Real-Time Data-Acquisition-System for Rf- and Laserspectroscopy.

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Abstract:

A low-cost real-time Data-Acquisition-System utilizing a master (PC-XT) and a slave (Z80) computer for high-resolution atomic spectroscopy is described. The master and slave computers are linked through a serial communication port and a high-speed parallel FIFO-interface permitting data-acquisition rates in the upper kHz-range. A modular interface-box allows the system to control complex spectroscopic experiments. The use of commercial software packages allows fast and efficient data reduction and analysis on the same computer system at a fraction of time and costs.

Introduction:

Spectroscopic investigations, i.e. the studies of emission and absorption of electromagnetic radiation by matter are the main source of our information about atomic structure.

Two principle experimental techniques have been utilized by our group for the determination of atomic structure. First, the Atomic-Beam Magnetic-Resonance (ABMR) method in combination with state-selective laser-induced detection of resonant atoms (rf-spectroscopy) has been used to determine hyperfine structure (hfs) and g_J-factors of such stable elements as Pb, Mo and Lu[1]. Also High-Resolution Laser Spectroscopic (HRLS) methods have been used to determine hfs and isotope shifts (IS) in elements with metastabile states[2] (e.g. Zr, Ne, Th).

In order to achieve a more exact measure of the hfs and the isotopic shifts rf- and laser spectrometers with higher sensitivity and resolution are required. This necessitates development of high-resolution computer automated spectroscopic methods (e.g. saturation spectroscopy). The Data-Acquisition-System (DAS) should be able to control the physical experiment in real-time and to process a large amount of spectroscopic data, in a fast and reliable manner. In this paper we describe a versatile PC-based DAS that meets these requirements.

Hardware-Description:

Powerful computer systems are normally necessary to control high-resolution rf- and laser spectrometers. Several criteria need to be considered in designing and implementing such a Data-Acquisition-System.

The response time of the DAS should allow real-time applications, with no limits set by the operating-system. In addition the whole DAS should be constructed in a modular way so that it may be used to control different experimental setups, with a minimum of time consuming hardware and interface modifications. The DAS should also be a convenient tool for the user. This means that the system should be easy to use and reliable. It should also allow fast and efficient program development and be easy to maintain.

In order to satisfy the above requirements, a two-processor-system configuration was selected. A two-processor-system offers the advantage, of separating the tasks of fast data acquisition and time consuming data processing. Thus the slave computer manages all the timing, data acquisition and experiment control; while the master computer stores and processes the data efficiently. The master computer uses a high level user friendly operating system. The hardware of the DAS then consists of three main parts:

(a) The PC-master computer. This computer interfaces with the user, and controls the data analysis and storage. (b) The Z80-slave computer. This computer controls the real-time data acquisition. (c) The interface-box (IOB). This box contains several standardized I/O-modules, which links the DAS to the physical experiment. Figure 1 shows the schematic of the whole system.

Fig. 1.: Block diagram of the Data-Acquisition-System

a.) Host computer:

An IBM[3]-compatible Personal Computer (PC-XT) was selected as the host computer because of its versatility and the availability of commercial hardware extensions and software packages. The main computer used in these experiments consisted of:

A PC-XT-compatible (8088/8 MHz) with 640-KBytes memory and a numeric coprocessor (8087/8 MHz). The system also used a 32-

MByte NEC harddisk (RLL[4] controller) and two floppy drives (1.2 MByte/360 KByte) for storage of the programs and spectroscopic data. The system was also configured with a high resolution monochrome monitor, a HERCULES-compatible graphics card (720x348 resolution) and an EPSON FX-100 printer. Input/Output was controlled by a multifunction card containing two serial ports (COM1, COM2), an additional parallel port and a real-time-clock (RTC). A home made parallel interface card was used to connect the Personal Computer to the Z80-slave computer. This interface card was equipped with 96 parallel I/O-ports and two 16-bit timers mounted on a PC-prototype board. In order to avoid stray pickup and to suppress signal distortion, dual-line drivers/receivers[5] were used to buffer the data-channels between the host and the Z80-slave computer. An optional HP IEEE-488 interface-card[6] may be used to link commercial measurement equipment (e.g. storage oscilloscope[7], HP spectrum analyzer[8], DMM) for experiment control to the computer.

b.) Slave computer:

The Z80-slave computer consisted of a modular europe-card-bus (ECB) system containing the following components:
(1) A Z80-CPU card (CMOS, 4 MHz) with 32 kB static RAM, 32 kB EPROM, and two parallel ports (Z80-PIO). (2) A parallel interface card (4 x Z80-PIO) to control the interface-box. (3) A serial Interface card (3 x Z80-SIO) for RS-232 communication with the PC host computer (19.2 kBaud) and for communication with the laser control-interface[9]. (4) A FIFO (First-In-First-Out) interface card (3 x Z8038-FIO) for high-speed data communication with the main computer. (5) A Timer card[10] (4 x Z80-CTC) for the exact timing of the measurements (using vectorized interrupts) and (6) an IOB driver card to maintain signal amplification of the I/O-modules.

A 16-bit parallel communication system between the host and slave systems using FIFO's has been chosen so that data may be transferred at a high data rate of approximately $4 \cdot 10^6$ bit/s and because of the asynchronous buffering of the data stream. Figure 2 shows a schematic of the host and slave computer communication provided by the FIFO's.

Fig. 2.: FIFO-communication between host and slave computer

c.) Interface-box:

A standard interface bus system has been implemented to guarantee system flexibility. There are 16 DATA-IN and 16 DATA-OUT lines for transmitting information from or to the experiment. The interface modules are controlled by 8 CONTROL lines and selected by 8 ADDRESS lines, allowing one to address a maximum of 256 I/O-modules. The hardware of the interface-box consists of the following modules:
(1) A voltage-to-frequency converter module[11] with two channels for voltage ranges of 0 - 2 V and 0 - 10 V, respectively. (2) A counter card (two 32-bit TTL-channels) to acquire calibration and measuring signal counts. The maximum count rate is 50 MHz. (3) A counter card (two 32-bit ECL-channels) for fluorescence photon counting up to a maximum counting rate of 150 MHz. (4) A parallel frequency decade[12] interface card for rf-spectrometer use. (5) A single-bit In/Out (16 bit) card to control digital signals (e.g. error signals) during experimental run. The interface-box block diagram is shown in figure 3.
The Z80-slave computer and the interface-box complex are contained in a standardized 19" housing. Due to its modular design a maximum of flexibility has been achieved allowing modifications and replacement of ECB- or I/O-modules without affecting the rest of the acquisition system.

Fig. 3.: The Interface-box contains several I/O-modules to link the DAS to the experiment.

Software-Description:

The controlling software is divided into two independent programs. The Z80-slave computer is responsible for the 'on-line' acquisition, and the PC-host computer is responsible for the data processing and storage. The software is written in the FORTH programming language[13], to facilitate convenient operation with large portions of data (without a 64kB limit) and to provide for the possibility of including machine language routines for direct memory control and I/O-port access. The FORTH-kernel and all its primitives (e.g. host communication, controlling the counters, setting the rf-decade) are ROM resident, to facilitate autonomous operation of the slave computer.

The actual measuring program is then loaded by the user into the Z80 RAM-memory. Program modifications and maintanence are then easily performed at the Personal Computers console by the user. The PC resident terminal program also enables the user to modify parameters (or even the measuring program), and to log on to the slave system. During an experimental run, the user is able to switch between the host and the slave. The operation software provides for the following options:

(1) Controlling the experiment in real-time. This means sweeping the dye laser (or controlling the rf decade) and reading the counters. (2) 'On-line' mode: displaying of the fluorescence signal on the PC monitor and its storage to host RAM, 'off-line' mode: reading of the counters and buffering the measured data in the memory of the Z80-slave. (3) Storing of fluorescence and calibrating etalon signals along with the operational parameters on the harddisk. (4) Menu driven to guide the user ~~for~~ through the experiment and to provide convenient help facilities.

The PC also offers sufficient computing power for off-line analysis (lorentzian/gaussian curve fits) of the measured data. These may be compared with the results of a spectra simulation program, written in Turbo-Pascal[14]. A hardcopy of the spectra may also be sent to a graphics printer or to a plotter with no loss of resolution. For further mathematical processing of the measured spectra, the spectroscopic data may be transferred to commercial software packages (e.g. ASYST, SYMPHONY) or even to an IBM 3081 mainframe with advanced number crunching capabilities.

Experimental Arrangement:

The performance of the PC-DAS has been checked by measuring the hfs and IS of the neutral zirconium atom. A schematic diagram of the experimental arrangement used in the measurements of the ZrI-spectrum using the polarization spectroscopic method is shown in figure 4. It includes the discharge tube, additional equipment for monitoring the laser output, and the DAS. The laser system used in these experiments was a Coherent Radiation (model CR 699-21) single-mode dye laser, pumped by a Spectra Physics (model 171) Argon-ion laser. The single-mode operation of the laser was monitored by a scanning Fabry-Pérot interferometer (FSR = 2 GHz). The frequency scan of the laser was calibrated with a fixed 60 MHz reference cavity[15] (confocal FPI) and the fringes were monitored on the DAS along with the polarization-spectroscopic signal. In order to find the proper wavelength, a digital wavemeter with a Zeeman stabilized He-Ne reference laser was used. In this experiment the laser frequency was swept and the polarization signal was detected phase-sensitively by a lock-in amplifier (Ithaco, model 5206). The lock-in voltage was measured as a function of the laser frequency. A typical spectrum corresponding to the a $^3F_2$ <-> z $^5F_1$ (0 - 16788 cm^{-1}) transition in ZrI is shown in figure 5. At the top of the figure the 60 MHz fringes (used as frequency markers) are shown. In this way, isotope shifts of the neutral Zirconium atom have been measured by Doppler-free laser polarization spectroscopy[16]. Hyperfine structure measurements and parametrization results of hfs and IS will be published elsewhere[17].

<u>Fig. 4.:</u> Experimental Setup

<u>Conclusion:</u>

The PC-DAS is a powerful instrument for use in rf- and laser spectrometers with a wide variety of potential applications. Such a system based on an IBM-compatible Personal Computer and a Z80-slave computer was successfully applied in High-Resolution Laser Spectroscopy. The system performs real-time data acquisition in the sampling time range ≥ 100 µs. The present realization (two-processor-system) has the advantage of a very fast system-response, consisting of standardized components and is widely expandable. Hardware expansions could be performed at the interface-bus (e.g. A/D-, D/A-converters) or by exchanging the PC-XT console with a PC-AT (16 bit) or even a 32-bit-technology computer machine. Future versions of the software will utilize correlation techniques and on-line numerical analysis to totally reject bad scans and to achieve maximum data reduction. Thus, the ability to analyze the scan immediately on the <u>same</u> computer is an appealing feature. Further software improvements might also be added using commercial software packages and software-tools running under the PC-DOS operating system.

Fig. 5.: Measured ZrI-Spectrum of the a $^3F_2$ - z $^5F_1$ transition, at 595.535 nm wavelength.

Acknowledgement:

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rf-spectroscopy, laser spectroscopy, hyperfine structure, isotopic shift, g_J-factor, atomic-beam magnetic-resonance, high-resolution laser spectroscopy, laser-fluorescence, laser-induced detection, polarization spectroscopy

real-time, data-acquisition-system, host computer, slave computer, personal computer, on-line, off-line, IEEE-488, ECB, TTL, ECL, VFC, FIFO communication

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Figure Captions:

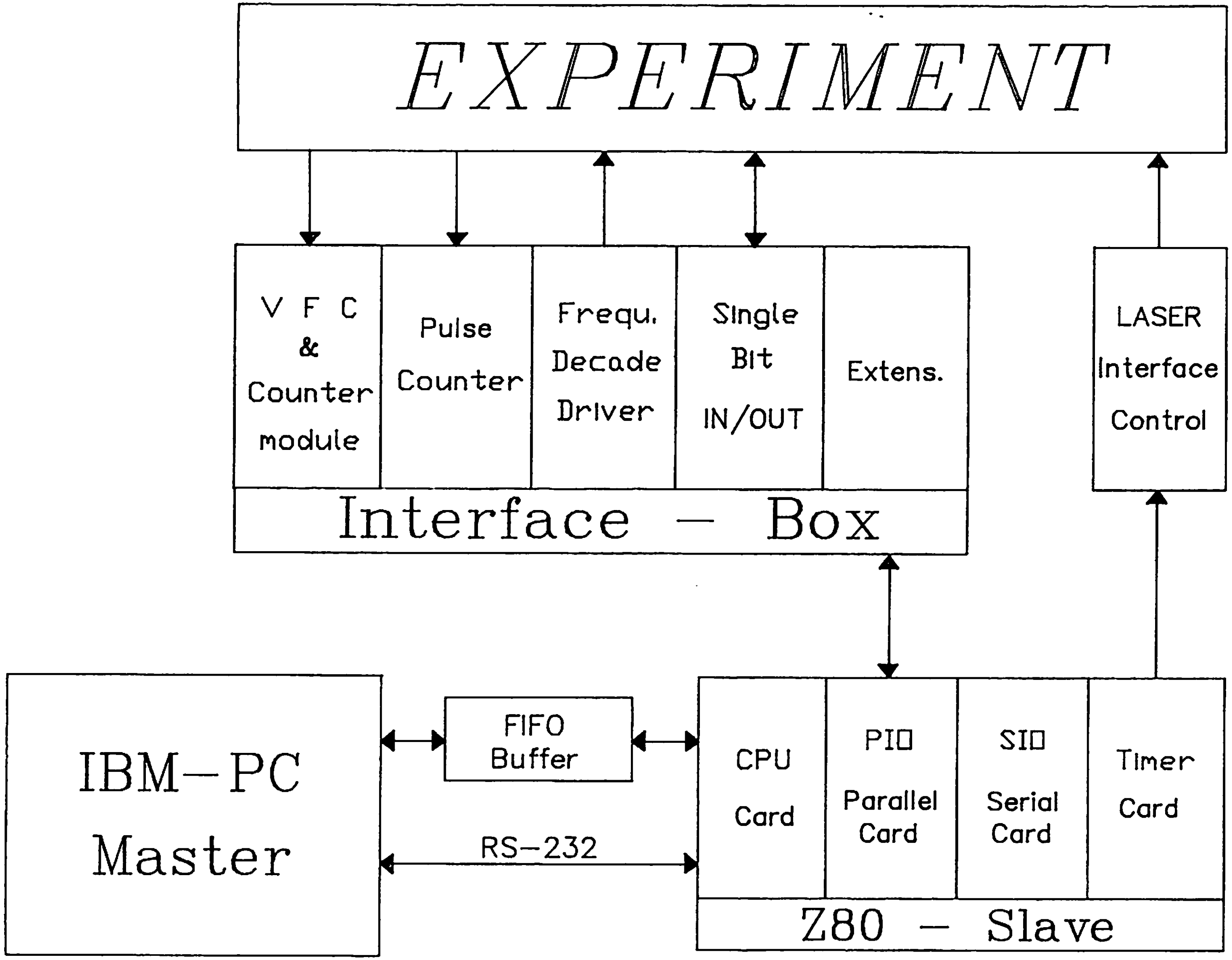
Fig. 1.: Block diagram of the Data-Acquisition-System

Fig. 2.: FIFO-communication between host and slave computer

Fig. 3.: The Interface-box contains several I/O-modules to link the DAS to the experiment.

Fig. 4.: Experimental Setup

Fig. 5.: Measured ZrI-Spectrum of the a $^3F_2$ - z $^5F_1$ transition, at 595.535 nm wavelength.


EXPERIMENT
V F C
&
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module
Pulse
Counter
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Decade
Driver
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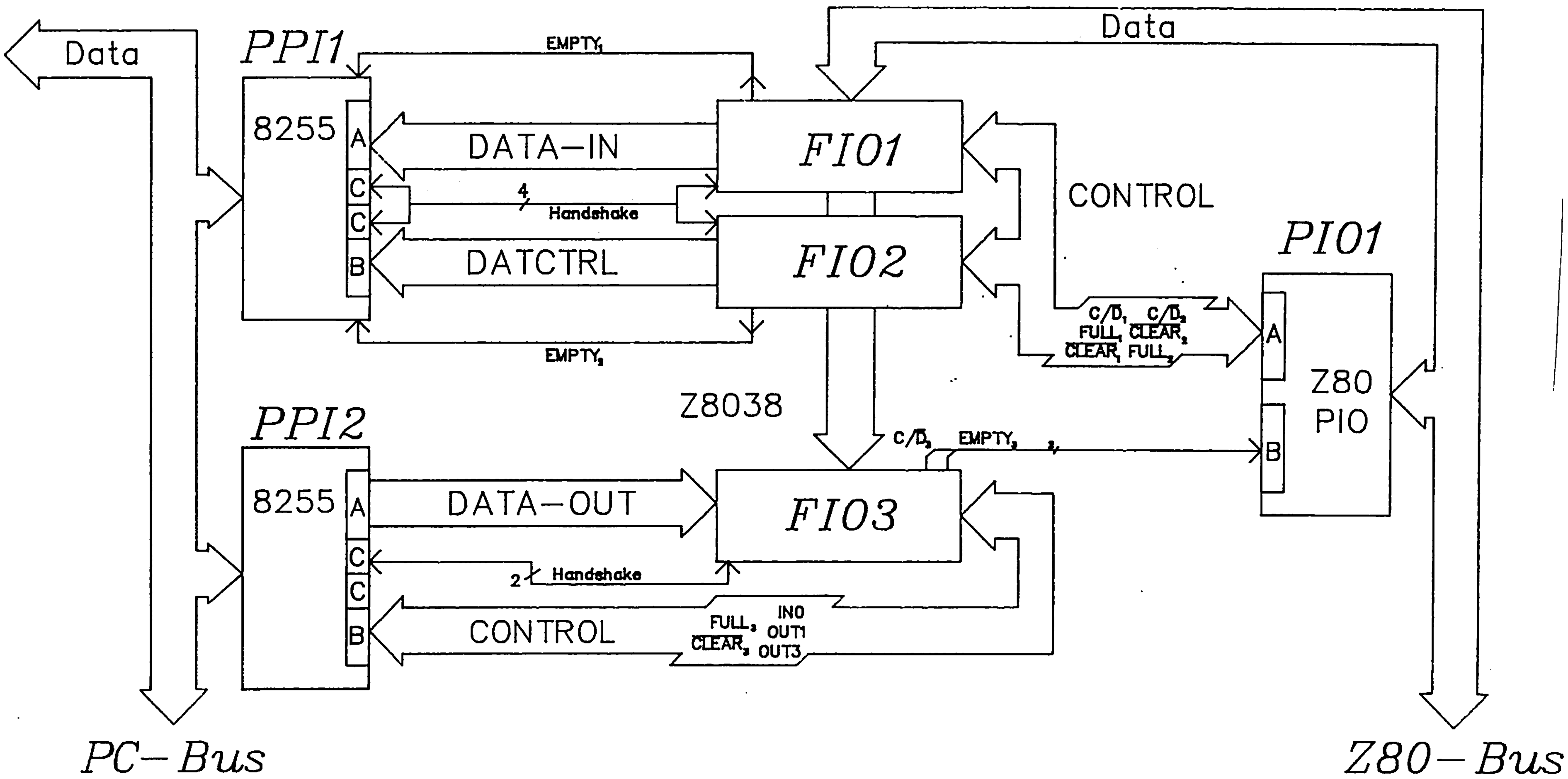
LASER
Interface
Control
IBM–PC
Master
FIFO
Buffer
RS–232
CPU
Card
PIO
Parallel
Card
SIO
Serial
Card
Timer
Card
Z80 – Slave

Fig. 1.: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DATA-IN
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Handshake
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EMPTY2
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CONTROL
Data
PIO1
C/D1 C/D2
FULL1 CLEAR2
CLEAR1 FULL2
A
Z80
PIO
B
Z8038
C/D3
EMPTY3
2
PPI2
8255
A
C
C
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OUT1
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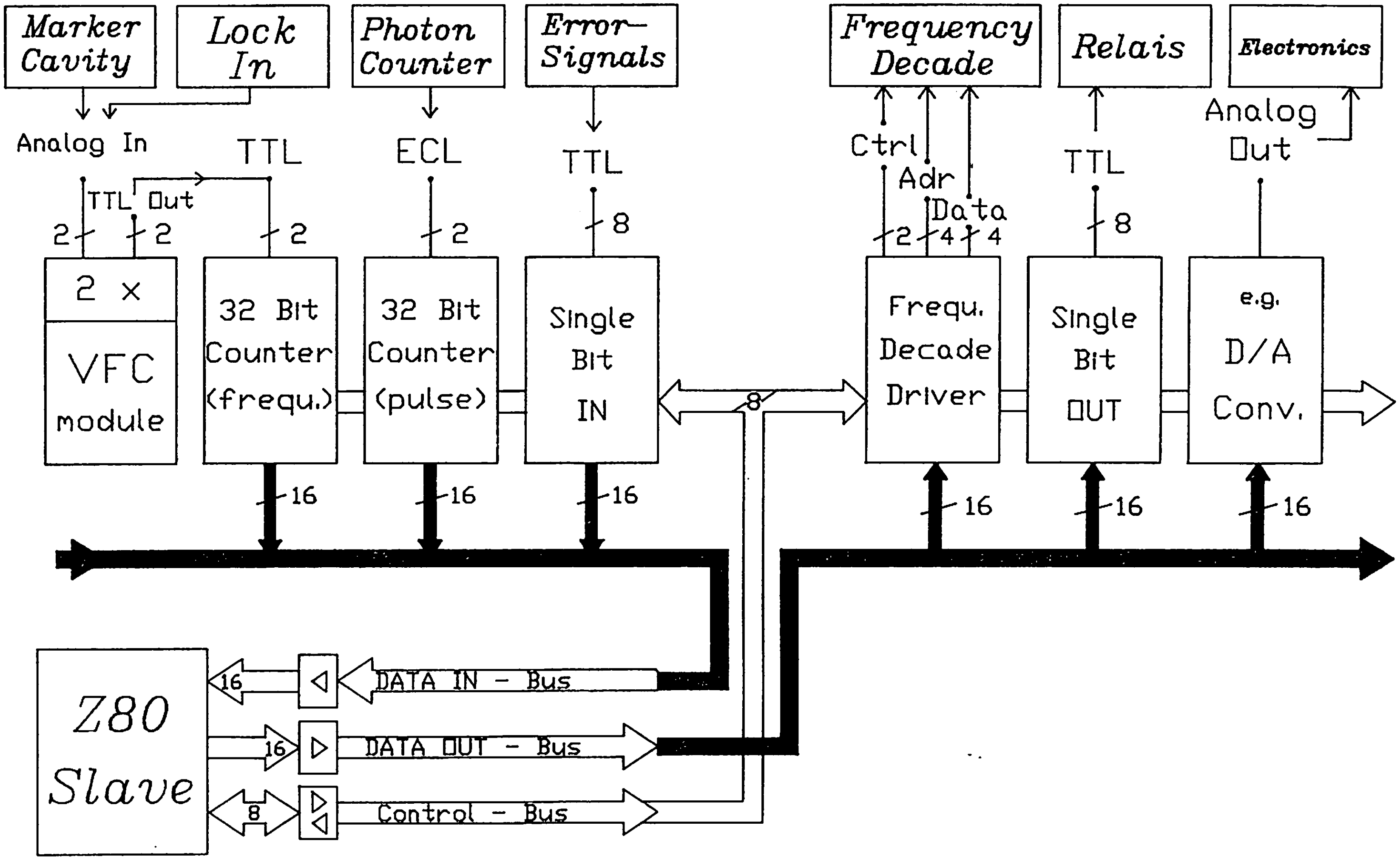
PC-Bus
Z80-Bus

Fig. 2.: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Lock In
Photon Counter
Error-Signals
Frequency Decade
Relais
Electronics
Analog In
TTL
ECL
TTL
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Adr
Data
TTL
Analog Out
TTL Out
2
2
2
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8
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4
4
8
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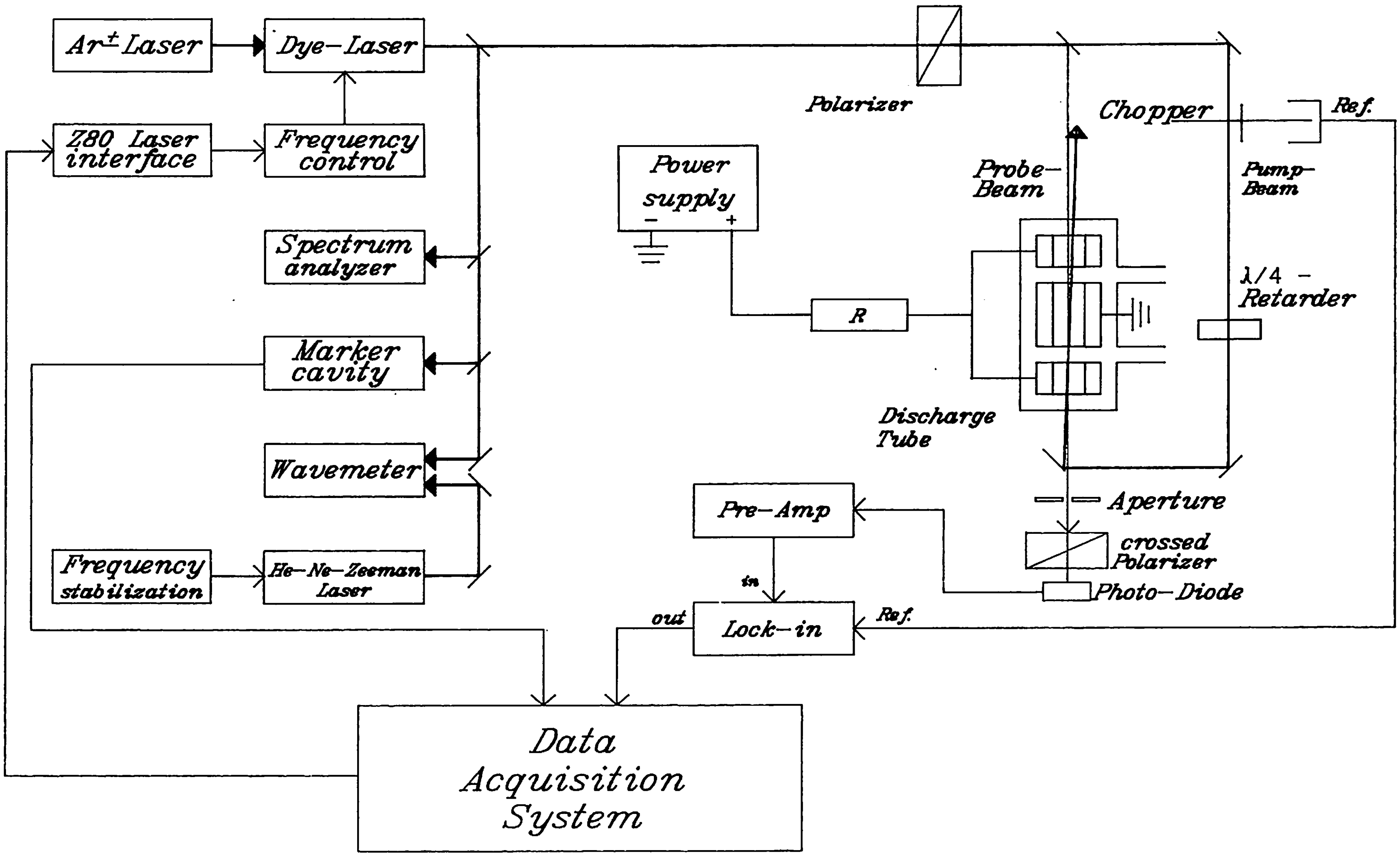
VFC module
32 Bit Counter (frequ.)
32 Bit Counter (pulse)
Single Bit IN
8
Frequ. Decade Driver
Single Bit OUT
e.g. D/A Conv.
16
16
16
16
16
16
Z80 Slave
16
DATA IN - Bus
16
DATA OUT - Bus
8
Control - Bus

Fig. 3.:


Ar± Laser
Dye–Laser
Z80 Laser interface
Frequency control
Spectrum analyzer
Marker cavity
Wavemeter
Frequency stabilization
He–Ne–Zeeman Laser
Polarizer
Power supply
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Chopper
Ref.
Probe–Beam
Pump–Beam
λ/4 – Retarder
Discharge Tube
Aperture
crossed Polarizer
Photo–Diode
Pre–Amp
in
Lock–in
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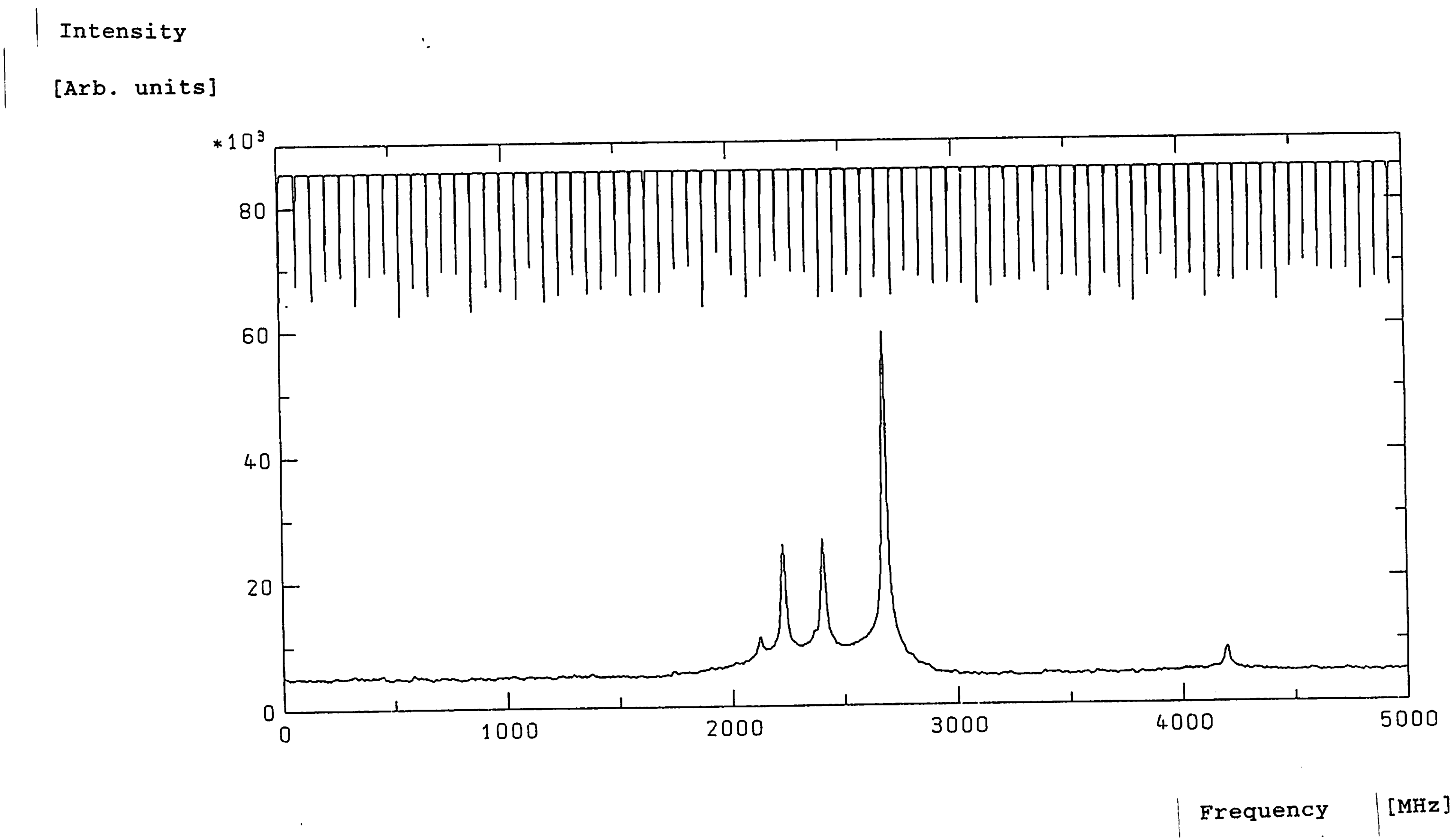
Ref.
Data Acquisition System

Fig. 4.: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5000
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Fig. 5.: