of the leading edge of a density change and its digitized width measurement, accumulated in a width scaler.

As the flying spot intensity is constant across the field, the photomultiplier signal can represent continuous tone photographs. An analog-to-digital converter samples the video signal amplitude. Density measurements are stored in the buffer along with related location measurements.

The Coordinate System (See Fig. 3)

It is only necessary to store the stage position measurement at the end of those scanning lines on which the image detector has discovered one or more image signals. This measurement is not the exact ordinate location of an image on the line but a base location to which must be added a distance whose value is a function of the line digitizing position. The locus of the scanning spot as it crosses the film and picket fence is a segment of an arc. This function is slowly changing (for typical relative dimension) and predictable from a look-up table in which abscissae are arguments and increments to the stage position are functions. The correction can also be applied analytically. The computer must also correct the coordinate system for distortion caused by the stage velocity.

Conclusion

This digitizer is a general purpose graphical data input device. A directly connected digital computer controls the digitizer operation and processes the location measurements of images on transparent films. A 4-in.

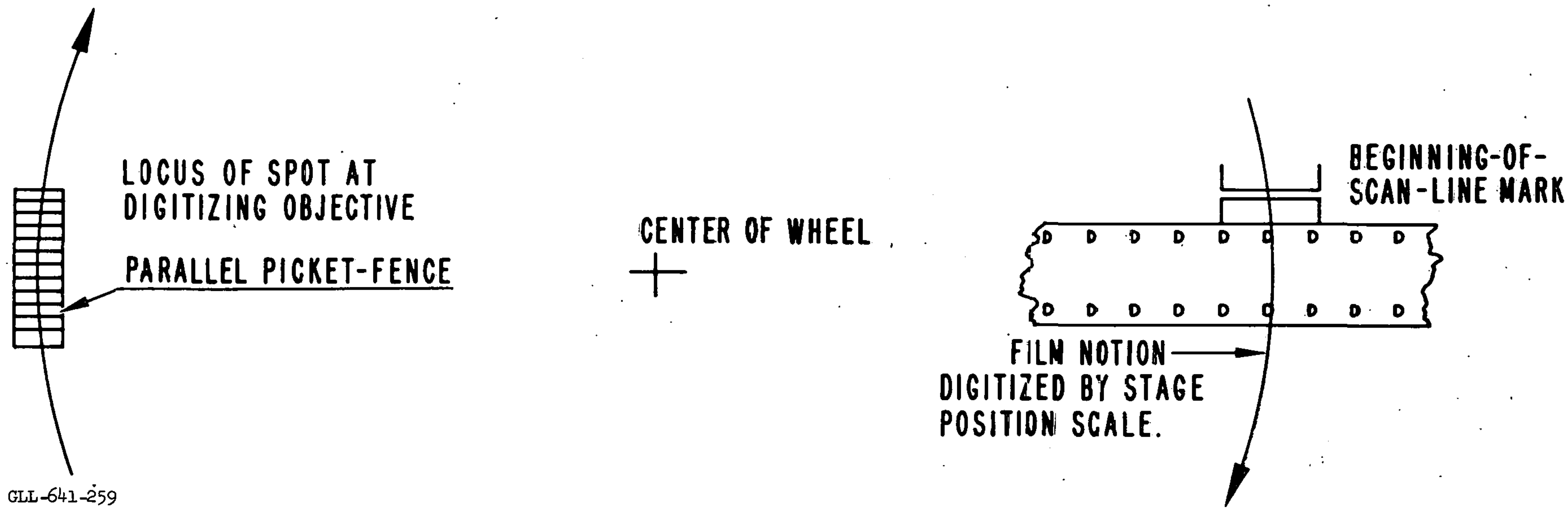

Fig. 3. Coordinate system.

× 5-in. negative can be scanned by a raster whose pitch is 50μ in about 3 min. A field 4 in. wide may be digitized to ±4μ, about one part in 25 000.

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