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SUMMARY ON SOURCES USING PUMPING SCHEMES

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ABSTRACT

The contributions on optically pumped sources presented at the 1986 Montana workshop are summarized. Design problems and the status of the three working sources are described. The optically pumped source shows great promise for high currents. Already now the highest pulse currents are reported for this type of source. A considerable improvement is expected for the proposed collisional pumping scheme.

1. Introduction

The principle of optically pumped (proton) sources comprises two basic ideas:

(i) Production of a dense electron spin polarized gas target (e.g. Na vapor) by optical pumping,

(ii) Pick-up of polarized electrons from the target.

The second step (ii) has already been proposed by Zavoiskii [1] in 1957 and Haeberli [2] in 1965, but no suitable targets were available at that time to generate high intensity polarized beams. A pioneering work was done along these lines by Witteveen [3] in the late seventees. He

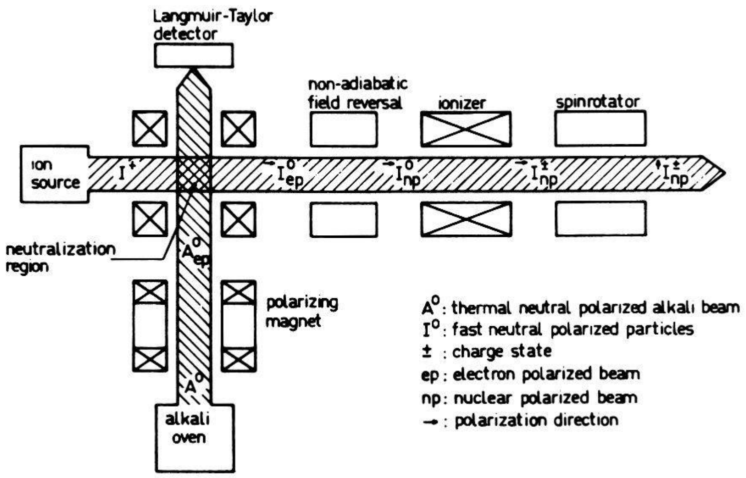

Fig. 1 Schematic representation of Witteveen's source based on polarized electron pick-up [3].

employed pick-up of polarized electrons from a Na atomic beam which was polarized by help of a strong quadrupole magnet. The apparatus used for these studies is shown in fig.1. Still the target densities were too low.

A breakthrough in target density was enabled by Andersons proposal [4] to produce a dense Na vapor target by laser optiocal pumping. The first operating optically pumped proton source was reported by Mori at the 1983 Vancouver workshop [5]. Since then a vivid development took place which is reflected in a large number of contributions to this workshop.

The "standard" scheme of an optically pumped (OP) source is shown in fig. 2. An H^+ beam picks up polarized electrons from a Na cell pumped by a dye laser and operated in a high B-field in order to avoid polarization losses. After performing a Sona transition, the neutral fraction of the beam is ionized to negative or positive ions by means of a second charge exchange target.

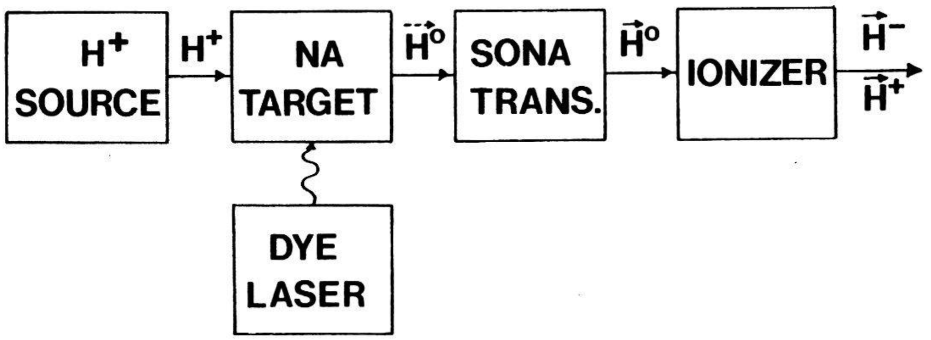

Fig. 2 Principle of a standard optically pumped source.

An improved scheme has been proposed by a Berkeley-Winsconsin group to generate intense polarized beams using "Collisional Pumping" [6]. It is based on a very dense Na target in low field where spin transfer in multiple collisions occurs.

Apart from these schemes there are several other methods involving optical pumping which have been proposed or applied to produce polarized beams or targets.Optical pumping of ^{3}He by ^{4}He lamps was demonstrated in 1963 [7] and applied to ^{3}He targets. The impressive progress in this field became visible in the remarkable contribution by Michele Leduc on direct OP of high density ^{3}He gas by tunable infrared lasers, which has some very interesting applications in atomic and condensed matter physics.

At the Vancouver meeting Happer proposed spin exchange of OP alkali atoms (Rp) to produce large amounts of polarized nuclei [8]. Polarized beams of Li and Na ions for injection into a tandem accelerator are generated by direct OP of atomic beams [9]. In the following we concentrate on methods for the production of intense H^- beams required for injection into high energy accelerators by stripping injection [10].

2. Status of existing OP sources

In his review Schmor described the "state of the art" of existing OP sources. Two of them, the operational KEK source and the prototype TRIUMF source, comprise an ECR H+ source and a Na cell in a strong magnetic field. The KEK source runs at a duty cycle of 0.3% and employs single mode dye lasers while the TRIUMF source delivers a dc beam and pumping is done with a multimode laser. A third OP source constructed for the Moscow meson factory has attracted considerable attention due to the spectacular results which have been obtained [11]. It is described in a written contribution to this workshop. In addition to e pick-up and ionization, two additional charge exchanges are employed in order to cross fringe fields in the neutral state and to avoid emittance blow-up. Peak currents of 1mA H^+ and 0.15 mA H^- with good emittance are reported. The source is pulsed at a very low duty cycle of $3 \cdot 10^{-5}$. Attempts to increase this figure are in progress.

3. Design and optimization of OP sources

Several contributions were dealing with Na target problems. Depolarization during wall collisions was studied experimentally by Swenson and Anderson and some good materials like "silicon rubber" or "dry film" were found. In fig. 3 the TRIUMF results on Na polarization as function of target thickness are shown. A viton wall coating clearly helps to increase polarization. The question of radiation damage to the wall coating material seems to be quite severe as reported by the TRIUMF group.

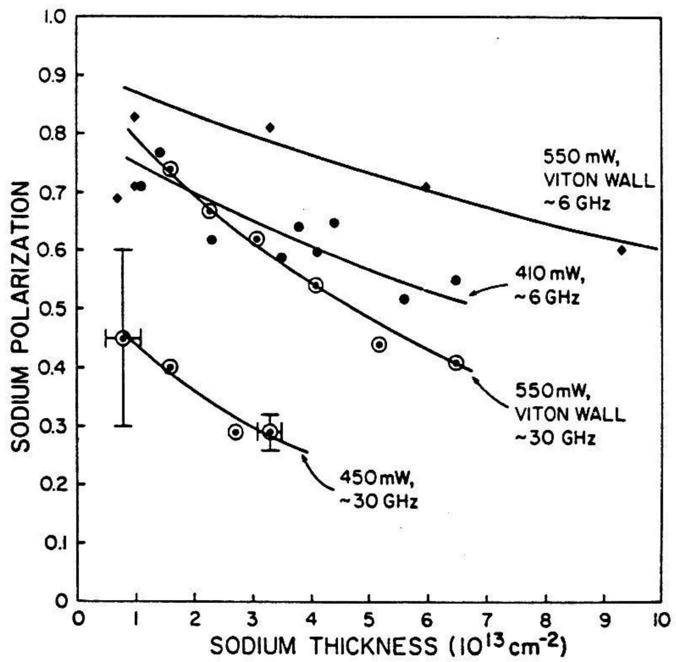

Fig. 3 Na polarization as function of the target density for different Laser power and wall material measured by the TRIUMF group.

Radiation trapping and wall relaxation limits the possible Na target thickness. This was illustrated in a contribution by Tupa and Anderson, in which model calculations for the time dependent polarization building up under variouzs conditions were studied (see fig. 4). It seemed that for the "low density" targets for standard OP sources radiation trapping is no problem, while the very thick collisional pumping targets ($1015/cm^2$) require Laser power of several tens of W/cm ^{2} which is beyond the present capabilities.

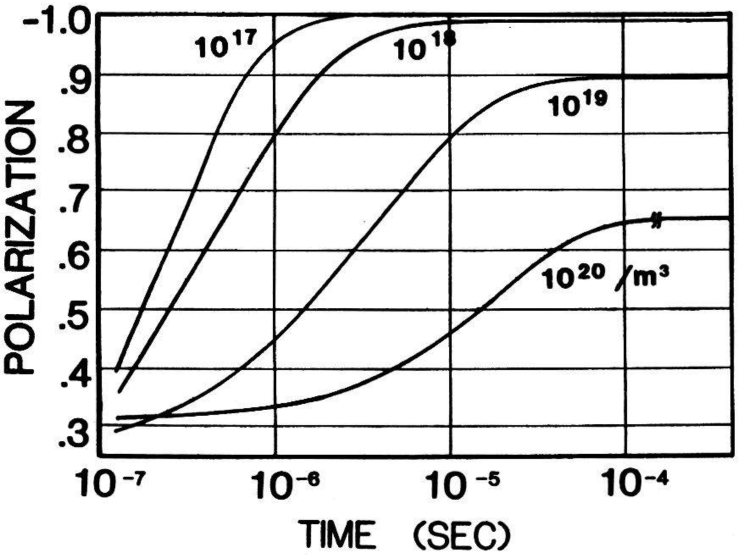

Fig. 4 Time dependent building-up of Na polarization for different target densities as calculated by Tupa and Anderson (P Laser = 1W/cm2, wall relaxation time T 1 = 150 μs).

Some discussion was about the optimum coverage of the absorption profile. As shown by the TRIUMF results in fig. 3, a reduced bandwith of 6 GHz resulted in a higher polarization. Recent results from Heidelberg [12] show that a further reduction to 2 GHz will be even better. Bi-directional pumping as found by the TRIUMF group leads to an increase in Na polarization by about 10%.

The B-field over the Na target region required for LS-decoupling [13, 14] is still under discussion. In his review, Schmor showed a comparison of experimental results with calculations of Hinds et al [14]. The experimental points are about 20% lower than the calculations, but it is not clear how significant it really is. A very interesting result was found at KEK. Mori reported that the polarization of H^- ions originating from the H_2^+ primary beam component was higher and less field dependent in the 6 to 10 kG range than H^- from the H^+ component. It was speculated that an OP source optimized for H_2^+ might run even better than a standard one.

4. Collisional pumping

As already mentioned, this method might be capable of delivering amperes of polarized beam which is of interest for generating polarized fuel for fusion reactors. This aspect was discussed in some detail by Wakuta.

Collisional pumping is now actively studied by the Berkeley-Wisconsin collaboration and at Kyushu. Anderson presented calculations on electronic spin-exchange as a new effective polarizing mechanism [15] for dense Na targets. These cross sections were already included into detailed model calculations presented by Kaplan. Similar calculations from the Kyushu group, but without spin exchange, were shown by Wakuzta. Due to spin-exchange, the required target thickness is reduced by almost one order of magnitude to values of $3 \cdot 10^{15}/cm^2$ for protons and $5 \cdot 10^{15}/cm^2$ for deuterons. Of course the corresponding laser power of $30\ W/cm^2$ is available at present only with low duty cycle.

5. Conclusions

At the Ann Arbor workshop in 1981 two papers on OP sources were presented, one by Wilmer Anderson about the method and the other by Yoshiharu Mori about the starting KEK development. Two years later at Vancouver, first operation of the KEK source was reported. In total, three papers on OP sources were presented. Now at Montana we had about ten papers on this subject which indicates a broad systematic development. We were pleased to learn that after many preliminary studies by the Los Alamos group now an OP source for LAMPF got funded and will be constructed soon. Three sources are working by now. The highest pulse currents ever observed are reported by the Moscow group for this type of source. All this is a spectacular success after half a decade of development. We even expect much higher currents from the Collisional Pumping scheme. Let me close by saying the we are looking forward to the progress in optically pumped sources which will be reported at the next workshop!

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