TIME PULSE PROFILES ON A NEW DATA ACQUISITION SYSTEM FOR NEUTRON TIME OF FLIGHT DIFFRACTOMETER

R. VENEGAS, L. BAEZA, G. NAVARRO
Comision Chilena de Energia Nuclear,
Centro Nuclear de La Reina,
Santiago, Chile

XA9949660

Abstract

A new differential acquisition system was built for a neutron diffuse scattering instrument. We analyze the time, space and velocity behavior of neutron pulse profiles, which can be obtained in a neutron diffuse scattering system of this nature, consisting of a black disc slit chopper and a circular detector bank, in order to design accurate scattering data analyzing methods. Computed direct pulse time spectra and measured spectra show statisfactory agreement.

1. Introduction

Diffuse scattering of neutrons by solid samples using wavelengths longer than Bragg scattering may be used as a tool for examining long range ordering, or defect structure. Whether Bragg scattering is a main tool for a description of the average unit cell of the crystal, the analysis of diffuse (incoherent) scattering is useful to obtain information concerning departures from this average structure, and in special case, for the analysis of inelastic scattering cross sections on solid systems. Many studies using incoherent elastic scattering and inelastic scattering of neutrons on solid and liquid systems have been performed on neutron spectrometers based on simultaneous analysis of neutron velocity and scattering angle, having a similar design to the instrument we discuss here. The neutron beam for this spectrometer is provided by a 5 MW MTR light water reactor at the La Reina Nuclear Center labaratories. Beam flux from this type of reactor is low, and the data acquistion system must be very efficient to collect most of the information in short operating runs.

Two problems associated to this kind of instruments are 1) the need of sufficient counting statistics to have a reasonable signal/noise ratio and b) the eventual mixing of elastic and inelastic scattering. While the first problem can be reduced by an appropriate design and optimisation of the data collection system to obtain the best performance when using a given of sufficiently low energy, the instrument may serve the purpose of inelastic scattering experiments. By the contrary, when the inelastic transitions occur outside the instrument range of Q values available for observation, a situation that is not uncommon, the instrument allows the observation of elastic scattering.

Here, after a brief reminder of the instrument details, we describe an optimised data acquisition unit which was built with the purpose of a simultaneous time differential analysis on every angular position available, in order to obtain the maximum possible data collection capability during operation time. Besides, a stopping motor computer controlled sample changer has been built, to allow the accurate (better than 0.05 mm error in position responsability) change of a minimum of 4 samples, required for calibration during each measurement run. Differential time profile has been measured for $\theta = 0^o$. The agreement between computed and observed time profile for $\theta = 0^o$ shows that the instrument is reliable for the study of differential neutron scattering cross sections.

2. The "Glopper" diffuse scattering time of flight apparatus

Figure 1 shows the schematic presentation of the diffuse scattering instrument at CEN-LA Reina. This consists of a polycrystalline Bi-Be filter, followed by a Fermi type "parallel beam-axis" chopper, sample changer and holder, two U fission chamber monitors and a radial detector bank.

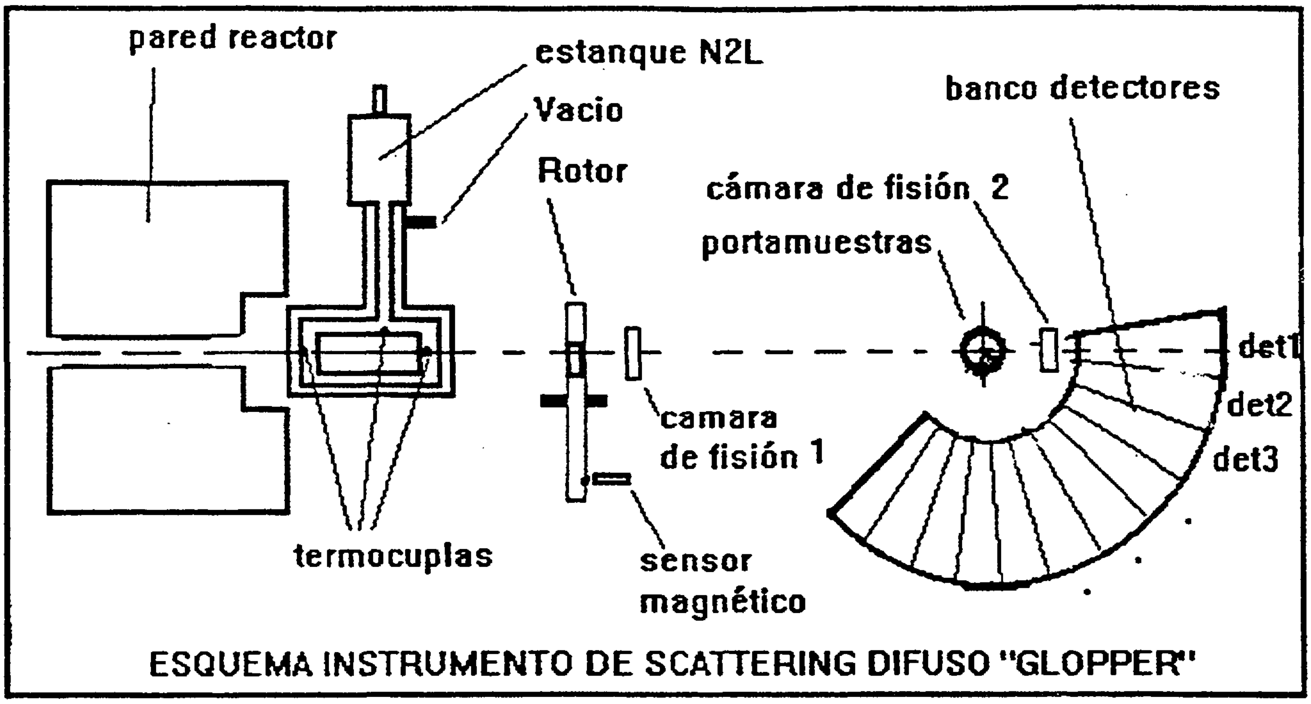

FIG. 1. Shematic presentation of the diffuse scattering instrument "GLOPPER" at the CEN-La Reina (Chile)

The Be filter removes neutron wavelengths with l≤3.99 Å (removing neutron energies above 5 MeV, or velocities above 1 m/μSec) and the Bi filters decreases the γ ray contents. The filter is cooled at liquid nitrogen temperature to avoid neutron intensity reduction inside the crystal due to inelastic scattering. The chopper is a thermal neutron absorber rotor disc fitted inside of an aluminium casing with six regularly spaced 2cm x 2cm square apertures oppening near the disc border, to pulse the beam. The disc rotates at a nominal speed of 3000 RPM, and a pulse repetition time of 1.67 mSec at a distance of 1.6 m from the chopper disc (Figure 2). A coil pick up generates magnetic trigger signal from the passage of a steel pivot placed at an accurate distance from each rotor window. The time of flight detector bank consists on a multiple He detector assembly, each detector mounted vertically, placed inside of a shielding case and spaced regularly on a circle sector of 1 m radius. Two monitoring fission chambers are placed, one after the chopper tube aperture and one at the front position on the detector bank, to monitor the beam before and after air/sample scattering.

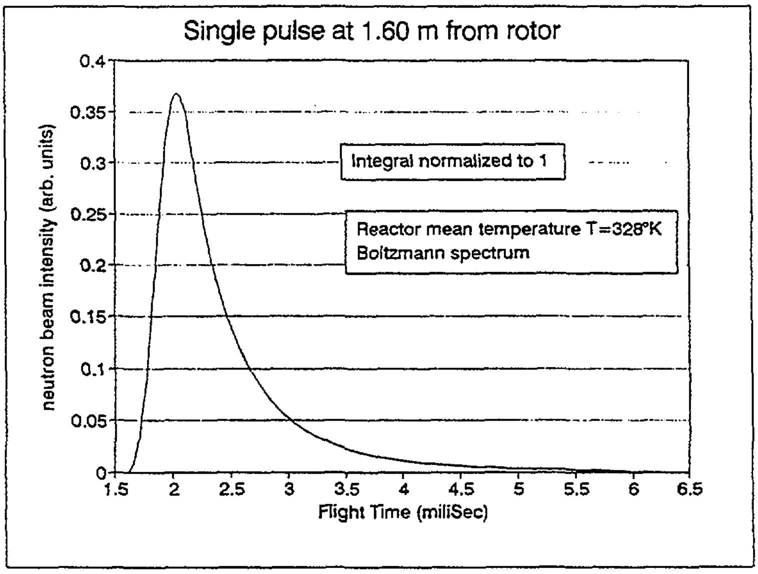

FIG. 2. Single pulse at 1.60 m from rotor

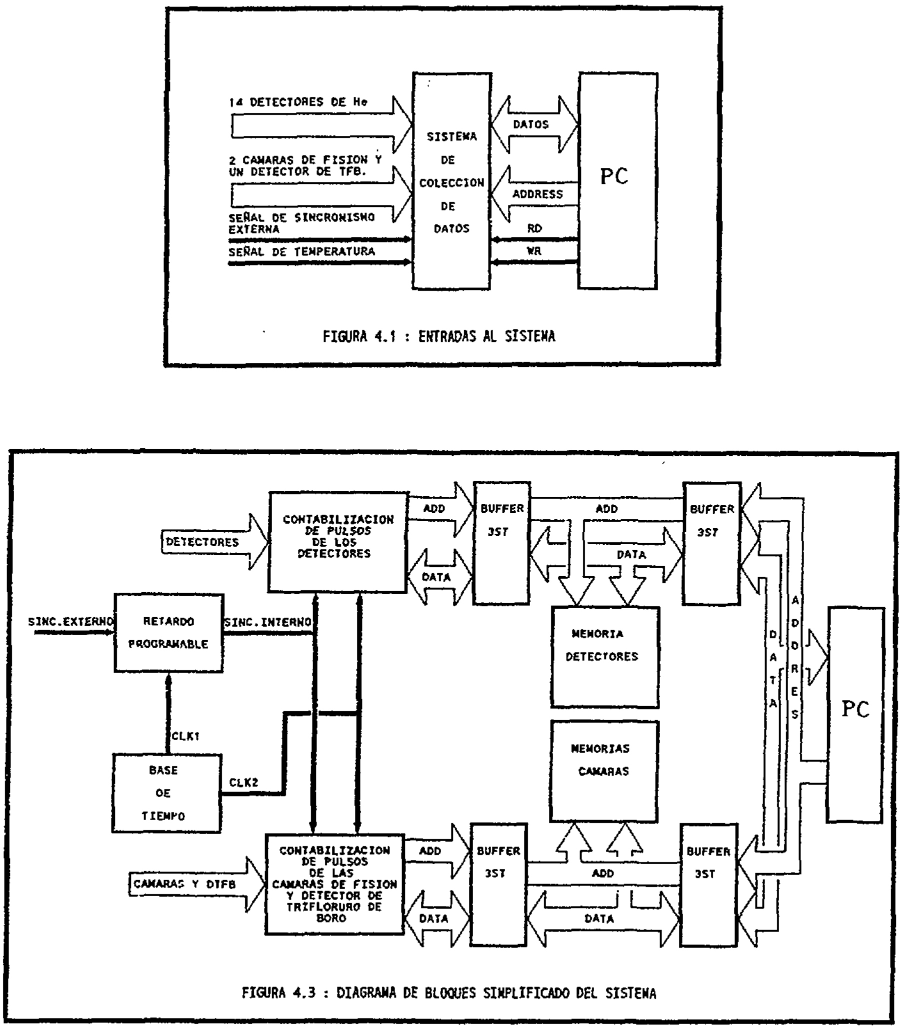

FIG. 3. Schematic diagrams of data acquisition for neutron time of flight diffractometer.

2. 1. Time of flight data analyzing system

The designed time of flight analysis system essentially consists of a mixer-router with two address generators and a memory increment unit: the time channel address generator (higher address bits) provides the detector identifying capability. The memory increment unit increments by one the contents of a memory address built from the timing and detector channel information.

The address generator was designed to start a time measurement sweep after each trigger under program control in increments of 1μSec up to 2.56 mSec. In order to substract and adjust the sum of the pulse flight time offset due to the distance of the window to the position detector. Software selectable dwell times are 5, 10 and 20 μSec for a total of 128 time channels for each detector. This scheme allows the analysis of 0.64 , 1.28 and 2.56 mSec time span.

Counting data rates are sufficiently low (from 0.1 to 10 counts per second) to insure negligible probability of detection event collision. However, two independent analyzing units were built in, one for the off axis detectors and another for the on-axis detectors, in order to avoid data contemption between low frequency counting detectors at the off axis positions and the higher frequency data rates observed at on-axis detectors (fission chambers and front channel detector). This avoids competition between relatively different counting rate channels requesting acces to a single memory addressing and increment unit, which would lead to an indesirable variation in the relative counting ratios on the off axis counters.

The analyzer is packaged in a single circuit board and communicates with a PC Compatible via I/O ports and standard AT-Bus for operation, control and memory data transfers. The operation is transparent for the computer, and communications are based on a master-slave protocol. A detailed block diagrams (Figure 3) are available on request.

3.Neutron Pulse Profiles

We consider here a square section beam tube and a square slit window openning, cut out near the border of the neutron absorbing chopper disc. Distances are measured from the origin at the rotor position towards the sample and the detector bank. The chopper turns at constant angular velocity ω. Under these assumptions, the neutron flux at distance $d = 0$ must have a triangular time profile, as depicted in Figure 1. We call τ_p the total opening time of the window. Obviously, τ_p depends on the chopper disc angular velocity, the window width l_w and the radius of the window center position:

$$\tau_p = \frac{l_w}{\omega r} \tag{1}$$

The neutron pulse time profile at $d = 0$ is resulting from the continuous superposition of neutron group pulses of different velocities, because of the polychromatic nature of the filtered reactor beam. At this position, the velocity spectrum will obviously be the same as the incoming spectra.

At every instant, each velocity pulse component must have a triangular time and space intensity profile $n_V(x,t)$, given by the expression:

$$n_V(x,t) = S_V T_V(x,t) = S_V T(x-vt) \tag{2}$$

where S_V is the beam flux of neutrons with velocity v and $T_V(x,t)$ is a triangular profile function, normalized to $T_V(x,t) = 1$ at its maximum.

3. 1. Velocity spectra

In principle, this function could be obtained from a time of flight experiment as we discuss below. This spectrum function must be normalized, so that

$$K \int_{v_{min}}^{v_{max}} S(v)dv = 1 \tag{3}$$

where K is the normalization constant; hence, the normalized $S(v)$ function is $S(v) = \frac{1}{K} S(v)$. For a rough thermal neutron spectra description, assumming neutrons in equilibrium with a moderator at temperature T, $S'(v)$ can be approximated by the maxwellian distribution:

$$S'(v)dv = \frac{4}{\sqrt{\pi}} \frac{v^3}{(\frac{2kT}{m})^{3/2}} e^{-\frac{v^2}{(\frac{2kT}{m})}} dv$$

where k is the Boltzman constant and m is the neutron mass.

3. 2. Monochromatic intensity profile

The normalized triangular profile function for the neutron pulse of velocity v, can be written as:

$$T_v(x,t) = 2(\frac{x}{vT_p} - \frac{t}{T_p} - 1)\left(h(x - vt - vT_p) - h(x - vt - \frac{3}{2}vT_p)\right)$$

$$- 2(\frac{x}{vT_p} - \frac{t}{T_p} - 2)\left(h(x - vt - \frac{3}{2}vT_p) - h(x - vt - 2vT_p)\right) \tag{4}$$

where $h(x)$ is the Heaviside step function, and $T_v(x,t)$ is written in terms of the monochromatic neutron group velocity v and the window aperture time τ_p. This pulse is placed behind the chopper window at t=0.

The monochromatic pulse intensity profile can not change its form during its travel towards the sample (however, some scattering may occur during its travel, which we will neglect now, but has to be taken into account for instrument calibration). If the interaction with the sample is only elastic, it will diffuse changing only its wavevector direction, so that the triangular intensity form will also be conserved after elastic diffuse scattering. As a result, the redially scattered pulse changes only its intensity as a function of the diffusion direction.

The profile function shown in eq. 4 is normalized in the sense that its maximum value will be 1; note also that $T_v(x,t) = 0$ only within the space interval $[v(t_0\text{-}T), vt_0]$ for every instant t_0 and position x_0. This function allows then the representation of the monochromatic triangular pulse profile for every instant t after the window openning and for every distance d measured from the chopper position. The time width of the pulse is allways T_p and its space width is vT_p.

3. 3. Pulse Intensity Profiles

The time intensity profile of the neutron pulse at a certain distance may be obtained by superposition of the individual velocity components. In general, the number of neutrons at distance x and instant t will be characterized with where v_{max} and v_{min} are the maximum and minimum velocities contained in the polychromatic pulse. That for computation purposes, we can suppose finite (v_{max} corresponds to the filter cut-off velocity at minimum wavelength and v_{min} is given by resonable lower limit, considering the probability per unit time).

The time profile at a definite position x may be described by:

$$N_x(t) = \int_{v_{\min}}^{v_{\max}} n_v(x,t)dv = \int_{v_{\min}}^{v_{\max}} S(v)T_v(x,t)dv = \int_{v_{\min}}^{v_{\max}} S(v)T(x-vt)dv \qquad (5)$$

as well as the space profile at some instant t:

$$N_t(x) = \int_{v_{\min}}^{v_{\max}} n_v(x,t)dv = \int_{v_{\min}}^{v_{\max}} S(v)T_v(x,t)dv = \int_{v_{\min}}^{v_{\max}} S(v)T(x-vt)dv \qquad (6)$$

The instantaneous spectrum, *i. e.* the instantaneous distribution of neutron intensities as a function of velocity at a given distance before diffusion at the sample, is given by $N(x,t) = S_v T(x-vt)$, where the contributing velocity groups at any time $\frac{x}{v_{\max}} \geq t \geq \frac{x}{v_{\min}} - T_p$ are those with velocities in the range $\left[\frac{x}{t-T_p}, \frac{x}{t+T_p}\right]$.

Figure 2 shows the time pulse profile computed for a 1.60 m distance, using expression 5 considering a maxwellian velocity spectrum. This spectrum is resulting from the convolution integral of the monochromatic time intensity profile with the reactor spectra.

The monochromatic intensity profile depends only on the window chopper time behavior and on the group velocity, and it go back, by deconvolution numerical methods, from $N_x(t)$ to the originating velocity intensity distribution $S(v)$.

4. Results

Figure 4 shows the time pulse intensity profile obtained by time analyzing the neutron pulse intensity at the "glopper" front channel (on-axis) position. Pulses are superimposed due to a time analysis span which is longer than the pulse period (5.12 miliSec). These time spectra were obtained with a null time delay between trigger signal and the analyzer start. The start signal then is not compensated for the flight time delay neither by the geometric relation between the pick up coil and the real window position, but this is unimportant for a detailed experiment where we want a maximum amplification of the time region of interest. The qualitative agreement between computed and observed spectra is clear (Figure 5).

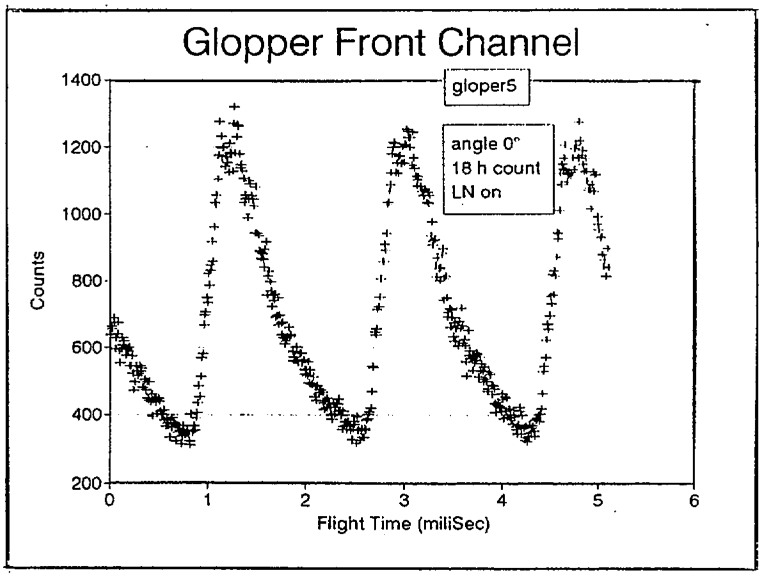

FIG. 4. Time profile intensity at the "Glopper" front channel position.

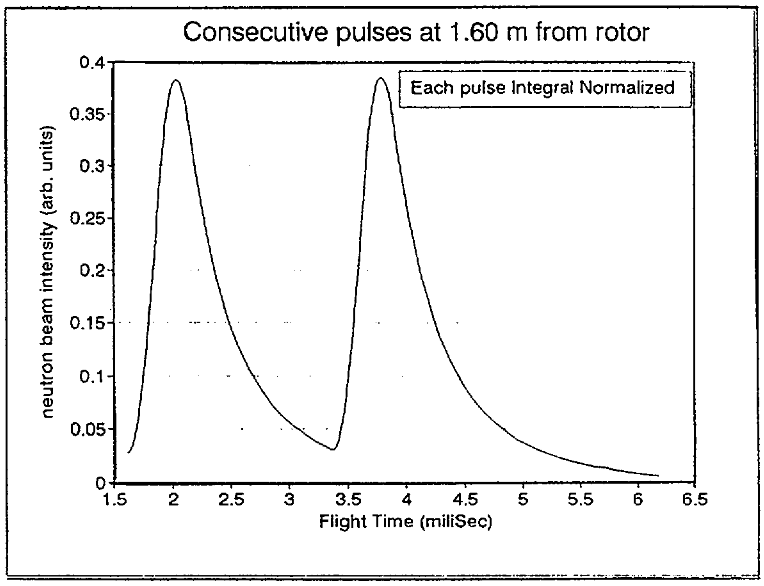

FIG. 5. Consecutive pulses at 1.60 m from rotor.

5. Conclusions

The main aspects of the repair and modifications of the scattering instrument are concluded. A new aquisition system has been built for this instrument, allowing higher time slicing during the acquisition than that which was available in the ancient version, and offering a full detector bank simultaneous measurement. A new window detector assembly is also considered, with the purpose of offering longer pulse repetition periods; an examination of the pulse shapes (slope at the low velocity tail) show that there are sufficient low energy neutron counts to profit from an expanded time analysis.

NEXT PAGE(S) left BLANK