Instrumentation - Summary of Contributed Paper and Discussion Sessions

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The contributed paper session included papers on the following major topics: Powder Diffractometers, Single Crystal Diffractometers, Small Angle Diffractometers, Inverted Geometry Spectrometers, Spectrometers for the Electron-Volt Energy Range, Choppers and Chopper Spectrometers, Polarized Neutron Instrumentation, Detectors, and Data Acquisition. There was also a general paper on the importance of the large dynamic range provided by most time-of-flight instruments. In the discussion sessions, additional material was presented on Inverted Geometry Spectrometers, Spectrometers for the Electron-Volt Energy Range, Choppers and Chopper Spectrometers, and Polarized Neutron Instrumentation. The summaries below combine material from the contributed paper session and discussion sessions under these major topic headings.

I. Diffractometers

Jim Jorgensen reported on the ANL powder diffractometers. His basic message was that these two instruments work extremely well. These instruments both use on-the-fly software time-focussing of the detectors, and this technique has been very successful. The high resolution provided by these instruments is being utilized by a number of powder diffraction users. These instruments have also proved to be quite good for obtaining high Q data from amorphous samples.

Art Schultz reported on the single-crystal diffractometer at ANL. This instrument uses an area-detector of the Anger type. The instrument, and its associated data analysis software, are now in routine use for crystal structure problems. Initial experiments also indicate the power of the area-detector-based time-of-flight Laue technique for finding low-intensity features such as diffuse scattering or satellite peaks between the Bragg peaks.

Ernest Epperson reported on the small angle diffractometer at ANL, and Masahumi Kohgi reported on the KENS small angle diffractometer. The KENS instrument is on a cold neutron guide and uses only the long-wavelength portion of the spectrum. It uses an area-detector made up of an array of linear-position-sensitive detectors. The ANL instrument uses a gas-proportional-counter area-detector, and is designed to use epithermal neutrons as well as cold neutrons. The KENS instrument is now routinely taking data. The ANL instrument has cleared up most background and collimation problems but is not yet routinely taking data. It is not clear that data reduction techniques are entirely satisfactory for either of the instruments yet.

II. Inverted Geometry Spectrometers

Joyce Goldstone reported on the Be-BeO filter-difference spectrometer, and crystal analyzer spectrometer, in operation at LANL. Torben Brun reported on the ANL crystal analyzer spectrometer, and Noboru Watanabe reported on the high-energy crystal analyzer spectrometer at KENS. Both the ANL and KENS instruments have resolutions of ~ 2% at 100 meV. The KENS instrument uses a planar time-focussing geometry, so its resolution remains at nearly 2% over the entire range from 100 meV to 1 eV. The ANL instrument uses a curved array of crystals which gives resolutions better than the KENS instrument at energies below 100 meV, but its resolution falls off to about 7% at 1 eV. The LANL crystal analyzer spectrometer also uses a curved array of crystals but has a resolution of about 5% at 100 meV. The LANL Be-BeO filter difference spectrometer (which is in a production mode) also has a resolution of about 5% at 100 meV and sufficient intensity to give adequate statistics, even after taking the difference, in about 12 hours. She contrasted its performance with the Los Alamos crystal analyzer which has slightly better resolution but a significantly lower count rate. This latter instrument will be replaced in the fall by a constant-Q inverted geometry spectrometer. Approximate parameters of the LANL filter difference spectrometer and the ANL and KENS crystal analyzer spectrometers are summarized below.

	Filter Diff.	Crystal Analyzer	
	LANL	ANL	KENS
Sample area max. = A_s (cm^2)	2.5 x 10	2 x 5	7 x 7
Source-sample dist. = L_i (cm)	1300	1000	530
Sample-det. dist. = L_s (cm)	28	100	72
Analyzer solid angle = $\Delta\Omega$ (ster)	1.1	0.12	.017***
Analyzer reflectivity = R	-	0.8	0.8
Filter transmission = T	0.4†	0.8	0.8
Analyzer bandwidth = B (meV)	1.46	0.33	1.0
Relative counting eff.* = R1	9.5**	0.25	1.9
= R2	3.8**	0.025	0.039
Resolution = ΔE (meV)			
at E_f = 5 meV	1.5	0.5	1.0
100 meV	5	2.6	2.6
1000 meV	110	70	25

† at 300K

* $R2 = 10^6 \cdot \Delta\Omega \cdot R \cdot T \cdot B/L_i^2$; $R1 = A_s \cdot R2$
Use R1 if large samples are available, R2 if not.

** Suffers from statistics and background problems due to difference technique.

*** Geometric solid angle is 0.05 ster., but effective solid angle is 0.017 ster., due to Θ_B-E_f correlation.

III. Electron-Volt Spectrometers

Bob Brugger and Andrew Taylor reported on the direct and inverted geometry resonance filter difference spectrometer prototype measurements at LANL, Gavin Williams reported on the inverted geometry resonance filter difference spectrometer prototype measurements underway by RAL at the Harwell Linac, and Jack Carpenter reported on the extensive development (in which he participated) of a resonance detector spectrometer at KENS. A general conclusion of the discussion was that the inverted geometry instruments were greatly superior to any practical direct geometry resonance filter difference instruments.

The filter difference techniques have the large advantage that the instrumentation is quite simple, involving only a resonance absorbing foil and standard neutron detectors. The difference method also means that background does not appear in the final results. However the difference method involves the subtraction of two large numbers and so has inherently large statistical errors. Thus it does not seem useful for measuring weak inelastic scattering. (However, Gavin Wlliams discussed the use of additional broadband filters in the incident and scattered beams as a technique to cut out most of the unwanted neutrons and hence greatly reduce this statistical problem. This technique will be tested on the Harwell Linac. This technique also suffers from the relative inefficiency of neutron detectors at these energies.

The resonance detector spectrometer also uses a resonant neutron foil, but in this case it is used as an energy-selective detector rather than as a filter. The capture gamma rays from the resonance of interest are detected by standard gamma techniques. This has the advantage of being a direct neutron detector technique, and so does not suffer from the bad statistics due to subtraction of large numbers inherent in the filter-difference techniques. However, shielding is much more complicated because the detector must be shielded from both gammas and unwanted neutrons.

Resolutions of about 70 meV (in a final resonance energy of several eV) are currently achievable.

IV. Choppers and Chopper Spectrometers

David Price reported on the chopper phasing techniques developed at ANL and on the results with the two chopper spectrometers there, Richard

Silver and Bob Brugger reported on current LANL attempts to phase a chopper to the LAMPF accelerator, and Spencer Howells reported on recent results on the chopper spectrometer operated by Brian Boland at the Harwell linac. ANL has solved its chopper phasing problems by running both the choppers and the accelerator from a fixed frequency crystal oscillator. A further refinement allows one "master" chopper to control extraction from the accelerator, thus effectively eliminating any effects of hunting oscillations for this chopper. Additional choppers can also operate as "slaves", in which case they cannot control extraction and so must follow the extraction frequency as best they can. At present the master can stay in phase within 1-2 microseconds while the single slave chopper currently operating is in phase within about 7 microseconds over 95% of the time.

LANL can control the LAMPF pulse within a 64 microsecond window which follows the line frequency. They are attempting to do this by using a relatively large permanent-magnet motor to provide sufficient torque to drive the chopper to follow the required rapidly-varying smoothed live frequency. Preliminary tests indicate the chopper can follow this frequency fairly well, although details about hunting oscillations, chopper heating and long-term ability to remain in phase were still sketchy.

The Harwell linac is phased to a crystal oscillator, so there is no major phasing problem for the RAL chopper spectrometer there.

Results on the ANL and RAL chopper spectrometers have mostly been aimed at the epithermal part of the spectrum. Both have used incident beams of about 500 meV. Background problems at these energies, although difficult, have been tractable in both cases. Progress is being made in understanding the resolution functions of these instruments.

Jack Carpenter discussed the use of Bragg reflection from a rotating crystal as an alternative to choppers for providing pulse-shaping in some cases for pulsed source instruments. In particular, this can provide a narrow time pulse with a wide energy band, which is difficult to do with choppers outside the biological shield. No plans are currently underway to build or test such a device, however.

V. Polarized Neutron Instrumentation

Masahumi Kohgi reported on the cold polarized neutron spectrometer and on tests performed on a polarized proton polarizer at KENS, Gian Felcher reported on progress on the spin refrigerator polarizer at ANL, on a proposed neutron spin precession technique for enhancing resolution in eV spectrometers, and on the current ANL efforts with cold polarized neutrons, and Gavin Williams reported on the RAL efforts using resonance absorption polarizers, including the prototype instrument being tested at the Harwell linac. The main effort continues to be directed toward developing efficient broad-band polarizers for thermal and epithermal neutrons. This work is technically very demanding and although some progress has been made the optimum solution has not yet been achieved.

The polarizing filter method based on the spin-dependent scattering of neutrons by polarized protons in a dynamically polarized ethylene glycol target is being pursued at KENS. A proton polarization of 43% has been achieved in a 1 cm thick target. Workers at KENS are now building an instrument based on a filter of this type. The spin refrigerator principle, which is an alternative method for polarizing protons, is currently being tested at ANL. It uses a crystal of Yttrium Ethyl Sulphate doped with Yb^{3+}, which is rotated in a magnetic field of 1.3 T. The apparatus is much simpler and more compact, and has much simpler cryogenic and field-homogeniety requirements, than the dynamic polarization method. A proton polarization of 30% has so far been achieved in preliminary measurements. Considerably higher proton polarization will be needed in both types of filter. These polarized proton filter techniques are extremely important to the future of polarized beam research at pulsed neutron sources, since this is the only known technique which provides white beam neutron polarization over a broad energy range up to KeV energies.

RAL is investigating the filter method using selective absorption by polarized nuclear resonances. Several statically polarizable nuclei have been identified as potentially useful neutron polarizing filters in the epithermal and lower eV energy range. ^{151}Eu is particularly interesting since it has a broad-band polarizing capability extending up to 0.6 eV. A new application using neutron resonances for combined energy and spin analysis (eg. for inelastic polarization measurements) was also described. These techniques will be extensively tested at the Harwell linac.

Cold neutron polarizers based on mirror reflections are easy to make, and many experiments have been performed on the TOP spectrometer at KENS. A novel application of the critical reflection of polarized cold neutrons from magnetized surfaces, is being used at ANL to probe the penetration of a magnetic field into the surface of a superconductor. Time-of-flight polarized beam measurements are particularly appropriate in this case, since a wide range of wavelengths can be covered with the sample set at a fixed reflection angle.

Gian Felcher discussed his proposed use of polarized neutrons in a spin precession technique which could yield energy resolutions of about 30 meV in the lower eV energy range. However, any tests of this technique await the development of a satisfactory white-beam neutron polarizer.

VI. Detector Development

There has been significant progress since the last ICANS in the use of scintillator detectors at pulse sources. The 30 cm square, 49 tube Anger Camera using square photomultipliers has been brought into service at the single crystal diffractometer at IPNS. The effects of the intrinsic backgrounds in the Li glass scintillator and its sensitivity to γ radiation have not so far proved troublesome though care is taken to minimize the amount of γ producing shielding material such as Cd or B. Work is proceeding on the difficult problems of reduction of data from PSD's used in diffraction studies. Powerful FEM computers with large memory are needed. Detailed studies of the properties of the detector such as long term stability and uniformity of detection efficiency over the scintillator area have not yet been made.

A coded scintillator detector using solid glass light guides rather than optical fibers was tried on the constant Q spectrometer at the Harwell linac but proved to have too high a background for that low count rate instrument. An alternative arrangement of individual scintillator elements and coupled to ½" photomultipliers was much more successful yielding background levels in use which were slightly lower than an 8 atmosphere 9mm diameter ^{3}He counter, with the advantage of higher efficiency and lower cost. The best results were obtained with 2 layers of scintillator 1mm thick separated by a layer of lead (3mm thick) to absorb the secondary electrons from γ capture events. Significant reductions in intrinsic background can be made by using a separate plastic scintillator to veto cosmic ray events in the glass scintillator.

In discussion of the origins of the intrinsic background in ^{6}Li-loaded glass scintillators, Tom Holden referring to CRNL work by Aslam Lone, pointed out that this may be due to reactions induced by the triton recoiling from the $^6\mathrm{Li}(n,\alpha)$ T reaction; triton decay itself is not a problem. The most likely candidate reaction is

$$\mathrm{T} + {}^{16}\mathrm{O} \rightarrow {}^{19}\mathrm{F} \rightarrow {}^{18}\mathrm{F} + n$$

$${}^{18}\mathrm{F} \xrightarrow[109.\ \text{min.}]{} {}^{18}\mathrm{O} + \beta^{+} \ (.633\ \text{MeV})$$

The Coulomb barrier is 2.4 MeV, while the triton energy is 2.7 MeV. Other possibilities are

$$\mathrm{T} + {}^{29}\mathrm{Si} \rightarrow {}^{32}\mathrm{P} + \gamma \quad \text{and} \quad \mathrm{T} + {}^{30}\mathrm{Si} \rightarrow {}^{32}\mathrm{P} + n,$$

$${}^{32}\mathrm{P} \xrightarrow[14.3\ \mathrm{d}]{} {}^{32}\mathrm{S} + \beta^{-} \ (1.71\ \text{MeV})$$

The Coulomb barrier is 3.8 MeV. The key to diagnosing the background problem is probably to measure the decay time of the background, following neutron irradiation. Neutron activation of other isotopes in the scintillator may also account for the "cooling off" effect seen when a detector is removed from a neutron field.

Good lithium-loaded scintillating glass is now being produced in Japan by Nikon. There is enough difference in the pulse shape for neutron and γ interactions to enable pulse shape discrimination to be used. There was no evidence of α activity in the pulse height spectrum. Work is also going on in Japan on fibre optic coupling.

VII. Data Acquisition

There have been no significant conceptual developments in data acquisition systems for neutron scattering instruments since the last ICANS meeting. However, since then the IPNS data acquisition has been brought on line. Tom Worlton reported on the performance of this system which is quite satisfactory. RAL has just placed the initial order for VAX computers for the SNS neutron scattering data acquisition system.

VIII. Importance of Dynamic Range

Ferei Mezei discussed the importance of providing instrumentation which covers a wide dynamic range, noting that many experiments at ILL must be done on several different instruments in order to cover a sufficient dynamic range. He also cited several examples of experiments which led to the wrong conclusions because the experiments did not span a sufficient dynamic range. He noted that this makes pulsed source instruments potentially very attractive, since the wide dynamic range is an inherent feature of most time-of-flight instruments.

IX. Standard Samples

There was a general discussion of the adoption of a standard sample material for the intercomparison of inelastic spectrometers. It was decided to adopt as a standard the material sodium bifluoride ($NaHF_2$). Sodium bifluoride has a sharp peak (~ 11 meV wide) at 159 meV, and has a much broader peak at 179 meV. Some peaks at higher energies have also been observed.

Measurements are to be made at low temperatures (20-30K) using sample geometries optimized for the instrument on which the measurements are made. Results of these measurements are to be distributed informally among the ICANS laboratories by the experimentalists involved.