PERFORMANCE OF ROTAX

H. Tietze-Jaensch[1,2,3], W. Schmidt[1,2], R. Geick[1]

1.) Physikalisches Institut der Universität Würzburg, Am Hubland, 8700 Würzburg, F.R.G.
2.) ISIS Facility, Rutherford Appleton Lab., Chilton OX11 0QX, U.K.
3.) Institut f. Festkörperforschung, KFA Jülich, Pf. 1913, 5170 Jülich, F.R.G.

Abstract

The rotating crystal analyser spectrometer ROTAX started commissioning in October 1992, yet a general survey about the state of the project is given.

The general capability of ROTAX has been presented and discussed in detail at the last ICANS XI held at KEK, Japan in 1990. Therefore, we now concentrate on improvements, new developments and particular problems: A) technical feasibility and reliability; B) multiplex advantage, intensity and background; C) basic and advanced operation scheme of ROTAX, in particular synchronisation and veto action; D) operation schedule.

1. ROTAX instrument

Unlike other crystal analyser neutron spectrometers ROTAX uses a programmable non-uniformly spinning analyser crystal in order to scan almost freely the energies of the neutrons scattered and deflected by a single crystal sample placed in a white pulsed beam. On ROTAX this gives a superior flexibility and versality to perform particular scans throughout the (Q,ω)-space when compared with competetive machines. The principles and many details about ROTAX have been discussed in length elsewhere [1-3]. In a series of test experiments using a provisional setup of the ROTAX spectrometer on the ISIS Test Beam facility it has been proved that ROTAX does fulfill standard expectations to an inelastic coherent neutron spectrometer. In fact, the intensity performance was competetive with a setup of a standard crystral analyser spectrometer [3], angular accuracy and technical reliability of the ROTAX motor drive and the overall scan versality were proved satisfactory under realistic conditions at the ISIS test beam. This has lead to the decision to finally build ROTAX at its own construction site behind PRISMA [4] on the N2 beamline of ISIS.

Fig. 1 shows what ROTAX looks like: a large area Tanzboden-like concrete floor is enclosed to a wax tank blockhouse for shielding. The spectrometer components are remotely operated and moving on air pads. Three different sample positions are provided to adjust the scattering geometry to the individual requirements of a particular experiment. The sample tank is made to the RAL standard granting access to all sample environment equipment available at ISIS. The Germanium analyser crystal is of cylindrical shape, 5 cm in height and 1.2 cm in diameter. Other analysers are under consideration for later use. The linear position sensitive JULIOS scintillaton counter, devised by KFA Jülich [5], is used on ROTAX.

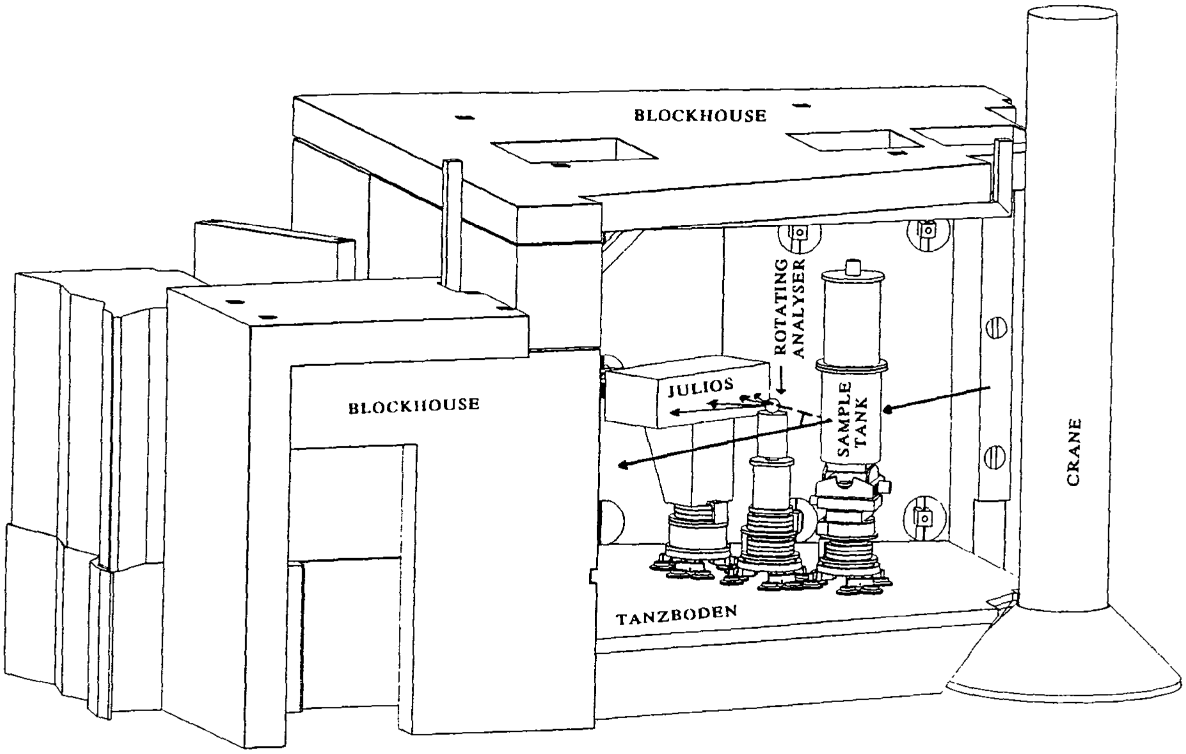


Fig. 1: The ROTAX hardware installed at the N2 beamline at ISIS

2.) present status

Very recently, ROTAX has become operational, but still runs at a first stage of limited operation control comfort.

After basic development and construction was finished, ROTAX started commissioning on 20 October 1992 with actually opening the neutron beam in the ROTAX shielding blockhouse. All major components, i.e. the detector, the analyser drive and the whole mechanics, i.e. the various rotational stages, sample alignment, analyser and detector support frames and double pivoting arm, are installed and at present operated by individual PC controls. In fact, the JULIOS detector actually used is a loan from KFA Jülich. Our own unit is in manufactoring process and expected for installation later this year.

A major improvement has been achieved with the accuracy and reliability of the ROTAX analyser drive: the digitally controlled gear-less direct drive is now entirely software controlled. The advantages are: a) much improved angular accuray, now at a max. angular misfit of $\Delta\Theta_A < 0.15$ deg, b) on-line verification of desired and achieved performance at 10kHz sampling rate (100 μs), c) on-line dynamic correction scheme according to the dynamic response function of the regulator/motor drive system [6], d) permanently guaranteed and stabilised regulation parameters over the whole range of technically feasible drive parameters without any operator's interaction, e) hardware independence and portability of the drive control program. All the user of ROTAX needs to do is to think of a desirable and suitable TOF-scan throughout (Q,ω) space and then to check technical feasibility for his particular ROTAX-scan with the aid of our instrument control program and finally dump the desired anayser scan curve in a file that is read by the signal processor running the analyser motor control.

At present we are working on the integration of all the individual components to one whole system. Nevertheless, all major components (mechanics, analyser, detector) are individually operational already. The timers of the detector and the motor drive are not yet synchronised, which needs the full implementation of the transputer board and interface. Until now, they are externally triggered by a common pulse signal that indicates the start of a neutron pulse at the moderator. Time resolution now is ca. 2-3 μs.

3.) results

3.1.) multiplex advantage

Longitudinal acoustic phonons of Aluminium were measured with ROTAX using the Ge-(220) analyser. Within the accessible time window of 3.5msec and 11.5msec of an ISIS frame the Al-(200) and Al-(400) Brillouin zones were scanned simultaneously with a constant-Ψ scan. In fact, 3 individual phonons of the LA(100) branch of Aluminium were traced with only one TOF-curve, namely the phonons at a) $\hbar\omega=3$meV, $q=0.05$, b) $\hbar\omega=10$meV, $q=0.1$, c) $\hbar\omega=12$meV, $q=0.11$. This multiplex advantage can be quantified as follows: If n time channels are used simlutaneously the spectrometer performance is improved by a factor $\sqrt{n}$ as compared to measuring each time channel separately ain a sequence of measurements with the same total measuring time in both cases.

Additional multiplex advantage is obtained from the 2-dimensional neutron data acquisition. The JULIOS detector counts neutrons in position (x) and total time-of-flight (t) channels; the position channel is correlated with the analyser Bragg angle. Hence, every single detector pixel is uniquely correlated with one particular space element ($\Delta Q, \Delta\omega$) in (Q,ω) space, thus, we can plot the original detector data in (x,t) coordinates together with the traces of the sample's reciprocal space and the traces of energy transfer hω. Fig. 2 presents such a plot; for reason of clarity, only 3 levels of intensities are shown. No further intensity correction or background suppression has been applied. The long dashed lines correspond to Q_x and Q_y, short dashed lines to energy transfer. The solid track along $Q_y=0$ is, in fact, the scan path used by ROTAX. It is worth to monitor the distribution of intense pixel along and aside the actual scan path, because this is an immediate image of the actually achieved resolution in (Q,ω) for that particular scan. Furthermore, from this 2-dimensional data-set cuts along constant energy or constant-Q directions can be calculated to obtain directly the peak width in these dimensions. However, computational problems in proper normalisation may occur, because every detector pixel is linked to a ($\Delta Q, \Delta\omega$) element of different and varying size. For details, refer to W. Schmidt, session A6, this ICANS XII workshop.

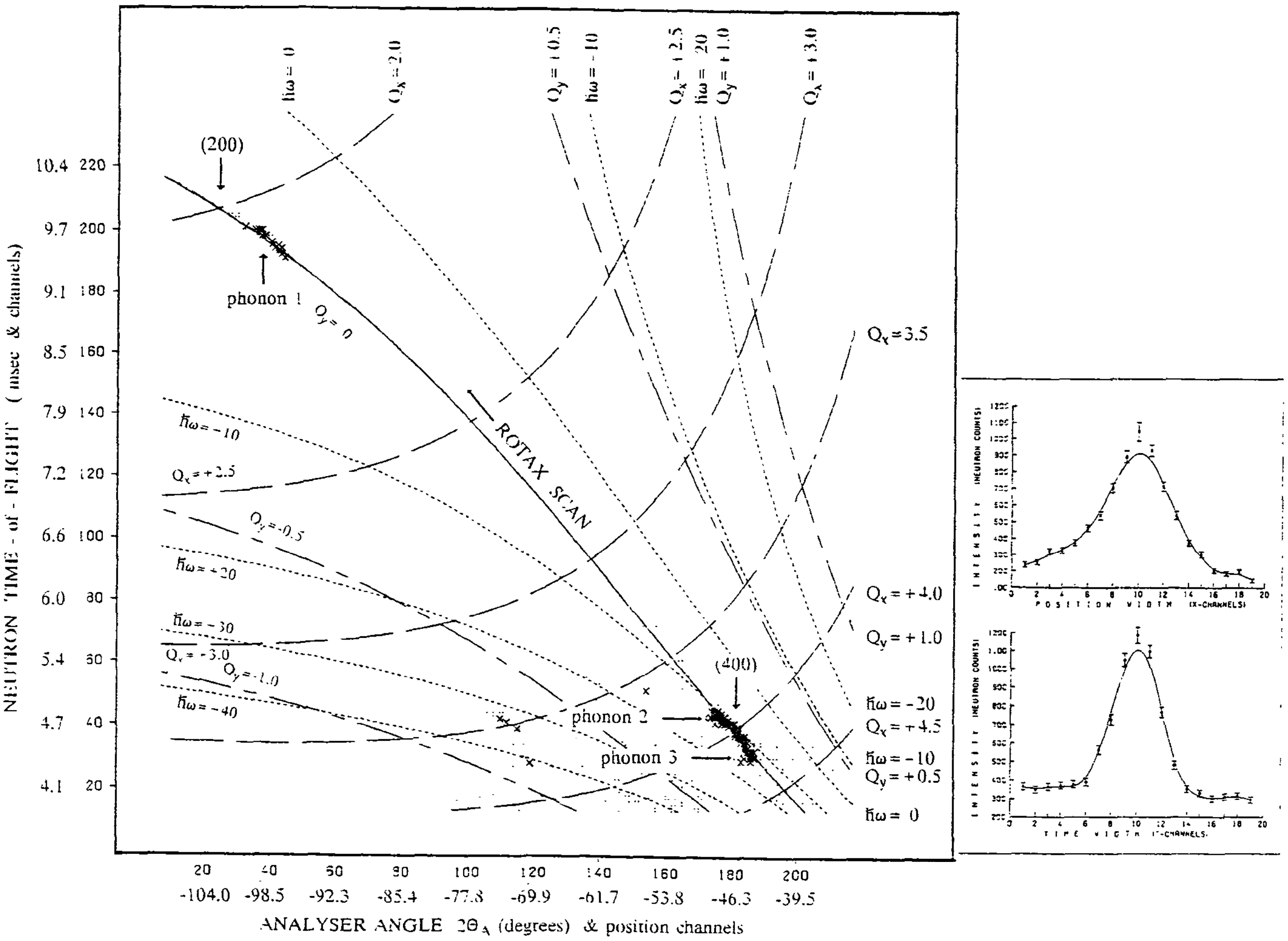
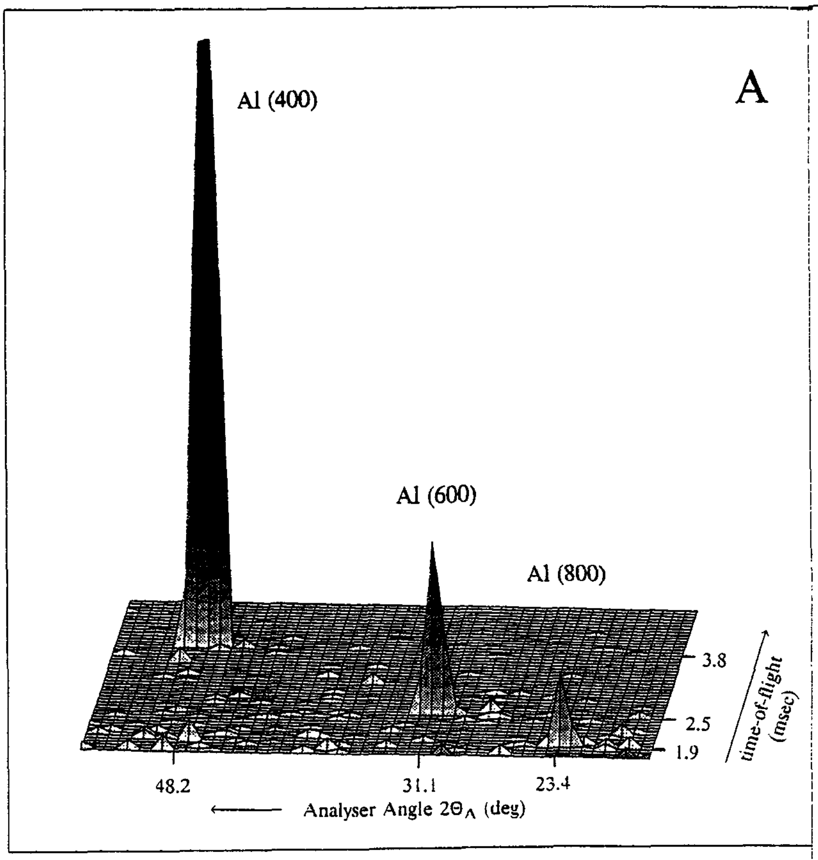


Fig 2: Inelastic neutron scattering on ROTAX showing several LA(100) phonons of Aluminium in the original position and time coordinates of the detector display. The traces of i) the ROTAX constant-Ψ scan, ii) the Q-space in units of the reciprocal lattice of Al and iii) of the energy transfer $\hbar\omega$ in meV are also shown. On the right the intensity profile of phonon 1 is shown along position and time channels

3.2.) background suppression with ROTAX

A very interesting and more general feature of ROTAX is its dynamic background suppression, because the rotating analyser grants access to the detector only those neutrons, that fulfill the analyser's Bragg condition at the desired time channel. This pronounced effect can be seen very clearly in fig. 3a) showing 3 Al-Bragg peaks, that are rotaxed simlutaneoulsy in 10 min total measuring time. To perform the same experiment with an idle, non rotating analyser needs to perform 3 individual measurements consecutively, fig. 3b. This does not only take more then twice the total time, neglecting spectrometer setting and positioning time, even more



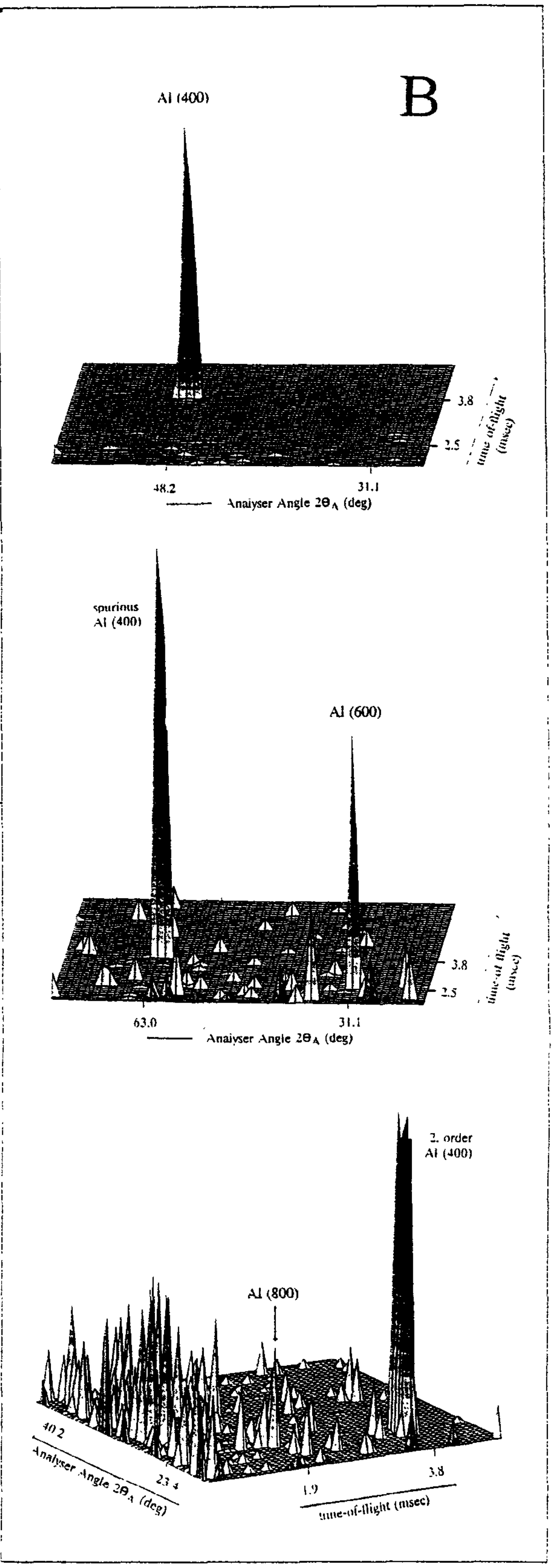


Fig. 3: a) series of simultaneously rotaxed Al-(h00) Bragg peaks with considerably reduced spurious background scattering; b) the same series of AL-(h00) Bragg peaks in 3 consecutive measurements using a non-rotating analyser: terribly increased spurious and second order scattering.

striking is the effect of additional spurious background and second order scattering, that cannot be suppressed by the static analyser condition used on all conventional crystal analyser spectrometers. In fact, it would be very hard to detect the weak Al-(800) Bragg peak from the bottom intensity pattern shown in fig. 3b, unless it was known precisely where about to search for. This particular pattern was obtained after the same total measuring time of 10 minutes as the one shown in fig. 3a.

4.) basic and advanced ROTAX operation

In principle ROTAX consists of 3 major parts: i) the rotating analyser and its drive control, ii) the detector and iii) the control of all auxiliary equipment such as the suite of rotational stages, goniometer, sample environment etc. that are needed to set up an experiment properly. In fact, all these units are operational on ROTAX in a stand-alone mode yet. This may be considered satisfactory as a fall back level and is very suitable for error checking and maintenance. It is, however, not very recommendable for a user run mode, where the control of the machine from one unique command level is admired. In addition, there are technical reasons as well to fully integrate namely the detector and analyser motor control into one single interaction shell.

In fact, the correct visualisation and interpretation of detector data relies crucially on the proper knowledge and, hence, monitoring of the actual motor performance. And, last not least, it must be guaranteed, that both the detector and rotating analyser are well synchronised with the neutron source ISIS and that they both run at the same and unique absolute instrument time. Naturally, neutrons travel at their own time scale, that has to be matched. However, neutron pulses start with a certain unpredictable irregularity and this fact means that every active spectrometer component has to be triggered on and rephased with every incoming neutron master pulse. The logic to synchronise active (moving) components of ROTAX with ISIS is shown in fig. 4. ISIS issues an absolute time-zero signal to start a neutron frame. Its repitition frequency is 50 Hz ± a tolerance value, which is usually very small: approx. ±400ns. The ISIS time zero refers to the time-zero channel of the digities desired motor curves, in fact, there are two, one for the analyser angle Θ_A, a second one for the analyser's angular speed ω_A. For both, a certain bandwidth is tolerated. The event of the ISIS time zero signal causes the signal processor to reset to its time zero channels for Θ_A and ω_A. This causes the first regulation amplitude on the ROTAX motor drive, it can be as much as 2 degrees. However, the regulator would not realise this angular error until the next ISIS signal to occurr. Therefore, it is inevitable to fine tune the synchronisation with an additional 1 MHz counter for the time Z (cf. fig. 4) between the ISIS zero signal and the next subsequent signal processor clock tick. The fine tuning produces another offset to the desired scna curve in every frame and guarantees the syncjronisation between the processor clock and ISIS.

The same logic is also used to synchronise the anticipated frame length of 20ms to the real frame length of ISIS that is not always at 50 Hz. There are periodic undulations in minute time scale as well as unphased statistical beam trips. On ROTAX the analyser goes immediately stand-by if only one missing ISIS pulse was to be detected. And it will not resume operation, unless an adjustable number of consecutive frames (100 at present, i.e. 2 sec) in the appropriate repitition frequency window has been encounted for.

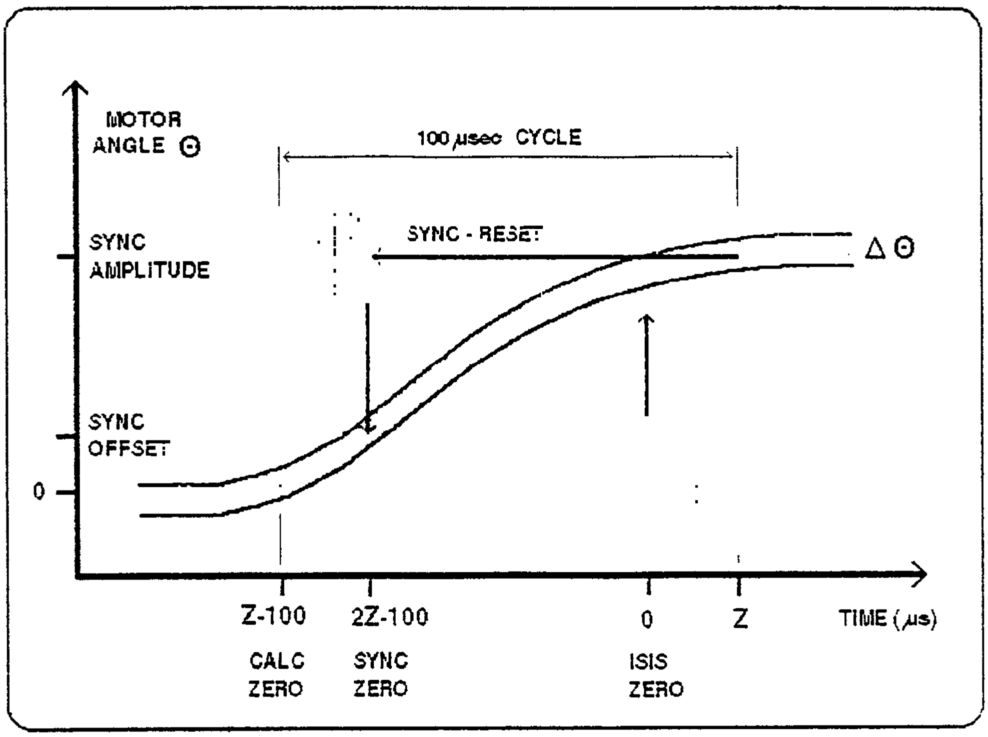


Fig 4: the scheme to synchronise the ROTAX analyser motor with ISIS

This veto scheme for the ROTAX analyser can be used also to hook up other kinds of vetos or machine disruptions. Moreover, a whole individual veto and action scheme can be put into force. On ROTAX, for instance, it will be likewise:

A) vetos:
analyser motor out of desired range
motor running hot
ISIS off 50 Hz
detector idle
shutter closed
sample environment out of range
...

B) automatic action scheme:
control program to monitor vetos
encount absolute time
determine event type
analyser motor to go stand-by or resume
detector suspend/resume counting
issue user information/warnings
...

The logical structure of ROTAX is compiled in fig. 5 and as more and more recently designed spectrometers employ dynamic or active components, we feel that our specific solution may be of general interest. The user of ROTAX does not neccessarily take much notice of the automatic veto/action scheme unless a severe malfunction has occurred that could not be rectified by the machine itself. In this case the experiment will be aborted or in minor case a warning will be issued onto the console terminal and logfile. His job, however, is to create an initial experimental set-up with an idea of the scattering geometry and particular ROTAX scan he requests. By then, typing in a number of commands, the mechanics will move to the anticipated angles, the detector starts counting and the signal processor reads the desired ROTAX scan curve of the analyser and starts rotating it. The actually achieved motor position is montiored by a fast incremental decoder and fed back to the regulation unit every 100μs, i.e. 10 kHz sampling rate. At this rate, regulation feed-back action can be taken by the motor's main amplifiers. However, the actual motor performance can be read with much higher sampling rate of 1 MHz into the transputer system. If ROTAX is operated at its power limits, then its real TOF-trace in (Q,ω) space can be calculated within a few ISIS frames. The user can then decide to veto out these frames or to keep them, if they are not too far from their anticipated target. In addition, the user can create a modified, more precise ROTAX scan to run. Fig. 5 shows ROTAX of its final design. At present, there is not yet a synchronisation between detector and analyser motor, nor is there any on-line data feed-back to the computer system. Instead, a scope is used to verify the analyser motor performance and all control commands are to be issued on different computer keyboards of the μVAX and 2 PCs.

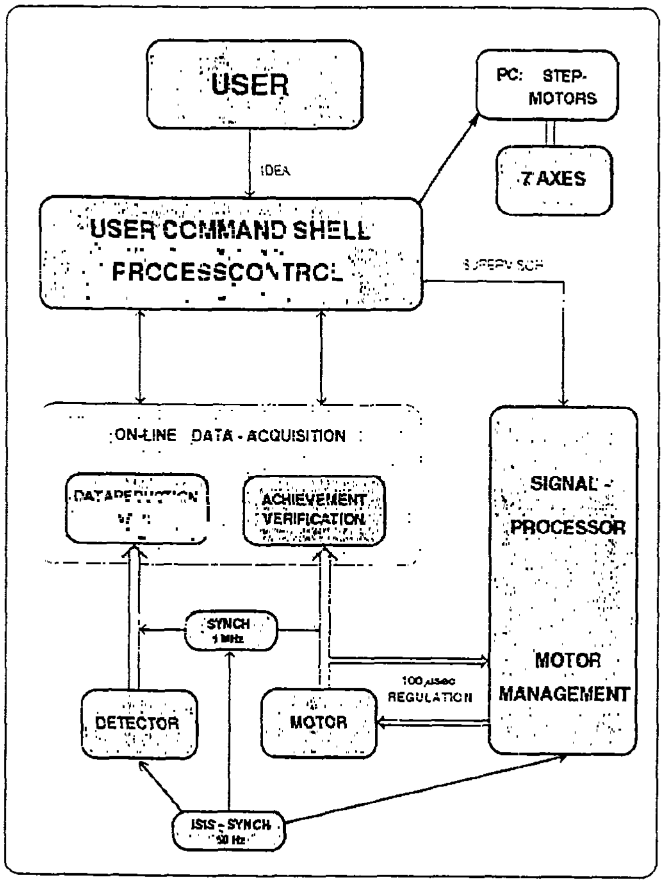


Fig 5: Logical structure of ROTAX

Technically, the full ROTAX design structure can only be accomplished by using one general computer with one common interface and a precise real-time clock. Because of the very high data rates to be acquired, on ROTAX we have an input load of 2 x 16 bit parallel data at 1 MHz rate, in total 3.2 Mbaud, this cannot be done with present PC, VAX or RISK workstation machines. A technical solution for ROTAX is currently developed, using a specifically designed transputer interface board with 4 dual SRAM input buffers and the general real time clock. A number of transputer links are set up in a few μs of time to forward the data to subsequent transputer nodes that run the veto-interaction and data reduction software. All data are finally stored in VAX accessible files. The hardware was tested successfully, the software still needs further development and improvement.

5.) ROTAX operation schedule

ROTAX has become operational at its first stage already. Further improvements are to come, the final detector will be installed later this year and we look forward to opening ROTAX as a scheduled instrument to the public by the late autumn 1993. One half of the available beam time on ROTAX will be under control of the ISIS selection panel, the other half will be controlled by a German board, still to be installed.

The fully advanced feature of ROTAX will be in place as soon as resources will allow us to complete.

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