

VI. ELECTRONIC INSTRUMENTATION*

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RESEARCH OBJECTIVES

Electronic instrumentation plays a significant role in almost every branch of scientific research. Similarly, progress in electronic instrumentation is increasingly dependent on advances in chemistry and physics. The formation of the Electronic Instrumentation Group is an effort to stimulate instrumentation research and development with state-of-the-art needs in other areas of science.

The activities now under way in our group are centered on instrumentation for mass spectrography. Profile analyses and spectrographic data-reduction methods already require extensive use of high-speed digital computers. Data from a Mass Spectrograph are collected, however, on photographic plates that must be processed by time-consuming methods to achieve a form acceptable to a computer. Many experiments, which are impossible to perform with present methods, could be conducted with the addition of a real-time interface between a Mass Spectrograph and a computer with on-line processing capability. Reports on progress in areas related to the development of suitable interface hardware and software appear in Sections VI-B, -C, and -D.

Since much of the present and future Mass Spectrograph instrumentation is and will be environmentally sensitive, a semiclean, temperature- and humidity-controlled shielded room is being provided. The instrument will be mounted within the room on a 1-Hz air piston antishock and vibration assembly. Nearly complete environmental control will permit an investigation of system-produced instabilities that can be corrected by sophisticated instrumentation. The resulting influence on next generation equipments will allow spectrographic analyses to be carried out on low-vapor-pressure compounds that require very long (several hours) exposures. It is virtually impossible to make analyses of some of these compounds with present methods. Progress on the shielded room facility is discussed in Section VI-A.

D. H. Steinbrecher, K. Biemann

A. SHIELDED ROOM FACILITY

This report outlines briefly the current status and the rest of the work to be done on the wrought-iron screen room that is being constructed in Room 56-031, M.I.T. The iron walls, floor, and ceiling have been erected and the continuous seam welds are

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approximately 80% complete. Also, the electrical ground for the room has been completed.

We estimate that the completion of the basic room (i. e. , welding of iron) will soon be accomplished. In addition to the basic-room design, additional time will be needed for (a) installation of an air-conditioning system, (b) interior finishing of the room (i. e. , acoustical walls, ceiling, etc.), (c) making available electrical power and water to the room through pierce points in the roof of the room, (d) exterior finishing of the area surrounding the room (i. e. , block wall in the corridor, etc.), (e) installation of a motor generator set for the mass spectrometer primary power, (f) installation of line filters and other accessories to provide services for the room.

R. E. Lovins

B. MASS SPECTROMETER DETECTOR

The simplest detection scheme, that of collecting each ion beam on a metal plate and amplifying the resulting current, would require that we push the present capability to measure low current levels downward by at least two orders of magnitude. There is an alternative, on the other hand, which involves use of state-of-the-art components, and thus affords a better chance of success in building the final instrument.

We are considering replacement of the photographic plate by a slit mask containing 300-1000 slits, each 1 mm long and with an expected width of 5 microns. The mask could be made of metal foil on a rigid frame, with slits formed either by high-resolution photo-etching (by Bendix Research Laboratories) or by multiple drilling with a pulsed laser (Raytheon Company, among others). Since the slits would have fixed positions on the mask, either the beam of the spectrometer or the mask itself could be scanned in steps through a total distance somewhat greater than the spacing between adjacent slits. The ions issuing from the slits would be counted by continuous-channel photomultipliers mounted behind each slit. These novel devices are made by the Bendix Corporation, and consist of a glass tube (as small as 0.25 mm O.D. by 1 cm long) coated on the inner surface with a secondary-emitting film of high resistivity. A high-voltage applied across the ends of the tube accelerates the electrons as they carom down the tube and build up their numbers to produce, finally, a constant-amplitude space-charge-limited output pulse for each incident ion (with at least 60% ion-collection efficiency).

1. Block Diagram

The essential components of the interface system between computer and ion beams are sketched in Fig. VI-1. The diagram is a preliminary description of one form of logic that transfers the complete spectrum from the focal plane of the spectrograph into

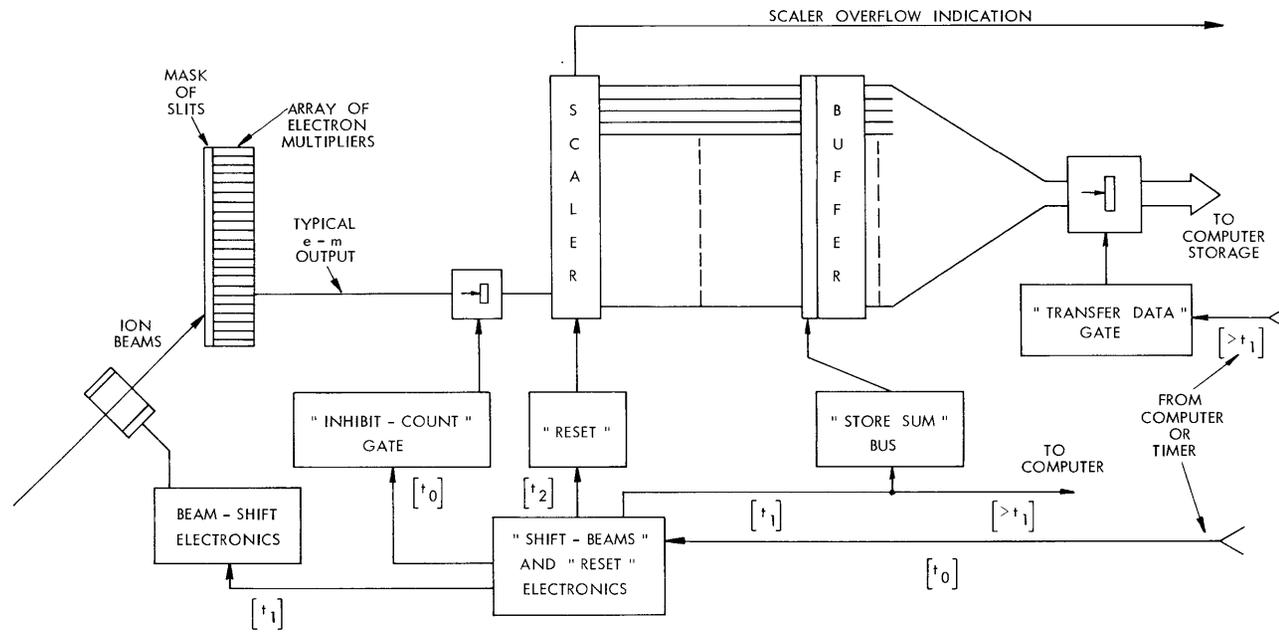


Fig. VI-1. Logic diagram of the spectrometer focal-plane-to-digital computer - a typical channel (of 300-1000 channels).

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the computer. The ion counts are accumulated in the scaler until the time t_0 , at which time the counting is stopped; the sum is transferred to the buffer an instant later, at t_1 , and, if it is desired, the beam is shifted to align the next samples of the spectrum with the slits. The scaler is disconnected from the buffer and is reset at t_2 ; and the counting begins at t_3 , after a total delay of a few milliseconds. Meanwhile, the count in the buffer remains available, for transfer to the computer memory, until the beginning of the next cycle at $(t_0 + T)$.

2. Sampling and Retrieval of the Spectrum

The interactions among timing, slit width, and resolving power can be solved by considering that the ion beam intensity is an unknown function of the distance x along the focal plane. The profile of an isolated line is approximately Gaussian with a well-defined half-width. We may therefore consider the whole spectrum to be a function that consists of a sequence of Dirac delta functions with different areas and x coordinates, which has been convolved as a whole with a Gaussian. (In reality, the width of the profile changes by approximately 5 times from one end to the other of the 30-cm focal plane, so that a one-dimensional transformation of the spectrum must be performed first if mathematical rigor is to be preserved.) In this way, the problem is reduced to classical terms. Ideally, then, each slit in the mask obtains a sample of the smoothed spectrum; however, because of the nonzero width of the slit, we must consider that the smoothed spectrum is convolved again by the slit, and the output from an electron multiplier then represents a sample (in the mathematical sense) of the resulting spectrum.

3. Anticipated Difficulties

The assembly of slits and multipliers must be located at the edge of the magnet gap, within a magnetic field of approximately 10,000 Gauss. We do not yet know whether the multiplier tubes can be operated in such a high field. In order to prevent the first emitted electron from striking the wall too soon, before it has acquired enough energy from the electric field to dislodge secondaries, we shall probably align the axes of the multipliers with the magnetic field; other problems and/or experimental solutions will undoubtedly turn up.

The second problem is the unknown response of the active film in the electron multipliers to ions at the heavy (hence low-velocity) end of the spectrum.

S. H. Zisk

C. RESOLUTION OF MASS SPECTROMETER

A proposed analog-to-digital converter for the ion-beam outputs should not significantly decrease the mass spectrometer's resolution.¹ It is important, then, to determine quantitatively the factors that degrade the resolution: (i) energy dispersion in the

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ion source; (ii) defocussing in the ion-optics systems; and (iii) electronic noise in the detector. A search is being made for an electrical equivalent circuit for an ion-beam output in which these 3 factors will be lumped in noise sources.

J. I. Glaser

References

1. K. Biemann, Mass Spectrometry: Organic Chemical Applications (McGraw-Hill Book Company, Inc., New York, 1962).

D. SAMPLING AND RETRIEVAL OF THE SPECTRUM

To increase the speed with which results may be obtained from the Mass Spectrometer, the data will be gathered digitally and processed in a computer. The ions will be detected by electron multipliers, on related devices, and the pulses counted and stored for transfer to the computer.

Digital acquisition of data from the Mass Spectrometer poses the problem of how well a discrete number of digital samples characterizes the continuous spectrum. A computer program has been written to simulate the sampling process on a normal Gaussian curve and to reconstruct the curve from the samples for comparison.

J. M. Steele

