AD-A031 042 OFFICE OF NAVAL RESEARCH LONDON (ENGLAND) F/G 20/8

NUCLEAR ORIENTATION STUDY,(U)

AUG 76 T A KITCHENS

UNCLASSIFIED ONRL-C-24-76 NL

1 OF 1

AD

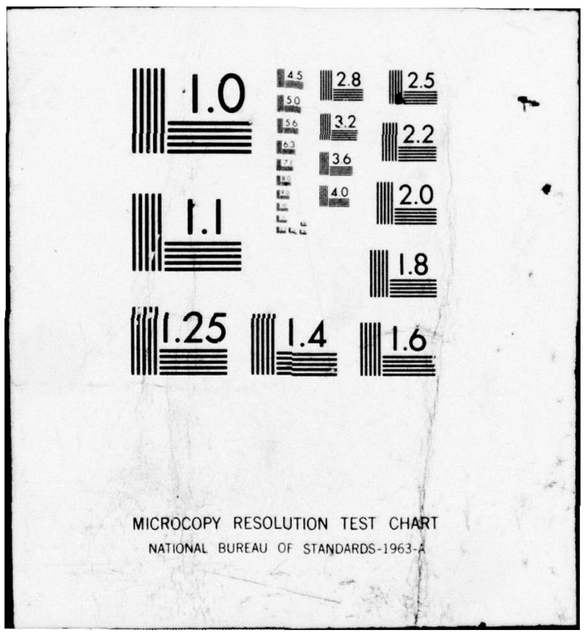
A031042

END

DATE

FILMED

11-76


1.0
1.1
1.25
1.4
1.6
1.8
2.0
2.2
2.5
2.8
3.2
3.6
4.0
MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

(12) FG.

ONR LONDON CONFERENCE REPORT

ONRL-C-24-76

OFFICE OF NAVAL RESEARCH

BRANCH OFFICE LONDON ENGLAND

NUCLEAR ORIENTATION STUDY

DR. T.A. KITCHENS

19 AUGUST 1976

UNITED STATES OF AMERICA

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER C-24-76	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) Nuclear Orientation Study,		5. TYPE OF REPORT & PERIOD COVERED
		6. PERFORMING ORG. REPORT NUMBER ONRL-C-24-76
7. AUTHOR(s) Dr. T.A. Kitchens		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Office of Naval Research Branch Office London Box 39, FPO New York 09510		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 19 Aug 76
11. CONTROLLING OFFICE NAME AND ADDRESS		12. REPORT DATE 19 August 1976
		13. NUMBER OF PAGES 5 (12) 7p.
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report)
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

NUCLEAR ORIENTATION
NUCLEAR MOMENTS
ADIABATIC DEMAGNETIZATION
γ-RAY ANISOTROPY
RECOIL IMPLANTATION
BRUTE FORCE ORIENTATION
ION IMPLANTATION
POLORIZED NUCLEI
PARITY VIOLATIONS
TIME REVERSAL
NUCLEAR MAGNETIC RESONANCE

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

In mid July 1976, a European Study Conference on Low Temperature Nuclear Orientation was held in Oxford. The conference concentrated on techniques and brief summaries of the state-of-the-art. The techniques covered were adiabatic demagenetization, dilution refrigeration, brute force orientation, ion implantation, recoil implantation, γ-ray anisotropy and radiative detection of nuclear magnetic resonance of oriented nuclei. The understanding gained by these techniques of the nuclear decay schemes, nuclear dipole and quadrupole moments, nuclear level assignments, parity and time-reversal NEXT pg

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE
S/N 0102-014-6601

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

265 000 JB

(20) Continued
violations, metallurgy, magnetic order, relaxational effects, and the Kondo and spin glass phenomona was reviewed.

NUCLEAR ORIENTATION STUDY

St. Edmund Hall is one of the oldest colleges in Oxford, having been founded in 1270. It has several significant points of interest, such as an early window by Burne-Jones. And St. Edmund was the site of the European Study Conference on Low Temperature Nuclear Orientation in mid-July. About 60 attended the meeting, the first of its kind, which was arranged by Professor N. Stone of the Clarendon Laboratory. The Conference schedule was very suitable for intensive private and small-group discussion between the participants, who came from 11 countries and represented about a dozen of the 15-18 international groups interested in this subject. Each day had three one-and-a-half hour sessions leaving both the afternoon and late evening free. Each session chairman gave an hour summary of a subtopic, bringing up the current points for discussion and introducing subsidiary speakers.

Over half of the Conference was devoted to technique. This was appropriate because the Leuven Hyperfine Interactions Conference last fall, which was recounted in *ONRL-C-24-75* and in *Hyperfine Interactions* (Academic Press), provided a recent review of the scientific state of the majority of this subject. Because these reports adequately cover the science, the technical aspects will be emphasized in this summary. The participants were all very open with their "tricks-of-the-trade," and the discussion was quite informative.

Dr. G. Eska (Zentralinstitut für Tieftemperaturforschung, Garching) began with a *discussion of adiabatic demagnetization.* He reviewed the cooling-power and thermal-contact problems with the dilute paramagnetic salts and the enhanced-nuclear-spin Pr intermetallic compounds, especially $PrNi_5$ and $PrCu_6$. Typically, the radioactive source heating in these experiments can be reduced to about 10 nW (0.1 erg/sec). Most of the groups are using temperatures below 20 mK routinely, several have the capability of cooling sources below 5 mK, and a couple even below 1 mK. J. Saunders reported on the apparatus at the University of Sussex which demagnetizes 4 moles of Cu nuclei from 13-15 mK in 8 T to reach temperatures below 1 mK and incorporates ^{60}Co nuclear orientation (NO) and Pt nuclear-magnetic-resonance (NMR) thermometers. This apparatus produces temperatures below 2 mK for more than half a day. Dr. W. Steyert (Los Alamos Scientific Laboratory) has demagnetized In nuclei below a mK with 4 T and has used a novel thermometer, ^{60}Co in Au, which is a Kondo system with the ^{60}Co seeing about 40% of the applied residual field of 0.2 T. Eska reported reaching 0.7 mK with his $PrNi_5$ coolant.

Eska also discussed the technique of radiative detection of Nuclear Magnetic Resonance of Oriented Nuclei (NMR/ON). Perhaps the major difficulty with this method is that of obtaining a smooth and known transmission coefficient of the rf power over the range desired, usually 200-800 MHz. Eska and a colleague illustrated the problems of resonance by ending the session on a Bavarian note with a violin and flute duet!

Dr. W. A. Steyert (Los Alamos Scientific Laboratory) discussed the state-of-the-art in dilution refrigeration and electric quadrupole orientation in metals. He discussed the ^{4}He circulating dilution refrigerator being developed by R. de Bruyn Ouboter at Leiden, the multiple mixing chamber ^{3}He dilution refrigerator being developed by A. Th. A. M. de Waele at Eindhoven University of Technology and the sintered-silver continuous heat exchangers developed by G. Frossati and D. Thoulouse at the CNRS laboratory in Grenoble. (These last two developments were discussed in *ESN-30-7:328*.) But more important to NO studies is the top-loading ^{3}He dilution refrigerator first developed by B. S. Neganov at Dubna. This device allows investigations involving radioactive nuclei with lifetimes as short as a few hours. Steyert reviewed the present state of low temperature thermal contact techniques. He has been utilizing a Cerium Magnesium Nitrate (CMN) demagnetization specimen which contains 50 volume percent of gold powder to improve the thermal transport to a bundle of gold-plated high purity copper wires. Earlier attempts to use copper powder proved unsuccessful because the CMN chemically attacks the copper. He will soon try using the silver powder.

In the discussion period W. Truscott (Sussex University) reported on the great cooling power of the ^{3}He adiabatic compression cooler (the Pomaranchuck Effect refrigerator) in the few mK region, but he admitted that thermal contact to the cooling source is difficult to obtain.

W. D. Brewer (Freie Universität Berlin) reviewed the Brute Force Orientation (BFO) technique, in which the nuclei are oriented by the Zeeman splitting by bringing the nuclear spin system into thermal equilibrium in a large applied magnetic field. For most nuclei a value of 500 Tesla/K for the pertinent experimental parameter, H/T, is adequate for about 10% polarization. This is about the smallest value of polarization for which reasonable BFO experiments can be done. State-of-the-art H/T is about 1000 Tesla/K. However, very few of the BFO experiments seem to produce as much orientation as expected from the magnetic moments obtained by other means such as NMR. Brewer reviewed critically the twenty-some BFO measurements made to date and presented what he believes to be the reason for the lack of orientation. Some of the discrepancies, such as $Mn^{55}\underline{Co}$ and $Co^{60}\underline{Fe}$, are probably due to Knight shifts, magnetic 4d or 5d impurities, radiative heating effects, or quadrupolar fields that exist even in the cubic metals due to radiation damage during sample preparation. Other discrepancies may be due to long thermal relaxation times caused by specimen preparation which gave rise to cluster formation, precipitation, or even chemical reactions involving the radioactive nuclei. For example, the difficulties in $^{95}Nb\underline{Ta}$ may be due to the fact Nb is a good getter and niobium oxide is precipitating.

L. Vanneste (Katholicke Universiteit, Leuven, Belgium) reviewed the technique of ion-separator implantation and nuclear-decay scheme studies. He showed that if the Hume-Rothery rules obtain, the implant into iron is nearly always good. The Hume-Rothery limits are: atomic radius between 1.10

and 1.50 Å and electro-negativity between 1.30 and 2.10. Vanneste reviewed the efforts on the 5s-5p series work of the early 1970's at Oxford, Gröningen and Leuven and the very recent annealing studies of ^{129}I in Fe by Reinstsema in Gröningen. This work shows that at room temperature about 61% of the implanted ^{129}I is in substitutional sites, 21% in interstitial sites and about 18% in a low hyperfine field configuration, while at 600°C over 95% has moved into the low-field configuration. The work on the Xe and the 6s-6p elements and the implantation models used by the Groningen and Leuven groups were also covered. In the discussion D. Hamilton showed that the Hume-Rothery rule also seems to work for rare-earth isotopes implanted in gadolinium.

Professor I. Berkes (University of Lyon) reviewed the technique of recoil implantation and contrasted its characteristics with ion implantation. In recoil implantation the primary ion beam is stopped in a target and the recoiling ions are implanted in the sample foil immediately behind the target. The energy distribution of the recoiling particles is nearly flat, leading to a flat depth profile of implanted ions up to some maximum distance. The flux of implanted ions is about 1000-fold greater for the recoil technique than in conventional ion implantation, and the damage near the implanted ion is less, but there will be more damage far from the implant due to recoiling α-particles. Berkes discussed the nuclear moment studies on ^{99}Tc, ^{103m}Rh, the Te and the Pt isotopes by the NMR/ON technique and gave some possible reasons for the discrepancies with regular NMR measurements. The reasons for these difficulties are more or less the same as those discussed by Brewer with regard to the BFO technique.

The sixth session was chaired by Professor B. G. Turrell (University of British Columbia) who reviewed NO of antiferromagnetic structures. The first experiments of this kind were done by J. Daniels (University of Toronto) on $MnCl_2 \cdot 4H_2O$ at temperatures above 90 mK in 1961, and the $CoCl_2 \cdot 4H_2O$ system was studied in 1973 by Turrell. The behavior of these materials is consistent with the spin-flop theory developed by Keffer and Chow in 1973. The participants concluded that a study of a metallic antiferromagnetic and a nonmetallic ferromagnetic material would be extremely useful in obtaining an understanding of the fundamental existence of magnetic order and the NMR signal enhancements.

H. Postma (Gröningen) gave a comprehensive review of the facilities available in the world for NO investigation with polarized and unpolarized neutrons. The thermal contact problems with thin targets used in transmission experiments and the pros and cons of the three methods of polarizing neutrons, Bragg reflection from a magnetic single crystal such as Co, polarized filters such as ^{149}Sm and magnetic mirrors, were discussed. A recent development of the magnetic mirror idea at the Institut Laue-Langevin in Grenoble now allows this technique to be used for neutrons up to a higher critical angle than before [see F. Mezei, *Communications on Physics*, 1, 81 (1976)]. Postma then reviewed his and also Fisher's (Stanford University) experiments on ^{59}Co in a Co single crystal to see whether a tensor potential was necessary to account for the spin-spin interactions. It appears that a spherical potential is consistent with the results. He also discussed experiments on the anisotropy of the fission fragments from neutron-induced fission of oriented uranium isotopes and others and also of γ-rays from neutron-capture experiments. The session was brought to a close by H. W. Weber who spoke on the "neutron spin-echo" work in Vienna on ^{51}V and ^{93}Nb.

D. Hamilton (University of Sussex) chaired the session involved with fundamental tests of symmetry violations. He reviewed the physics of parity and time-reversal violations and the possible experiments to test them. Details of the Sussex apparatus, which incorporates a dilution refrigerator capable of continuous operation below 50 mK and two γ-ray detectors, the operating procedure, and the elimination of systematic errors due to solid angle and other detector characteristics were presented. Hamilton and Postma are setting up a facility for polarized-neutron scattering from oriented nuclei at Institut Laue-Langevin at Grenoble and need active collaborators by next year. During the discussion a description of the Cal Tech apparatus which cools a 1-2 mCi ^{57}Fe source to 17 mK was given by N. K. Cheung. The session closed with Steyert reminding the group that only one of the dozen isotopes studied for time-reversal shows a violation outside statistical error, and that about the same was true for the parity violation experiments.

The final day's discussion began with a review of NO in Kondo and spin-glass systems by J. Flouquet (Laboratoire de Physique de Solides, Orsay). He described the Orsay adiabatic demagnetization cryostat which is capable of 3 mK, automated to run on a ten-hour cycle and using ^{60}Co<u>Co</u> and ^{54}Mn<u>Ni</u> as primary thermometers. After reviewing the physics of the Kondo Effect, Flouquet argued that the NO technique has the following advantages over other techniques: experimental simplicity, allowing one to study the hyperfine field of a specific nucleus at very low concentrations, and because higher energy γ-rays can be used than in Mössbauer studies, many isotopes may be studied. However, as he described the results of experiments on the spin glasses in particular, it became clear that a major disadvantage is the fact that NO is an integral method; it measures an averaged hyperfine field and is incapable of determining whether or not the hyperfine field is distributed or sharply defined at the nuclei. In the discussion W. Brewer argued that perhaps 50% of all NO data is useless because of impurity-interaction effects and that more care should be taken in specimen preparation. Flouquet completed his presentation with a compilation of the existing NO data and a discussion of the Kondo-model used to interpret NO data.

P. D. Johnston discussed the work at Oxford on relaxation effects done by NMR/ON. He reviewed the Oxford experiments on ^{60}Co<u>Fe</u> and the effects of the electric quadrupolar field, especially on the γ-ray anisotropy during a single adiabatic sweep of the radiofrequency. Because of the level mixing, the anisotropy is irreversible. Much the same complications exist for ^{197}Au<u>Fe</u> where the spin-orbit coupling gives rise to a stepping of the quantum number during the adiabatic passage. During the discussion, experiments on the Korringa relation in ^{60}CoFe at Vancouver, University of New South Wales (Australia) and Berlin were discussed by B. Turrell, G.V.H. Wilson and E. Klein, respectively. After Johnston, M. Finger (Charles University, Prague), who had not been present on the first day, took a few minutes to describe the facilities for NO investigations at Dubna, USSR. He is part of an international team including D. Hamilton and B. S. Neganov working on several NO projects. They are now using the off-line irradiation facilities at Dubna to study the nuclear properties Tb isotopes with Neganov's top-loading dilution refrigerator. This refrigerator allows radioactive samples to be changed in 10 minutes and to refrigerate them to 14 mK in less than three-and-a-half hours. The next phase at Dubna is to provide an on-line irradiation facility.

The final session of this study Conference was chaired by G.V.H. Wilson (University of New South Wales (Australia) who had the task of innervating the participants to do some crystal ball gazing. Much of the content of this session had been alluded to in the other sessions and I have incorporated the remarks in the appropriate places above. I. Campbell (Physique des Solides, Orsay) gave a rather negative critique of NO from the theoretical point of view. He admitted that over the last decade the technology has made enormous strides, but the results of the investigations are not yet ten-fold more significant. He did not discuss the nuclear studies. He felt that the metals and magnetism are of primary interest to the theorists. Nevertheless, the Kondo problem, the last problem in this area to attract much theoretical discussion, is now a dozen years old. Theoreticians are currently interested in superfluid ^{3}He and phase transitions, and NO is not the most sensitive technique to investigate these phenomena. Unless something suggests that the RKKY and well-known anisotropic effects do not explain the spin glasses, the difficult problem they present will not initiate a major theoretical effect. The remainder of the session was devoted to various enigmas that are of current concern. For example, W. Brewer discussed the problems of β-detection by detectors below 4 K, and Eska discussed the use of channeltrons to 77 K, while H. Marshak reviewed the capabilities of his dilution refrigerator set-up at NBS-Washington.

Finally Stone, following the suggestion of several of the participants, discussed the circulation of research results on NO. He agreed to maintain a list of NO publications at Oxford if each researcher will let him know of any new work. This list will be made available to each laboratory on request--not just to the participants of this Conference.

And, thus ended a very useful study conference.