SMALL ANGLE SCATTERING SPECTROMETER (KENS-SAN)

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1. Spectrometer Characteristics

KENS-SAN is the first TOF small angle scattering spectrometer to be enstalled at a pulsed cold neutron source. The configuration of the constructed spectrometer is shown in the upper part of Fig. 1. The spectrometer was designed so as to benefit from the characteristics of the pulsed cold neutron source. This paper discusses the preliminary results that have been obtained with this spectrometer during the two months initial operation. The principles of the design have already been described in a previous paper[1] and so that we present only a summary of the spectrometer characteristics.

1.1 Measurement of a Wide Range of Momentum Transfer

KENS-SAN is equipped with a two dimensional position sensitive He^3 counter bank (2D-PSD). This can be displaced inside a large vacuum detector chamber so that the distance between the sample and the detector can be altered between 1 m and 5 m without breaking vacuum. In addition, six sets of fixed 1" diameter single He^3

counters (Labelled A to F in Fig. 1) are installed at the scattering angles of 150, 90, 45, 26.6, 14.0 and 5.7 degrees. With this configuration and by utilizing all neutron wave lengths in the range 3 Å - 11 Å (or 4 Å - 12 Å), the spectrometer can be used to measure momentum transfers, Q, from 3×10^{-3} Å^{-1} to 4 Å^{-1} without changing the configuration as indicated in the lower part of Fig. 1.

1.2 Improvement of the S/N Ratio

KENS-SAN is installed at the exit of a bent guide tube whose length is longer than the direct view distance. The level of background radiation is therefore quite low and a thin 0.5 mm Cd plate is sufficient to protect the detectors against background noise.

1.3 Increase of the Effective Scattered Neutron Intensity

By inserting a converging Soller slit between the exit of the guide tube and the sample chamber, the sample size can be increased to 33 x 13 mm^2 (in case of focussing at 5 m from the sample). The statistics of the accumulated data may also be further improved by combining the data obtained at different wavelengths.

1.4 Quick Display of 2D-PSD Data

The quantity of data generated by the 2D-PSD using TOF scans is extremely large (43 detectors x 64 position channels x 32 time channels = 88,000 discrete data points) and so direct correction and display of the results is not possible. The three following simple on-line display systems were therefore developed.

i) Display of data obtained by integrating over one parameter (time or position).

ii) One dimensional display of the data in Q space obtained by integrating the data from all directions.

iii) Two dimensional display of the data in Q space obtained by integrating data from a limited range of wavelengths.

1.5 Use of a Second Chopper (cf. Figs. 1 and 6)

When a tooth chopper is positioned before the converging Soller slit (cf. Fig. 1), the inelastic scattering contribution can easily be removed. Conversely use of a convensional one window chopper enables the inelastic scattering to be measured.

2. Experimental Results

2.1 Fixed Single Counter Sets

The TOF spectra from an Al-10%Zn alloy measured by the fixed counter sets at an early stage of instrument development are displayed in a lower part of Fig. 2. The small angle scattering data obtained by the F counter set placed at 5 m from the sample is shown in the inset. The data has been corrected for the incident neutron intensity distribution. The agreement between data and that of Komura et al.[2] is satisfactory for Q values greater than 0.08 $Å^{-1}$, indicating that the fixed single counter sets themselves are quite useful for measurements of the high Q range. In this experiment we also found that the TOF spectra were contaminated by the fast neutrons which are seen as a spike in each spectrum in Fig. 2. This high energy neutron component, however, was spread over only ten time channels which could be omitted without introducing problems in the analysis. The level of the fast neutron background was later

substantially reduced on improving the shielding around three guides and this background is now completely absent when all the beam tubes in experimental hall B are closed.

2.2 Converging Soller Slit

The two dimensional converging Soller slit was made by combining 1 m long horizontal and vertical converging Soller slits in the manner shown in Fig. 3. Each of these components is composed of two separate 50 cm long sections so that the angular divergence may be alterned. The complete slit is designed so as to focus at a distance of 5 m from the sample. The sample size can then be as large as 33 x 13 mm^2. The measured spot size of the direct beam deriving from the finite angular divergence of the slit is 18.7 x 18.5 mm^2 and 35.4 x 17.1 mm^2 at respective distance of 5 m (focus) and 1 m from the sample. The direct beam could be stopped completely by a 1 mm thick Cd plate of dimensions 20 x 50 mm^2 even at the 5 m position. Use of this converging Soller slit, however, reduces the incident neutron intensity to 3% of that at the exit of the guide as expected from the design value of its angular divergence.

2.3 2D-PSD and Data Display

The 2D-PSD is composed of an array of 43 one dimensional PSD 1/2" in diameter and 24" in active length (RS-P4-0810-204) originally developed by Missouri University[3]. The preamplifiers which are attatched to each end of each PSD were specially designed for the low impedance of the PSD (R_c = 3.6 kΩ) and were installed inside the vacuum chamber with 2D-PSD. A high voltage of 1900 V can be safely applied to the PSD in the vacuum pressure of 8 x 10^{-3} mmHg enabling a distance resolution of about 10 mm to be achieved. An actual resolution test was performed under atmospheric condition using a neutron source of Pu placed at 50 cm from the detector. In this case the maximum voltage that could be applied was 1800 V and a distance resolution of 19 mm was achieved. The interface between the 2D-PSD detector and the central computer was manufactured Oki-Electric Co based on the design described in the previous report[4].

Fig. 4 shows a typical example of the display of data from 2D-PSD. Fig. 4 (a) (top) is a measurement of the direct beam after collimation by the converging Soller slits when the beam stopper had been removed from the center of the detector by means of a small servo-moter. Each line in the figure depicts the data from a single PSD after integrating the separate time channels at each position. The results indicate the size of beam at a position 3 m from the sample. For the data shown in Fig. 4 (b) a 4×5 cm^2 beam stop was placed at the central position. The direct beam was found to be completely shielded by this stopper. The lowest figure (Fig. 4 (c)) is the result of the small angle scattering from a Al-10%Zn-0.1%Mg sample. Although the displayed data are the result of the integration of data of all the wavelengths, they retains the characteristics of the conventional small angle scattering; a distinct dip can be observable at the center of each PSD. These results were converted on-line to a one dimensional $|Q|$ display by computing the Q value of each channel, adding the data for different channels with the same $|Q|$ value, and then dividing the sum by the numbers of contributing channels. The output from this process, as it appeared on the graphic display, is shown in Fig. 5. The total computing time necessary for this process was about 3 min. The open circles

in the figure represent the results obtained after correction for the sensitivity of the counters, the incident neutron intensity distribution (as monitored using the result of incoherent scattering from pure water) and the absorption were made by an off-line computer. The agreement between the on-line display and the corrected data is fairly satisfactory, suggesting that the simple on-line display may be quite helpful in understanding the general characteristics of the small angle scattering.

2.4 Operation of the Second Chopper

The lower part of Fig. 6 shows a typical simple example of the operation of the toothed second chopper illustrated in Fig. 6 (a). By rotating the chopper in coincidence with the neutron pulse, the intensity of the TOF spectra recorded by the fixed counters is modulated to produce a comb-like pattern and the level of the troughs in these comb-like spectra provides information on the contribution from inelastic scattering. This is the most simple method by which to separate the inelastic component from the total small angle scattering. The energy resolution is about $\Delta\lambda/\lambda = 0.05$ (~ 50 μeV). This technique will thus be quite helpful in, for example, separating the magnon contributions in small angle scattering.

3. Conclusion

KENS-SAN is found to function according to design specification for measuring and it proves quite useful even conventional small angle scattering. It will take some time, however, to establish measuring techniques for this new type of small angle spectrometer and to identify for which problems it will be most suitable.

References

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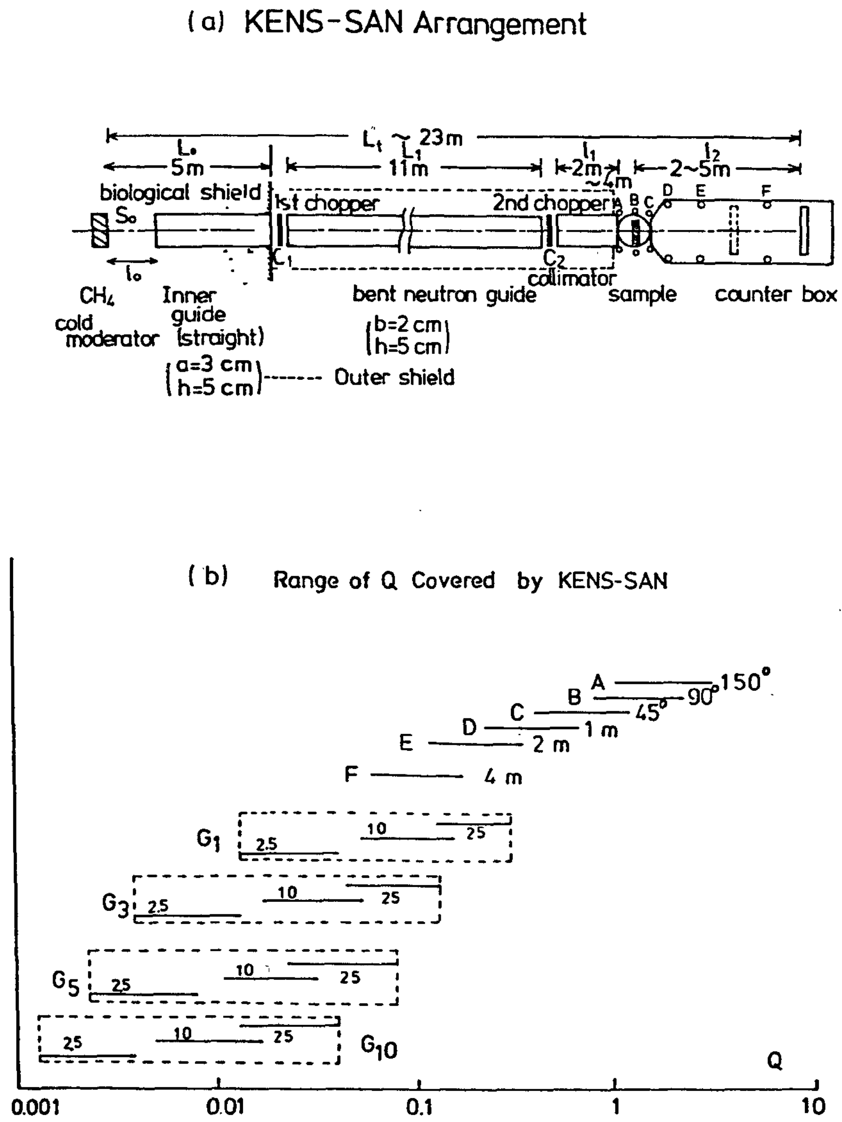
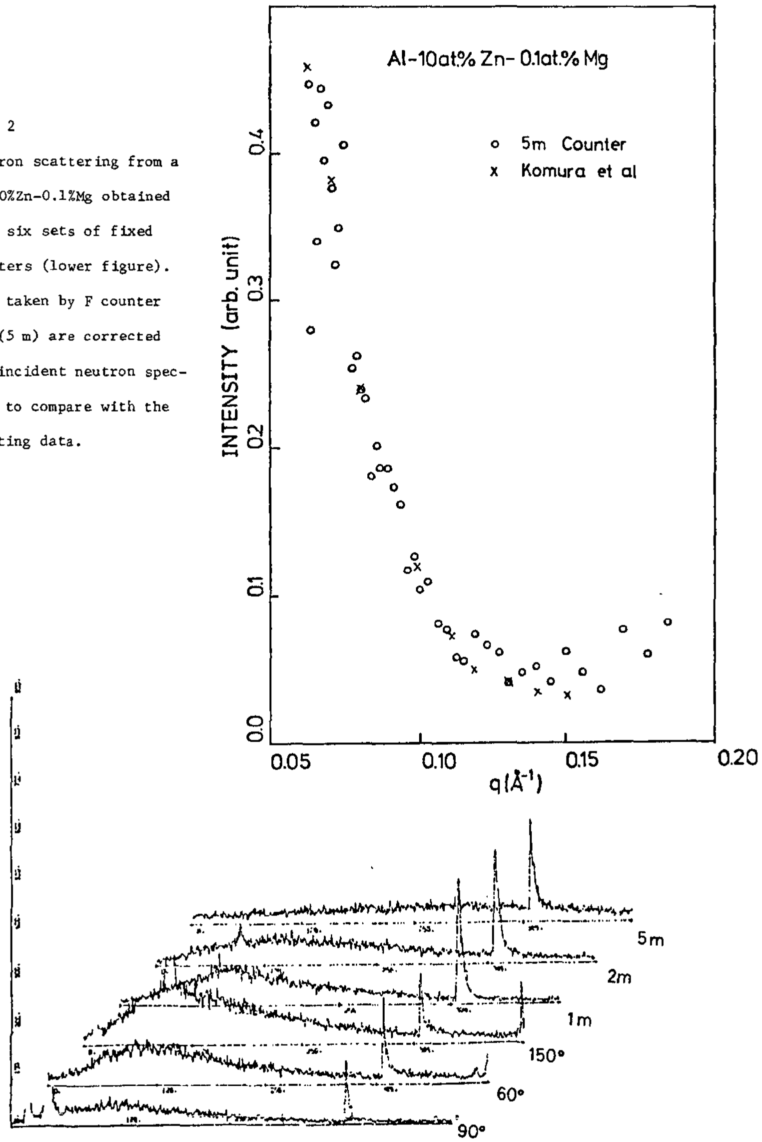


Fig. 1 Layout of KENS-SAN (a) and range of momentum transfers Q covered by this spectrometer

Fig. 2

Neutron scattering from a Al-10%Zn-0.1%Mg obtained with six sets of fixed counters (lower figure). Data taken by F counter set (5 m) are corrected for incident neutron spectrum to compare with the existing data.



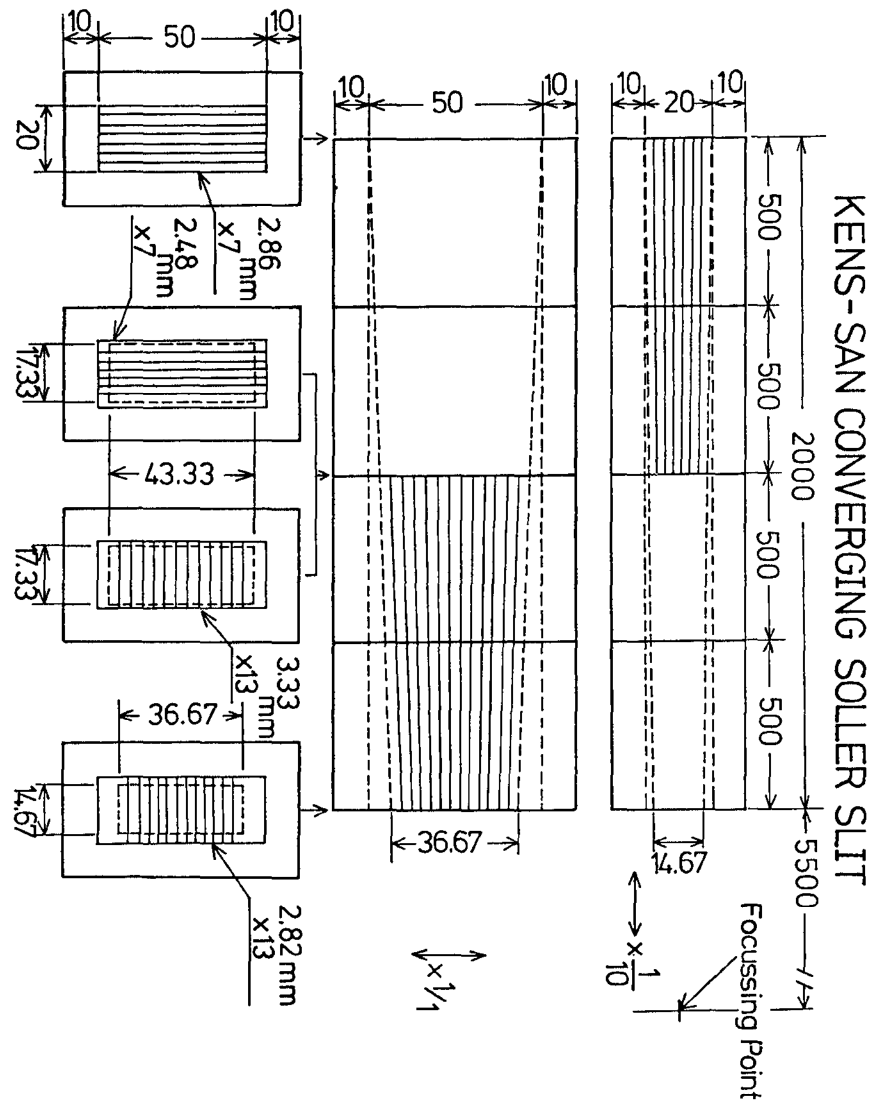


Fig. 3 Converging Soller slit

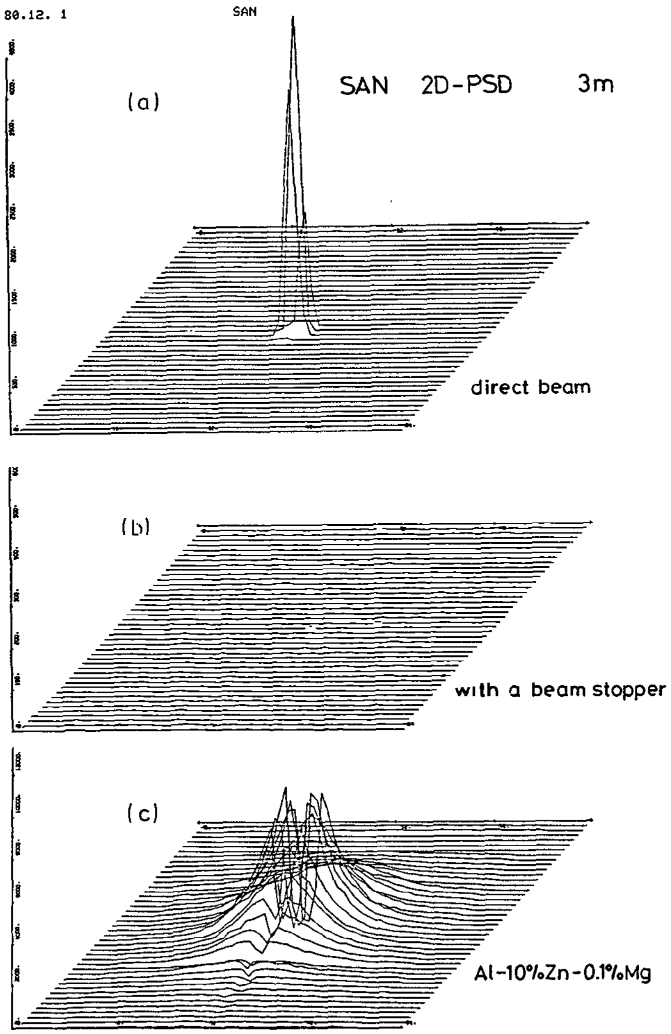


Fig. 4 A typical example of display of the 2D-PSD data. The data are integrated over all time channels. (a) profile of direct beam without a beam stopper (b) that with the stopper (c) small angle scattering from Al-10%Zn-0.1%Mg

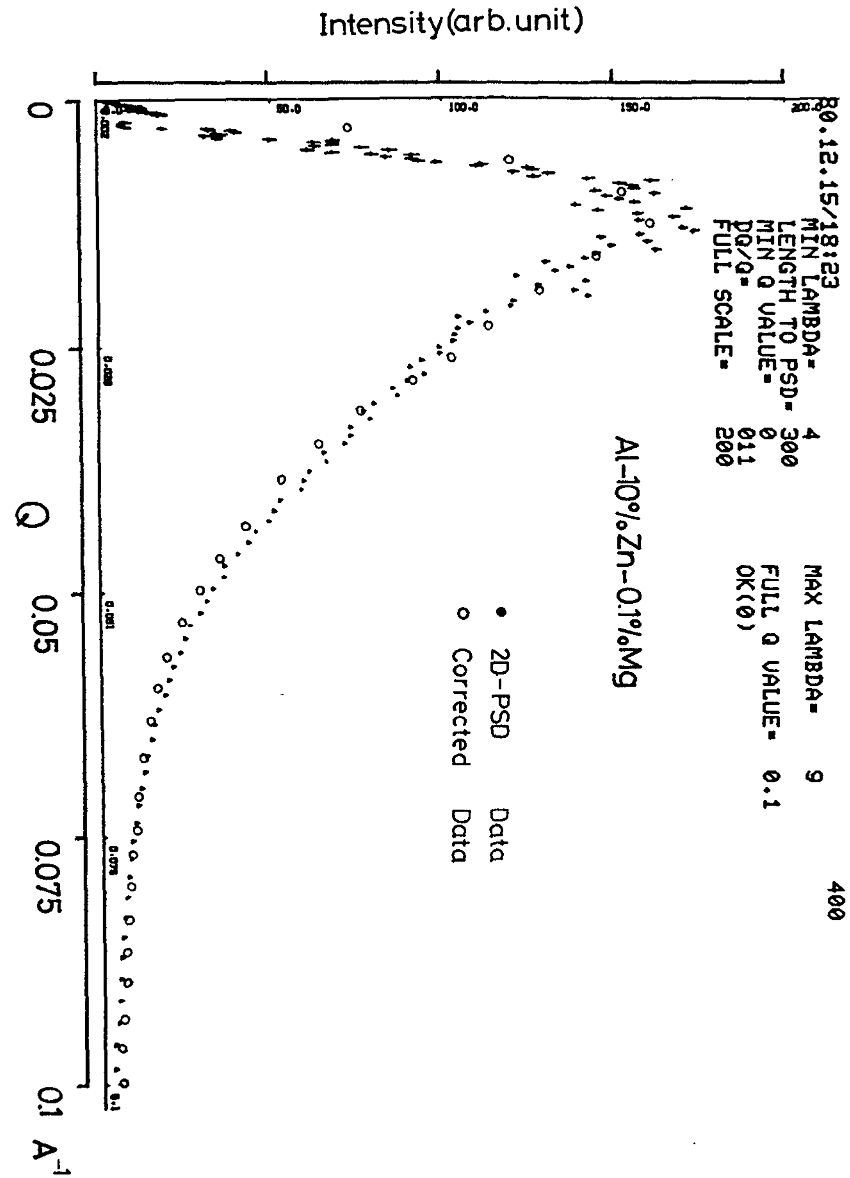


Fig. 5 On-line one dimensional display of small angle scattering (Fig. 4 (c)) against |Q| and comparison with the data corrected for incident neutron spectrum by V incoherent scattering

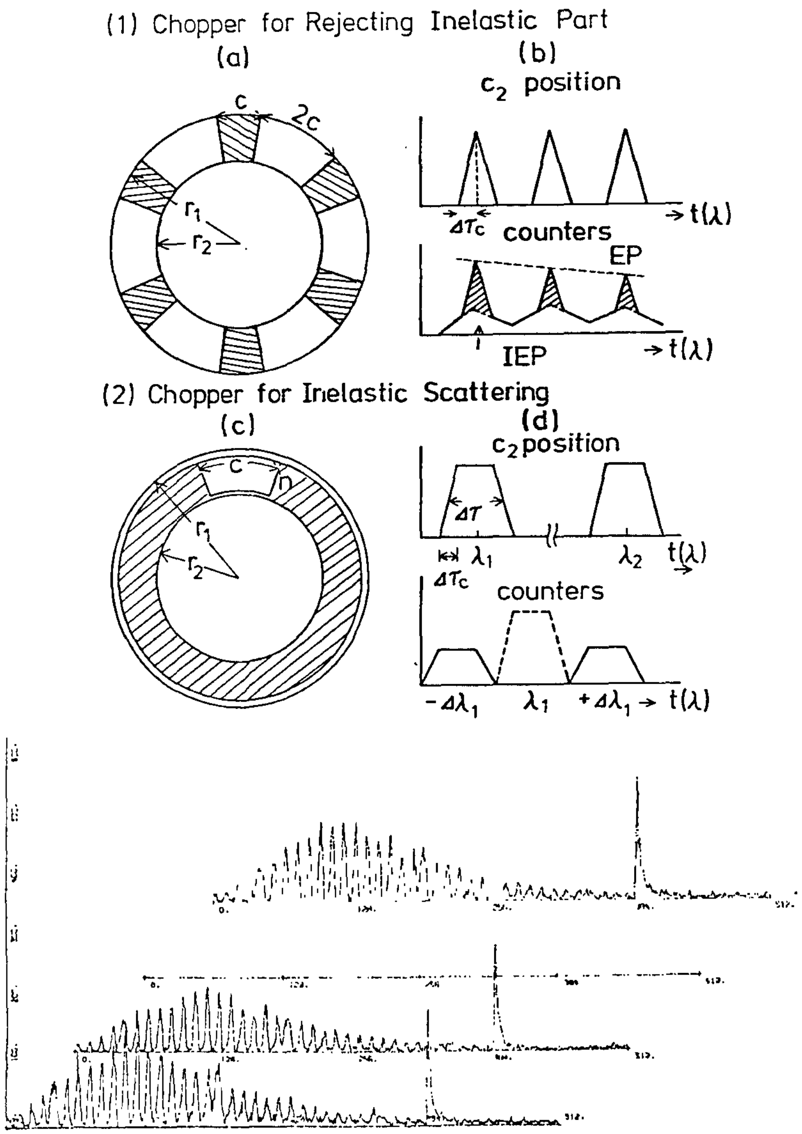


Fig. 6 Two types of second choppers (upper figure) and a result of opperation of a gear type chopper (a), (lower figure)