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APPLICATIONS OF MICROCOMPUTERS IN LASERS AND SPECTROSCOPY

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LECTURE 4 : APPLICATIONS OF MICROCOMPUTERS IN LASERS AND SPECTROSCOPY

I. INTRODUCTION

With the increasing availability of inexpensive and yet relatively high performance microcomputers and microprocessors, many researchers in physics are leaning towards the usage of microcomputers as an essential equipment in their experimental set-up. Microcomputers are used to enable some form of controlled operation and with on-line data acquisition and analyses. This is of even greater significance to physics research programs in the developing countries where such computerisation used to be an expensive considerations. This paper outlines the possible applications of inexpensive microcomputers in laser research programs, drawing some practical examples from the experiences acquired at the Laser Research Laboratory at the University of Malaya.

II. BASIC SET UP OF A LASER RELATED RESEARCH PROGRAM

One can broadly classify laser related research programs into two different categories, i.e. the design and development of lasers and associated electrooptic devices as compared to the usage of lasers as a powerful source of light in spectroscopy works for scientific and industrial purposes. In both areas of research, microcomputers can be of tremendous use.

To illustrate the possible role of the microcomputers in both categories of laser related research, one can divide the entire experimental set-up into the following basic experimental blocks. As shown in Fig. 1, the microcomputer is used as the master controller. The operation of each block

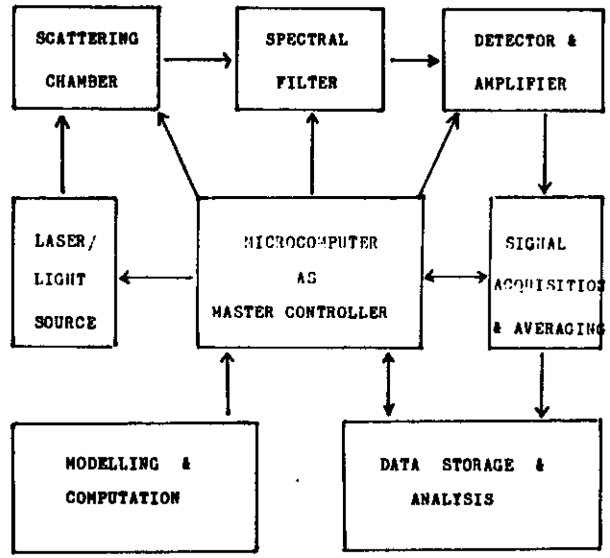

Fig. 1. Schematic Lay-out of a Microcomputer Controlled Laser Based Spectroscopic Experiment

in the experimental set up can be controlled by the microcomputer as discussed separately in the following:

1. **Laser System :** The firing and operation of the laser system can be controlled by the microcomputer. Thus, gas flow rates and pressures in the laser channel could be controlled using transducers interfaced to the microcomputer system. Other electrical and mechanical components could also be controlled by the microcomputer for synchronisation of firing of the laser, high voltage charging, Q-switching, mode locking as well as in the tuning of the output wavelength of the laser.

2. **The Scattering Chamber :** The output of the laser could then be directed to a scattering chamber where it serves as a source of light either as a probe for diagnostic purposes or as a powerful light source responsible for scattering or reaction events on interaction of light with matter. This scattering chamber may, on its own, be another complex experimental set-up requiring sophisticated instrumentation. Such a scattering chamber would of course be redundant if only the output of the laser is the main concern in laser test firing and experimentation.

3. **Spectral Filter:** The scattered light or the laser beam itself is then spectral analysed by a simple spectrometer, the operation and scanning of which can be computer controlled.

4. **Light Detection and Amplification** The operation of a single detector element such as photodiode or photomultiplier can be interfaced to the computer. In the case of multi-element detector such as a diode array, such systems are normally supplied with multichannel analyser interfaced to computer systems, and more recently to the more powerful microcomputer systems. The associated signal amplification and processing are computerised.

5. **Signal Digitising and Processing :** The amplified electrical signals could either be displayed in analog form or could be digitised. For computerisation, digital signal processing is preferred. Thus, one could design dedicated analog to digital converters for this purpose or purchase commercial systems such as transient digitisers. In the last ten years, relatively fast and inexpensive digital oscilloscopes have also proven to be an important element in the laser research laboratory as a general purpose equipment that can be used in diverse situations.

6. **Data Storage, Analyses and Presentation of Results :** Once the signal is digitised, it can be stored in the memory bank of the microcomputer system or in buffer memories. In most situations, the signal acquired might require some form of signal averaging for noise subtraction or background subtraction or lock in amplifier type of processing. Some of these functions can be performed using commercial equipment. However, these relatively expensive signal processing equipment are increasingly been assembled by researchers who could not afford the price and who are prepared to undertake some interface task based on their microcomputers. Thus, the microcomputer system can now serve as a data logger and data processor. The final results could also be resented on chart recorders or plotters, on-line to the microcomputer system.

7. **Numerical Simulation and Computation :** The microcomputer could of course be used simply as a readily available computing system for numerical simulation or modelling of the laser systems or for the theoretical study of the scattering events that incurred during the laser light matter interaction. One should bear in mind that with the rapid advances made in microelectronics, it would not be long before each laboratory will have its own computing capability as part of its standard laboratory equipment.

III. Specific Functions of a Microcomputer in Laser Research

After having discussed the different aspects in a typical laser experimental set-up, one can now broadly classify the functions of a microcomputer as follows :

III.1 Instrumentation Control and Process Monitoring

This is an important application of microcomputer in laser research. This involves using the microcomputer as a controller for the movement of mechanical parts like the turning of stepper motors for tuning of laser wavelengths or the scanning of a spectrometer. Such mechanical movements can also be used in mirror alignment for beam steering or in laser cavity alignment. There is of course the mechanical movements that might be needed to alter the scattering angles or in the positioning of the targets (as in a X-Y table for material processing) in laser interaction with materials. The microcomputer can also be used to control the triggering of the laser discharge and synchronisation of other electrical devices like Q-switches or timing of gate pulses in the detection electronics. The microcomputer could also be controlling the operation of various transducers like pressure of gases in the laser channel, gas flow rates and temperature stabilization of Fabry-Perot etalons. There is a myriad of applications where the microcomputer can be employed to precisely define the experimental conditions that may critically define the success of the experiment.

In the past, such interfacing jobs were carried out by electrical and/or computer hardware engineers. However, with the increasing versatility of the microcomputers, it is relatively easy to implement such interfacing task. In all microcomputers, there will be available some form of I/O ports through which communication is made to the external world. Apple II microcomputer is in fact the first microcomputer that has been designed with the users in mind. With an open architecture, one can easily expand the scope andfunction of the computer through its I/O expansion slots. Thus, many different devices are available commercially which are designed and fabricated to work with the minimum amount of efforts to the users. One has only to plug in the interface card that comes together with the device to one of the slots of the Apple II computer.

Apple II is an 8-bit computer. Its usage is now being displaced by the more powerful 16-bit IBM-PC and its compatibles. Presently, there is a rapidly changing scene at the computer scene with the appearance of more and more powerful and cost-effective computer and it is rather difficult to catch up with it. Nevertheless, it does seem that the PC-compatibles are very well entrenched and the users just have to decide when to joint the band-wagon.

With both the Apple II and the PC, relatively inexpensive A/D and D/A interface cards are available which will enable one to acquire data on-line as well as to control the operating conditions of an experimental set-up. We suggest that such a card be acquired as a first step in computerised operation (refer to the latest Byte magazine for the cheapest and fastest interface card).

Similarly, an inexpensive stepper motor drive card with power supply modules can also be purchased. These stepper motors can be used to drive mechanical parts as for example in the turning of spectrometer gratings.

On the other hand, for those who have the necessary electronics background, it will be highly satisfying for them to design and construct their own interface cards. This will require the knowledge of the computer system hardware better besides some knowledge on Assembler language(1). There is also the simpler route of using the game I/O port of the computer. Thus, for the Apple II computer, one can easily control the operation of a stepper motor for laser wavelength tuning and spectrometer scanning using the four announciator lines. The three pushbuttons and four game paddle ports can also be readily adapted for many different applications. In one application, we have also used the Apple II game I/O to act as a controller for balloon tracking (2) in the measurement of wind velocities up to a height of 8 km using a simple camera mounted on a tripod as a tracking device. It does seem to be highly profitable for one to be well acquainted with the functions and usage of the game I/O port of the Apple II system.

For the IBM PC computers, one can also achieved the same ease of interfacing as the Apple II through the usage of its game I/O on the multi-function card.

In summary, it does seem opportune to get started with microcomputer in the spectroscopy laboratory. Also, with the price differential between the Apple II and the IBM PC is not too great, it will be wiser to invest on a IBM PC at this stage. The market price of an IBM XT compatible with harddisk and even an IBM AT with harddisk is falling and should be a good buy. It should also be noted that most of the latest software and hardware developments are centered around the IBM PC's.

III.2 Data Communication with Scientific Instrument

In laser spectroscopy research, a number of highly dedicated advanced instruments are often used for low level signal processing. Thus, lock-in amplifiers, boxcar averagers, photon counters, transient digitisers and digital oscilloscopes and optical multi-channel analysers are some rather expensive and yet important equipment that are necessary in some laser related experiments. In the past, communication with such devices are rather expensive by itself through minicomputers or mainframe computers. Howerver, one can now readily hook such equipment to microcomputers.

These equipment normally comes with RS-232 or IEEE-488 communication interface either as standard features or as options. Thus, with these features also available with the microcomputers, one can easily receive data captured by these highly specialized equipment. In fact, in some of the newer products, these equipment are even packaged to include a host microcomputer to allow the user some flexibility in configuring the operations of the equipment besides a fair amount of data processing and analyses prior to output to display or other devices. However, there is of course a premium to such a sophisticated piece of equipment. It will be better for the user to obtain his own PC and configure the system the way he wanted it to be.

For a start, it is suggested that if new equipment is to be purchased, one should check whether the IEEE-488 output is a standard feature or only comes as an extra option for the equipment. With the IEEE-488 option, one will only need an inexpensive interface card (check Byte magazine) and relatively simple software programming to have the equipment interfaced to the computer. For those with better electronics background, an interface card can also be relatively easily constructed (3).

III.3 Data Storage and Processing

The other important function of the microcomputer is its data storage and processing capacity. In many cases of laser experiments, one will encounter large noise to signal ratios. One would have to perform signal averaging or process the data through some computational schemes in order to extract the require data. Such functions can easily be performed by the microcomputer once a communication link is established to the experimental set up. For this purpose, the 8-bit Apple II computer may be sufficient for smaller data storage or processing purposes. The IBM PC with hard disk will be more than suffice for most laser related experiments.

III.4 Computational Physics using Microcomputers

It has been discussed previously that microcomputers can also be used for computational purposes in numerical analyses and theoretical modelling. However, the 8-bit microcomputers will be too slow and inadequate for most purposes except for the simplest task. On the other hand, the IBM PC will be sufficient for most purposes. The addition of a Mathematics Coprocessor chip (8087) will greatly facilitate such numerical task. With the introduction of the genuine 16-bit IBM AT microcomputer (with 80286 chip and its 80287 co-processor chip), such computing capability is expanded even greater .

IV. A Microcomputer Controlled Laser Lidar Experimental Set-up

We have in the previous section dicussed the various functions of a microcomputer in a laser spectroscopy research program. In this section, we will present a specific experimental set-up for the laser Lidar (4) monitoring of atmospheric pollutant as an illustration of the various points discussed. Such Lidar works will be discussed in greater details by Professor Svanberg in later lectures.

In Fig.2 is shown an experimental lay-out for the laser lidar system. A laser beam is transmitted into the atmosphere and the backscattered return signal is collected by a telescope and spectrum analysed to obtain information on the amount of atmospheric pollution, like the presence of NOx or SOx and visibility of the atmosphere. In this set-up, a high power home built nitrogen laser (1 MW) is used to pump a dye oscillator-amplifier laser system. The triggering of the nitrogen laser together with the monitoring of its power is computer controlled. The tuning of the output wavelength of the dye laser is achieved using microcomputer controlled stepper motor. The returned signal is then detected and amplified by a photomultiplier and the

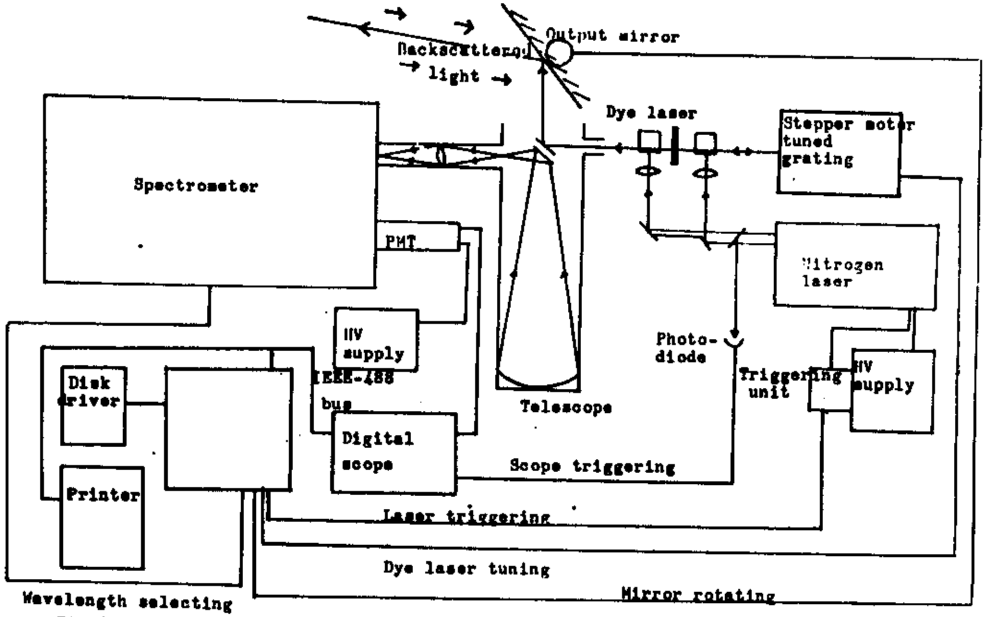

Fig.2 The schematic diagram showing the LIDAR set-up and its data acquisition system.

electrical pulse captured using a digital oscilloscope. By using a Tektronix 468 or Tektronix 2430 scopes which has option of IEEE-488 interface bus, the digitised signal can be transferred to the IBM-PC or Apple II microcomputer. The computer is not only used for data acquisition and processing but also for controlling the firing of the laser, tuning the grating through a stepper motor, wavelength selection of the spectrometer and rotating the output mirror in front of the telescope. In fact, the front settings of the Tek 2430 scope can also be controlled by the Apple II or the IBM-PC through the IEEE-488 bus. In this manner, the Lidar set-up is essentially automated. This Lidar system is presently used for the monitoring of atmospheric pollution.

VI. Conclusion

The areas where a microcomputer can be applied in laser and spectroscopy research has been reviewed in this paper. The different functions of the microcomputer has been broadly outlined with specific suggestions on how these could be implemented. A specific laser experimental set-up has also been reviewed to give illustration on the importance of microcomputers in laser research. It is important that researchers in laser physics begin to acquire some technical knowhow of microcomputers in order to benefit from the tremendous advances that will be made microcomputers in the years to come.

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