AN AUTOMATIC HIGH-RESOLUTION SCANNING DENSITOMETER APPLIED TO OPTICAL SPECTROSCOPY

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ABSTRACT

A high-resolution digital scanning densitometer was built to record spectral UV-VIS-IR lines on magnetic media from photographic transparencies. The system was assembled with a sliding table measuring machine driven from a PC and a silicon photodiode and A/D converter to record light intensities. A spectroscopic plate or film can be read and recorded with a sampling step of 1.20 μm.

1. INTRODUCTION

In the last three decades, the Centro de Investigaciones Opticas (CIOp), has produced many research works in atomic and molecular spectroscopy using different optical spectrographs, recording stimulated and spontaneous UV-VIS-IR emissions on photographic plates.

Spectral lines are identified visually by comparing photographic records obtained after long periods of exposition. This recording media reaches a very high resolution: about .01 nm/mm.

The use of an automatic plate reading system offers better resolution between lines and easier identification of weaker spectra, printing them on paper for direct eye observation.

Using a **GSIP** precision length measuring machine, usually hand operated, and joining a stepper motor to the fine displacement motion control, the sliding table moves horizontally carrying the film or plate to be read and recorded.

A white light optical beam strikes the bottom face of the film and the light intensity detected on the upper face. The detected signal is sampled with a 12 bit A/D converter and is saved to disk.

The recorded spectra is plotted spanning each slot a hundred times. This magnification between lines allows easier visual identification. A spectroscopic plate 25 cm long may be plotted at a 1nm scale per page, in about a hundred paper sheets size A4.

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Received: September 4, 1995. Accepted: May 7, 1996.

2. OPTO-MECHANICAL SETUP

The metrological machine **GSIP** (Societé Genevoise D'Instruments de Physique), mod. MU-214B, is a universal three-dimensional high-precision measuring apparatus that was used in the present project taking advantage of the quality of its linear displacements and ability to connect to a PC to perform the adquisition and control. This avoided the construction of an expensive system of the same mechanical precision.

The machine has a horizontal sliding table 50 cm long and 18 cm wide, with a 40 cm per 11 cm slit. It can be slid manually or by means of a stepper motor up to a distance of 27 cm.

The film is held on the table by a thin glass plate. If the spectra is recorded on a glass plate, this is held on the table by small weights on the edges of the plate.

The light of a 50 W dichroic lamp at the back of the machine is taken by an optical system to the base of the sliding table, lighting the area of the plate to be read.

The machine holds a microscope which slides normally to the table, making an image of the required size on the detector.

The detector optical system is a 10x microscope objective at the bottom of a tube 23 cm long, which makes a real image of the spectroscopic line on a stainless steel slit 50 μm wide by 3 mm height, aligned with the line image, at the opposite end of the tube.

3. MEASUREMENT AND CONTROL INTERFACE

Behind the slit is assembled a silicon photodiode integrated to a I-V variable gain amplifier ranging between 100 KΩ and 10 MΩ and offset adjust. The I-V amplifier output

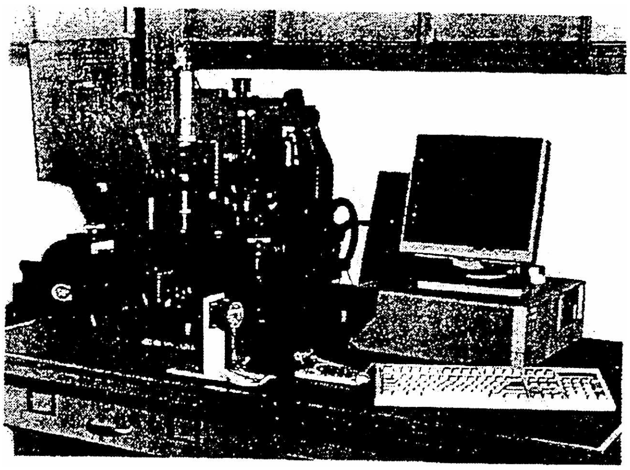

Figure 1. Photograph of the spectroscopic plate reading system.

drives a V-V amplifier stage of gain 130, and limited to a maximum of +5 volts. Both amplifiers are fed from the A/D converter board inside the PC which performs measurement and control.

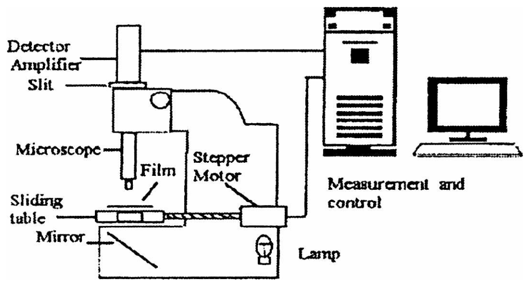

Figure 2. Schematic of the spectroscopic plate reading setup.

Another I/O board inside the PC together with a power supply and an external field switching circuit controls the stepper-motor motion driving the table.

The motor shaft coupled to the fine displacement motion control gives a linear step advance to the table of 1.20 µm, enough to resolve the spectral lines on the plate at a 0.4 nm/mm scale for the visible spectrum. The exact value of the linear dispersion ($\Delta x / \Delta \lambda$) must be computed for each slot of the spectrum.

The mechanical coupling between the fine motion control and the table suffers sliding that reaches a maximum lack of advance of 2.5 µm per each record of 8000 samples, that is, less than 0.026 % of the linear displacement. This lack of advance could be corrected by coupling the table to a linear precision transducer in a closed loop control.

4. SOFTWARE

The plotting mode chosen is the spreadsheet which requires recording of files of 8 KB consecutive samples at a full adquisition and recording time of 90 s per file of almost 10 mm of spectrum on the plate. As well as this, a file is created with the background transparency of the plate, averaged and substracted from each data file for contrast enhancement.

The resultant contrast is over 0.9, limited mainly by the residual noise of the modified file. These are plotted and observed later on the spectrum sector investigated.

The uncertainty noise of the A/D converter does not impair the recorded contrast, and is of +/- 1 LSB. The conversion time per sample is of 60 µs.

Every 8 KB samples the file is closed and the next is opened, avoiding the accumulation of sliding errors, larger than the error mentioned above.

Between every two registers, the zero transparency value is set to its least positive value, ensuring the intensity plotting errors below 5% for each record.

The following programs were written for an IBM PC.

1- **Zero setting:** inicializes the output voltage value of the detector amplifier before the plate logging.
2- **Background intensity:** fixes the reference level of the intensity data files.
3- **Adquisition and control:** saves the spectral intensity data to disk and controls the sliding table motion.
4- **Background substraction:** this program modifies all data files substracting the averaged background intensity of the plate and gives a sequential number to each modified data file for its recognition.

5. SUMMARY OF TECHNICAL CHARACTERISTICS

1- File generation of 8 KB samples in 90 s, equivalent to 9.6 mm of spectral plate or film.

2- Step resolution of 1.20 µm with an error of 0.026 % of linear position for each register, with a spectral dispersion better than 0.4 nm/mm (VIS) for each plotted page.

3- Intensity resolution of +/-5 %.

4- Posibility of substracting the background level from each record to allow the recognition of weak lines.

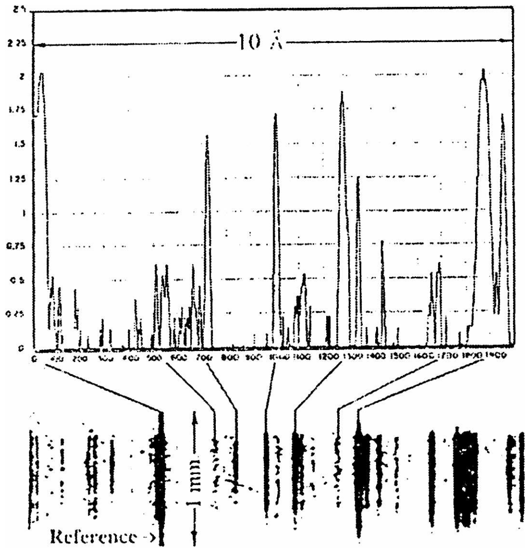

Figure 3. Spectral line logging obtained with the plate reading system.

6. CONCLUSIONS

A spectroscopic plate densitometer was built, adapting an existing machine at CIOp employed in three-dimensional metrology. A high spectral resolution was achieved and a plotting method was developed that simplifies the study and recognition of fine structures.

The open loop operation of the system and the I-V amplifier instability are the limiting factors of the precision of system in its current state.

The resolution reached is better than that of similar apparatus for transparency logging which have 60 μm [1] between samples, and 100 μm [2] between samples, and it allows the printing of spectrum pieces at a scale of 1 nm per page.

REFERENCES

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