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AN X-RAY GAS POSITION SENSITIVE DETECTOR: CONSTRUCTION AND CHARACTERIZATION

by

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ABSTRACT

A linear x-ray gas position sensitive detector with delay line readout has been constructed. The detector is described, characterized and used for detecting x-ray diffraction patterns from polycrystals.

Key-words: Crystallography; X-ray detection; Gas position sensitive detector; Delay-line readout.

INTRODUCTION

Scientists who are currently interested in studying the structure of materials by x-ray diffraction and scattering techniques often require sources of higher intensity. There is at present in Brazil a growing interest of crystallographers in more powerful x-ray sources; it is expected that the future availability of a synchrotron radiation facility at the Brazilian National Laboratory for Synchrotron Light (LNLS) in Campinas(1) will enhance the possibilities for crystallographers and material scientists to perform new experiments needing high-precision determinations of scattering intensity or high time resolution.

The laboratories which have intense x-ray sources also require more efficient detection systems, namely position sensitive detectors. In particular, at LNLS a Reticon array detector system for visible and U.V. light is being built(2) and will also be adapted for x-ray detection.

This communication describes the first results of a project for construction of x-ray gas position sensitive detectors at the Brazilian Center for Physical Research (CBPF), Rio de Janeiro. The x-ray detector group at CBPF intends to build these detectors locally and provide them to crystallography laboratories and to LNLS.

Two projects have been initiated which concern a) a one-dimensional and b) a two-dimensional position sensitive detector, using gas chambers, metallic anode wires and delay lines. We report here the construction and characterization of the linear x-ray detector and its first applications to diffraction experiments.

FEATURES

The linear position sensitive detectors consist of a gas chamber, a metallic anode wire and a cathode connected to a delay line. As in proportional detectors, the incoming photons produce electrical charges in the gas, which induce a pulse on the cathode. The measured values of the travelling times of the induced charges from the point of collection to the ends of the delay line, are used to determine the position of the photons[(3)].

A schematic view of a one-dimensional detector is presented in Fig. 1. The coordinate x of the position associated with the incoming photon is given by

$$x = k(t_1 - t_2 - \Delta t') = k\Delta t$$

where k is constant, t_1 and t_2 are the times at which the pulses arrive at the ends of the delay line, and $\Delta t'$ is an external delay time which is introduced for assuring positive values for the readout Δt intervals.

The relevant specifications of the built detector are:

- Anode (gold-coated tungsten wire) diameter: 20μm.
- Distance between cathode strips: 2.54 mm.
- Anode-cathode distance: 3 mm.

- Delay line characteristic impedance: 50 Ω.
- Total delay time: 0.5 μs.
- Gas (Ar-10%CH4) pressure: 2 bar
- Thickness of the beryllium window: 250 μm.
- Length of the sensitive area: 80 mm.

The assembling of the mechanical parts of the detector is shown in Fig. 2. Indium wires have been used to ensure the sealing of the gas chamber.

The electronic system (Fig. 3) for recording the photon distribution consists of two preamplifiers, two amplifier-discriminators, a delay-time generator, a time-to-amplitude converter and a multichannel analyser system associated with a PC compatible microcomputer.

CHARACTERIZATION

The characterization of the detector has been carried out by using a standard x-ray generator producing filtered CuK_α radiation, which mainly contains photons of approximately 8 KeV.

The counting rate of the detector as a function of the high voltage between anode and cathode, is represented in Fig. 4. The counting rate exhibits a "plateau" above V = 2250 Volts. Consequently, the operating high voltage of the detector was chosen to be 2300 Volts.

The resolution parameter R is defined as the full width at half maximum intensity (FWHM) of the counting distribution for an incoming beam of negligible cross section. This parameter has been determined by using a slit of 17 μm between the x-ray source and the detector. The measured values of R vary slightly as a function of the position of the beam around the average value of R = 430 μm (FWHM). With the total length of the detector window L equal to 80 mm, the relative resolution becomes R/L = 0.5%.

The linearity of the detector has been evaluated by measuring the intensity profiles recorded for a narrow incoming beam (width = 90 μm) for different beam -incidence positions. The center of gravity of the distributions in the multichannel analyzer as a function of the beam position is plotted in Fig. 5. This figure shows a qualitatively good linearity; the integral non-linearity has been determined to be lower that 1%. The data of Fig. 5 provide the factor which should be used to obtain the coordinate x of the incoming photon from the analyzer channel number N: $(\Delta x/\Delta N)$ = 0.154 mm/channel.

The plot in Fig. 6 represents the x-ray intensity as a function of the relative position of the incoming beam. We can see that the variation in photon count number is approximately 1.5%. The statistical relative error for the number of recorded photons Δ is $(1/\sqrt{N})$ = 0.50%. From this we estimate the relative variation in the intrinsic detector efficiency to be about 1%.

APPLICATIONS

For testing purposes the linear detector has been used to record the x-ray diffraction patterns of polycrystalline silicon and $C_{23}H_{48}$ paraffin samples. For comparison, a similar experiment has been carried out for the same paraffin sample using a scintillation counter and the standard step scanning procedure.

The diffraction diagram for the silicon sample is represented in Fig. 7 for diffraction angles ranging from 84 up to 98 degrees. The CuK_{α} doublet for the 333 and 224 Bragg reflections is partially resolved in the obtained experimental profile.

The small angle diffraction pattern corresponding to the paraffin sample is plotted in Fig. 8a. This diagram shows the 002, 004 and 006 Bragg reflections from the crystalline modification of the studied paraffin. The same portion of the pattern has been recorded using the step scanning procedure with a resolution slit of 90 μm. The width at half maximum intensity of the 002 Bragg peak profiles in Fig. 8a (position sensitive detector) and Fig. 8b (step scanning) are 0.18 and 0.13, degrees, respectively. This difference is expected because of the different resolution parameter associated with each procedure.

REMARKS

The characteristics of the first x-ray gas position sensitive detector built at CBPF, are comparable with those of similar detectors reported in previous works[4]. The detector is now used for x-ray diffraction and small-angle scat tering measurements. These experiments will allow us to verify the long-term reliability and, eventually, to improve the performance of the detector.

ACKNOWLEDGMENT

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FIGURE CAPTIONS

Figure 1: Detection cell (schematic).

Figure 2: Assembling of the detector, a) detection cell, b) beryllium window.

Figure 3: Electronic system for data readout, a) detector, b) preamplifiers, c) amplifier-discriminators, d) time-delay generator, e) time-to-amplitude converter, f) multichannel analyser and PC computer, g) high voltage supply.

Figure 4: Count number as a function of the detector high voltage.

Figure 5: Linearity test (channel number as a function of the beam position).

Figure 6: Homogeneity test (count number as a function of the beam position).

Figure 7: Diffraction pattern from a silicon polycrystal.

Figure 8: Diffraction patterns from a paraffin sample using: a) the position sensitive detector (counting time: 300s) and b) the step scanning procedure (total scanning time: 2400s).

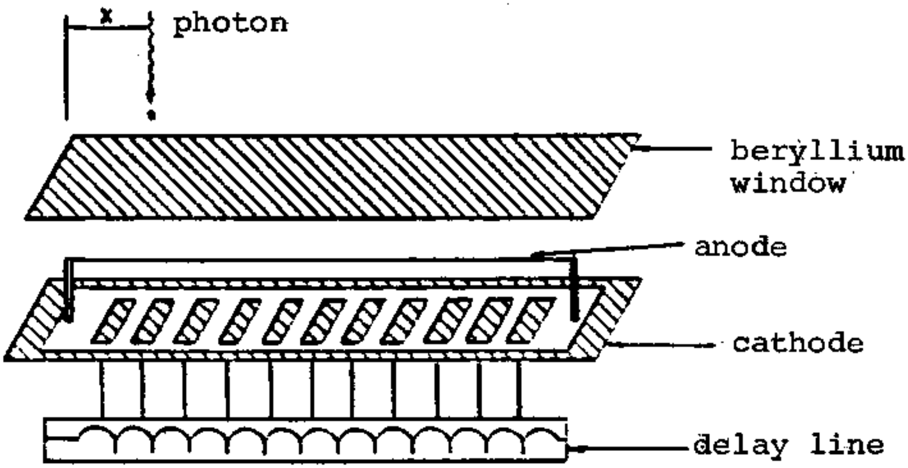


Figure 1

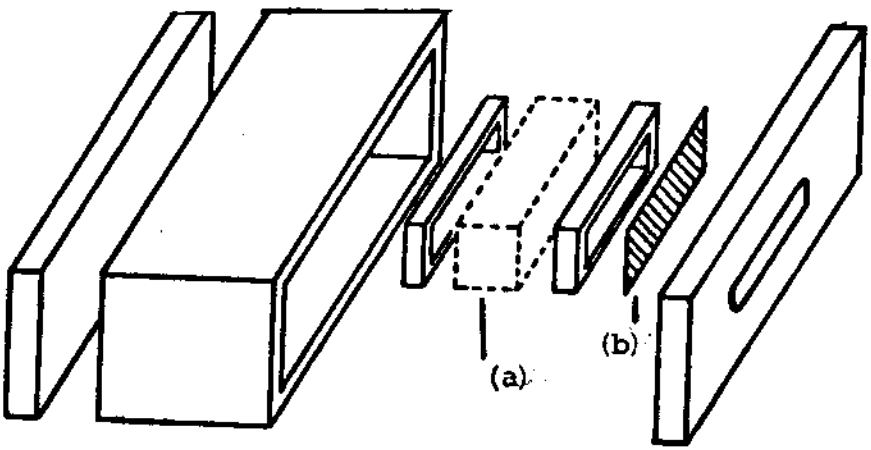


Figure 2

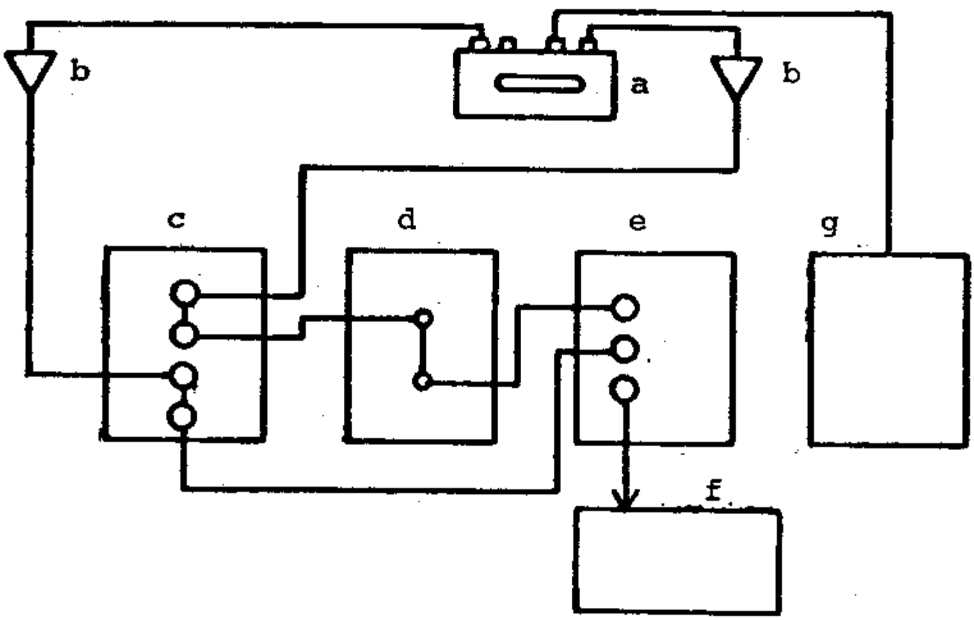


Figure 3

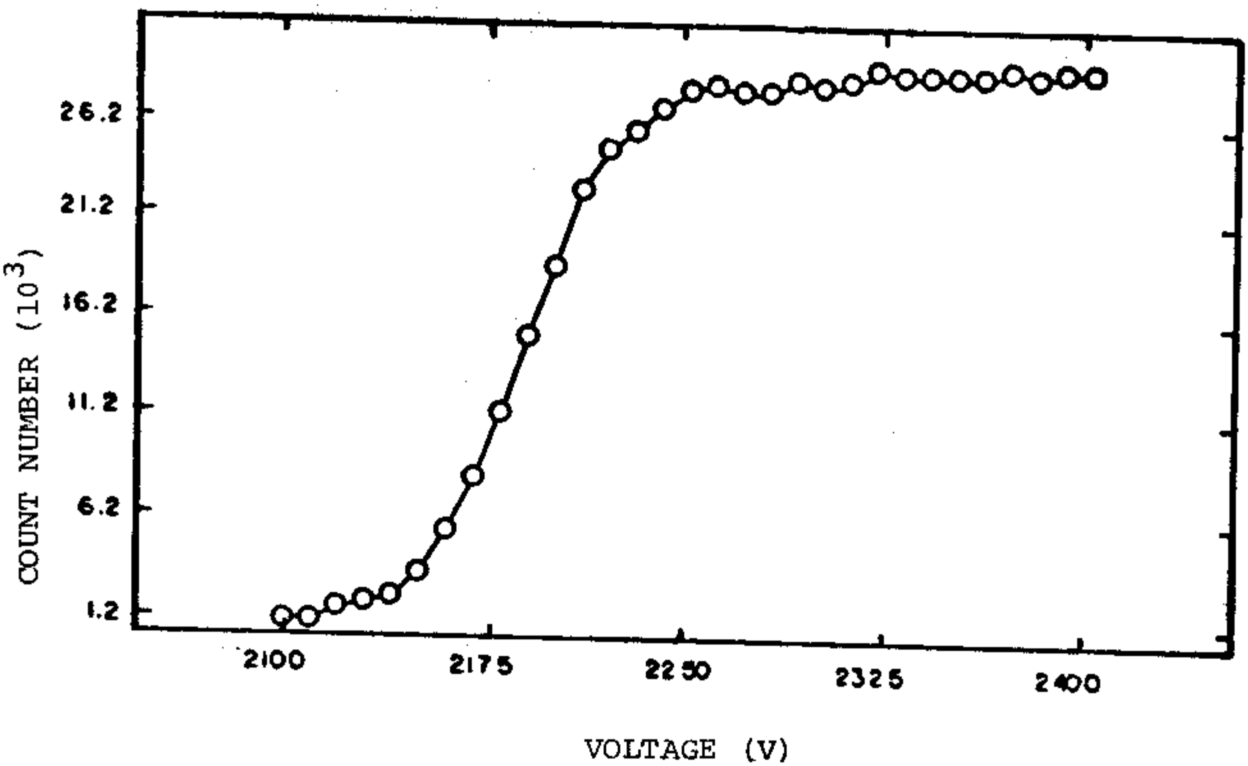

26.2
21.2
16.2
11.2
6.2
1.2
COUNT NUMBER (10^3)
2100
2175
2250
2325
2400
VOLTAGE (V)

Figure 4

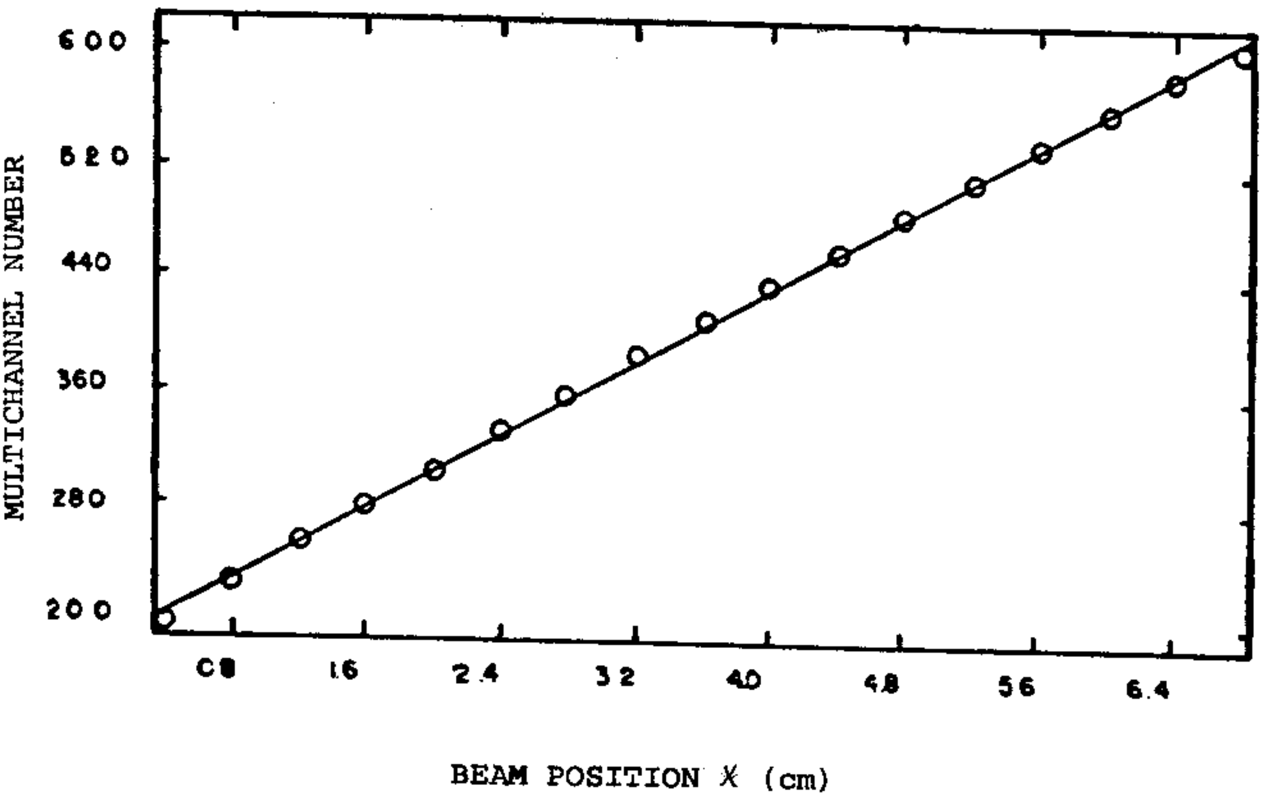

600
520
440
360
280
200
MULTICHANNEL NUMBER
0.8
1.6
2.4
3.2
4.0
4.8
5.6
6.4
BEAM POSITION X (cm)

Figure 5

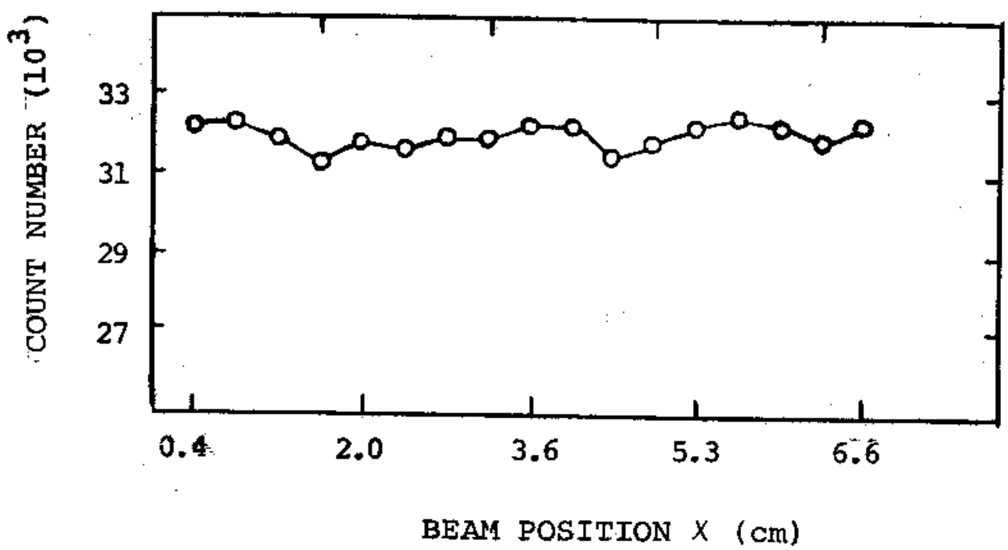


Figure 6

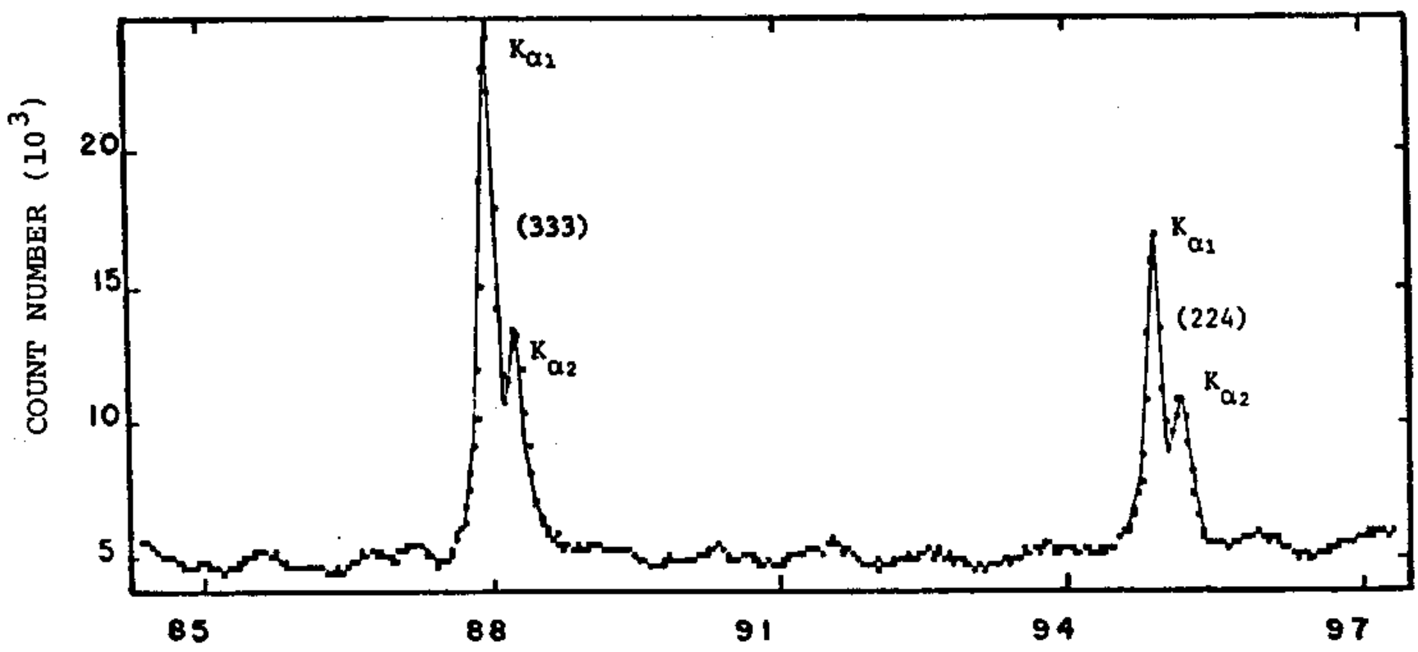
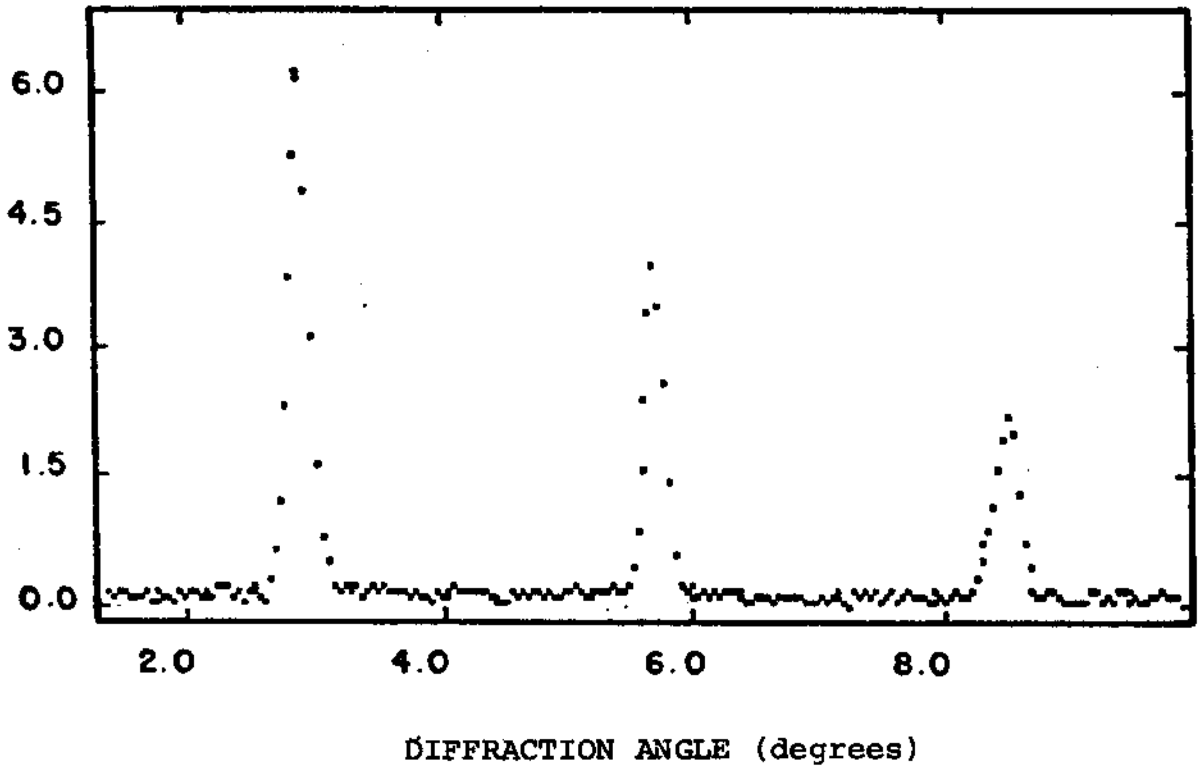

COUNT NUMBER (10^3)
20
15
10
5
85
88
91
94
97
BEAM POSITION X (cm)
$K_{\alpha 1}$
(333)
$K_{\alpha 2}$
$K_{\alpha 1}$
(224)
$K_{\alpha 2}$

Figure 7


6.0
4.5
3.0
1.5
0.0
2.0
4.0
6.0
8.0
DIFFRACTION ANGLE (degrees)

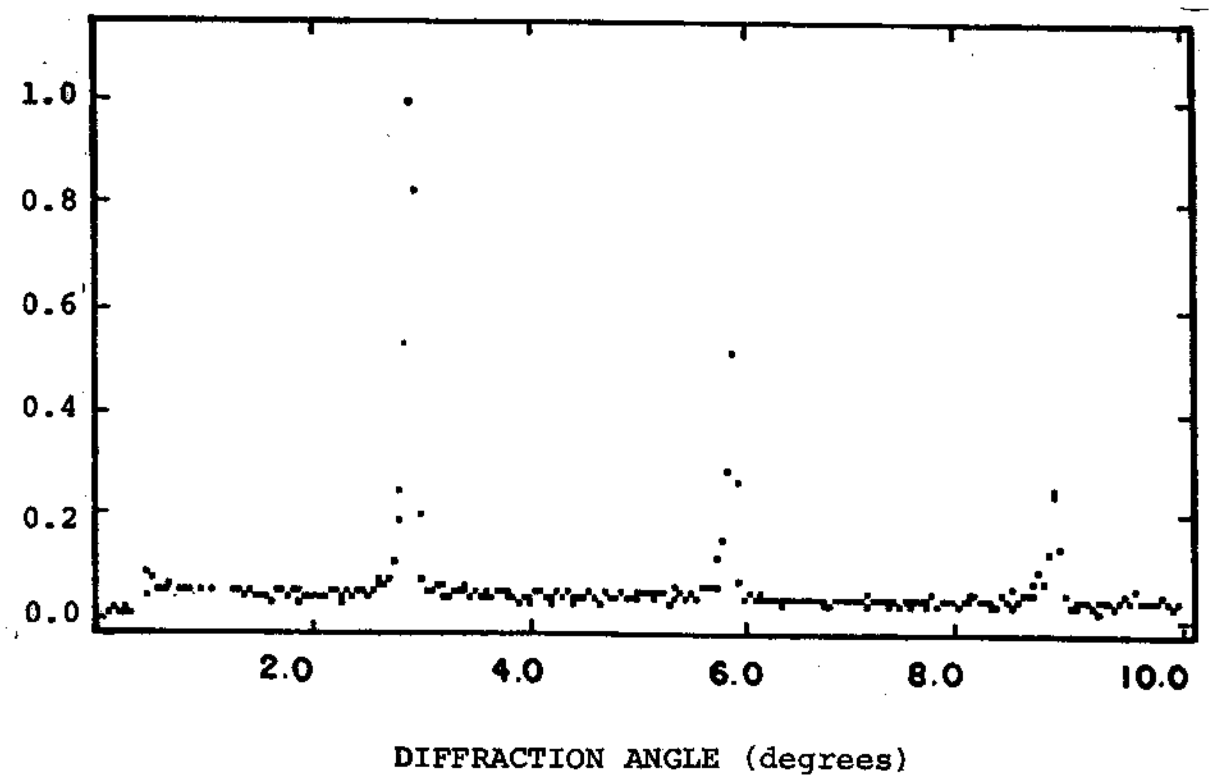

1.0
0.8
0.6
0.4
0.2
0.0
2.0
4.0
6.0
8.0
10.0
DIFFRACTION ANGLE (degrees)

Figure 8

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