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THE WORKSHOP ON POLARIZED TARGETS AND MATERIALS - SUMMARY

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The Workshop presentations and discussions centered on recent developments in the following areas:

- I. Irradiated Ammonia
- II. Polarized Atomic Hydrogen
- III. Polarized Target Technology
- IV. Chemical Doping

I. IRRADIATED NH_3 AND ND_3

Interest in irradiated ammonia as a target material has been generated by the original CERN report¹ of proton polarization > 90% and by subsequent observations^{2,3} of high radiation tolerance, coupled, of course, with a high content of hydrogen.

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The following presentations were made:

W. Meyer -	Irradiated NH_3 and ND_3 at the Bonn synchrotron.
H. Riechert -	A study of the polarizing mechanisms in irradiated ND_3 .
M. L. Seely -	Irradiated NH_3 , ND_3 , and other materials at SLAC.
D. G. Crabb -	Irradiated NH_3 at the AGS.

Table I lists the current principal results of these studies. Some qualitative features of the data are readily understood. For example, the required dose for "polarizing" at Bonn is much greater than that at SLAC or the AGS; but this would perhaps be expected at the higher irradiation temperature, at which fewer types and numbers of damage centers would be stabilized. Likewise, the required annealing temperature is higher at Bonn, in correspondence with the higher temperature at which the "polarizing" centers are formed.

The relationship among the observed "depolarizing" doses is somewhat less explainable. The ϕ_0 (NH_3) at SLAC is about 30 x that observed (at SLAC) for a conventional "Butanol" (butanol/water/porphyrin) target, whereas the Bonn ratio, and probably also the AGS ratio, is about 3x. The relation between the SLAC and Bonn experiences would qualitatively fit the dictum that "better radiation resilience is obtained when the target is used under the same conditions (temperature) that it is created". However, the AGS result does not fit this pattern; in fact, the AGS- ϕ_0 is not any greater than that of certain conventionally-doped materials.⁴ On the other hand, the AGS data is very preliminary.

Concerning ND_3 , SLAC observed that successful annealing of the damage is possible at a temperature of 10K or so, but that an entire new dose must subsequently be applied in order to substantially recover the polarization. At Bonn, the "polarizing" centers are quite stable at temperatures as high as 77K. This is extremely puzzling.

In summary, if we take the data at face value we conclude that

- a) very high values of ϕ_0 are obtained only at 5T, and
- b) low-temperature-irradiated material polarizes better at 5T, 1K than at 2.5T, 0.5K.

However, owing to the large number of potential variables involved, these conclusions are far from firm. The Workshop participants recommend that the following direct comparisons be undertaken:

- a) Try low- and high-temperature-irradiated material in the same apparatus.
- b) Compare a given sample at 2.5 and 5T, before and after a "depolarizing" dose.

TABLE I Summary of results of irradiated ammonia.

	BONN	SLAC	AGS
IRRADIANT	20 MeV e^-	6-20 GeV e^-	28 GeV/c p
DOSE	$\sim 10^{17} e^-/\text{cm}^2$	$\sim 4 \times 10^{15} e^-/\text{cm}^2$	$\sim 2.2 \times 10^{15} p/\text{cm}^2$
IRRADIATION TEMPERATURE	85K	1K	0.5K
BEAD TYPE	"Fast Frozen"	"Slowly Frozen"	"Slowly Frozen"
POLARIZATION (PROTON)	66% (.5K, 2.5T)	71% (1K, 5T)	$\sim 45\%$ (.5K, 2.5T)
ϕ_0 (DEPOLARIZING DOSE) (NH_3)	$3.4 \times 10^{15} \text{EQQ}/\text{cm}^2$ (a)	$\sim 10^{16} e^-/\text{cm}^2$ (b)	$\sim 1.2 \times 10^{15} p/\text{cm}^2$
ANNEALING TEMPERATURE (NH_3)	$\lesssim 120\text{K}$	$\gtrsim 10\text{K}$	$\gtrsim 40\text{K}$
POLARIZATION (DEUTERON)	31% (.2K, 2.5T)	$\sim 25\%$ (1K, 5T)	
ϕ_0 (ND_3)		$\sim 10^{16} e^-/\text{cm}^2$ (c)	
ANNEALING TEMPERATURE (ND_3)	(Centers stable at 77K)	$\gtrsim 10\text{K}$	

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- (a) - Compared to $1.2 \times 10^{15} \text{EQQ}/\text{cm}^2$ for a "Butanol" target.
 (b) - Compared to $3 \times 10^{14} e^-/\text{cm}^2$ for a "Butanol" target.
 (c) - Compared to $2.2 \times 10^{14} e^-/\text{cm}^2$ for a deuterated "Butanol" target.

The first suggestion may be readily implemented. The second involves a more expanded hardware capability and is therefore more difficult.

II. POLARIZED ATOMIC HYDROGEN

The following presentations were made:

- D. Kleppner - Spin-polarized hydrogen and possible target applications.
- T. O. Niinikoski - Possible applications and a new experimental initiative.

The details of Dr. Kleppner's presentation appear elsewhere in these Proceedings. The current experimental situation is that densities of (nuclear) spin-polarized gas of around 10^{17} H(++)/cm³ have been achieved, with inferred proton polarizations of around 99%. Dr. Kleppner presented conceptual designs for potential polarized target applications, one based on the gaseous form and the other based on the production of transiently polarized solid H₂.

Dr. Niinikoski discussed possible applications in the areas of intense, pulsed polarized sources, jet targets, and a stored, atomic-beam target. He also described an experiment in progress at CERN which will attempt to extend the present gas density limit, as well as give some additional experience with the behavior of the monatomic gas.

The merits of a target consisting of pure, polarized hydrogen would obviously be great, and the technology that is developing here certainly shows some promise. However, there remain some severe problems which may not yield to further developmental effort. In the case of the gaseous monatomic target, the greatest problem is the low density. (And if appreciably higher densities are achieved, the stored chemical potential energy density will be so high that a working target would represent a potential thermomechanical "bomb" in the event that rapid recombination were inadvertently triggered.) Another basic problem is that the polarization can be reversed only by reversing the strong "bottling" field. There are also difficulties with measuring the effective density and nuclear polarization of the gas, although these may give way to sufficient technological cleverness. The present consensus on the gas-type target seems to be that it may be useful for some specialized scattering experiments wherein cross-sections are large and background a severe detriment, provided that the spin reversal problem can be circumvented.

In the case of the proposed "solid" H₂ target, perhaps the greatest problem, at least in trying to make a critical judgment, is that the relevant physics is poorly explored so far. Difficulties in the following areas are anticipated:

- a) The exact polarization and density of the solid may not be well characterized.

- b) The density of the solid is, in any event, considerably less than that of bulk liquid ^4He . There is thus a potentially large degradation of the figure-of-merit of such a target owing to the presence of the necessary refrigerant (unpolarized background).
- c) Target heating via ortho-para conversion and beam-heating.
- d) Polarization reversal.

Overall, the Workshop participants believe that the possible applications of spin-polarized hydrogen to intense polarized sources are more promising than target applications. Moreover, the experience gained by working on the "source" possibilities should help to identify any realistic "target" applications.

III. Polarized Target Technology

The following specialized contributions were made:

- M. L. Seely ~ Irradiation and polarization studies of several potential target materials.
- W. Meyer ~ The preparation of ammonia beads for irradiation studies.
- W. Meyer ~ A horizontal dilution refrigerator for targets used in a photon beam.
- J. Deregél ~ A frozen-spin target with large aperture and three spin directions.
- A. Masaike ~ Experience with a dilution-cooled deuteron target.
- J. J. Jarmer ~ A frozen-spin target at LAMPF.
- J. J. Jarmer ~ A tandem target-dummy target arrangement.
- P. Cameron ~ A dilution refrigerator insert for the Michigan target.
- P. Cameron ~ Proposed future heat transfer measurements.
- V. P. Kanavets ~ A polarized target installation for the ITEP accelerator.

One notable general impression to be gained from the above accounts is the extent to which dilution refrigerators and frozen-spin techniques are now commonplace. Nearly every laboratory with an interest in high energy spin physics now has such equipment.

The report from KEK (A. Masaike) on partially deuterated propanediols demonstrates that the workings of "conventional" target materials can still be quite bewildering.

P. Cameron's proposals for heat transfer measurements point up the general dearth of hard information on this important subject, in the sub-Kelvin range at moderate-to-high thermal fluxes.

IV. Chemical Doping

The following presentations were made:

- D. A. Hill - Dynamic polarization in hydrogen-rich glasses.
- H. Riechert - An experiment with potassium-doped ammonia.
- M. Krumpolc - The preparation and properties of NH_4BH_4 .

Recent progress has been made in finding hydrogen-rich target materials suitable for "chemical" doping. The approach has been to look for high-hydrogen substances which readily form a glassy solid, since the formation of a true solid solution of the necessary paramagnetic dopant is greatly facilitated in a glassy matrix. Preliminary trials have yielded proton polarizations in excess of 70% in materials with hydrogen fractions up to 18 wt%. There appear to be quite reasonable prospects for hydrogen fractions up to 21 wt.% and higher polarizations, and the deuterated analogs of these materials are accessible.

As with even pure ammonia, there is a potential problem here with the background nuclei (^{14}N , ^{10}B , ^{11}B), which may be appreciably polarized. For pure elastic scattering experiments this problem might not be serious, but in other cases the possible polarized-background effects will not be easily isolated. With boron-containing materials, the problem may be mitigated by isotopic enrichment in ^{10}B , which species should be less polarized than ^{11}B . Beyond this, one would hope to be able to eliminate the background effects, if necessary, by "RF-killing" the polarization of the unwanted species in a frozen-spin configuration.

References

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