Easy Access to Polarized 3He by Centralized Large Scale Production

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Abstract:

Spin-polarised gases as Helium-3 offer the possibility for morphological and functional imaging of airspaces as the lungs via MRT. A large scale polariser, that is able to produce 3 bar*l /h (less than 200mb*l are needed to perform an image of a human lung) of hyperpolarised ^{3}He at a polarisation of more than 60% (P_{max}=84%) serves as a central production unit from which highly polarized ^{3}He can be shipped (e.g. by plane) all over the world. New results on the origin of depolarisation in the transport vessels make it now possible to conserve the polarisation in non coated special glass vessels for days (100h < T_1 < 280h). Since years lungs of volunteers and patients are being imaged at the university clinics in Mainz, weekly. Amounts of bar*l are shipped regularly by plane from Mainz (Ger) to Sheffield (GB) and Copenhagen (DK) for clinical lung studies. The longest transport so far was a delivery of 3 bar*l of polarized ^{3}He (P>60%) from Mainz (Ger) to Rochester (US).

Introduction:

Polarisation of ^{3}He by optical pumping techniques is well known in principle since the 1960ies. The first applications were experiments in fundamental physics. Because of the macroscopic magnetisation one started to use in the early 90ies spin-polarised gases as a kind of MRT-contrast agent to enable airspace imaging. The wide interest in this new method made it necessary to find a way to highly polarize ^{3}He in large quantities. In addition, the handling of prepolarised ^{3}He, i.e. its storage, transport, administration and recovery, have become important issues in assessing and spreading this new non-invasive diagnostic tool in research and medical practice. Our aim is to show that all the challenges mentioned above are now under control and the needed equipment to perform ^{3}He-MRI is now minimized to an adaptation of the coil and the MR-scanner to ^{3}He-frequncy. The gas can be ordered from a central polarizer and special skills on polarizing methods and apparatus handling are not necessary any more.

Figure 1: Polarisation unit

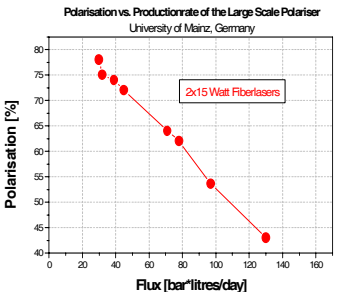


Figure 3: Polarisation vs. Productionrate

Method and Realisation:

The polarisation apparatus (Fig. 1) is based on the method of optical pumping of metastable ^{3}He atoms in an electrical plasma at a gas pressure of order 1 mbar. A beam of resonant (λ = 1083nm) circularly polarised laser light is irradiated along 5 plasma tubes of 2.2 m length wherein the atoms are picking up the polarisation of the light by absorption. Within less than a minute the total gas volume of 30 ltrs. is polarised up to P = 80%. The polarised gas is then sucked out by a large, specially developed non magnetic piston and compressed to usually 3 bars (max. pressure = 10bars) into storage cells blown from iron free glass. Without internal coating polarisation decay times of up to 280h are observed, sufficient for shipping everywhere within specially developed homogenously magnetized spin cases (Fig. 2). Fig. 3 shows the ^{3}He polarisation measured in the plasma tubes of the polariser as function of throughput. In a static mode a maximum of P_{max} = 84% has been observed. A typical working point would be around 70 bar*l/day at P = 65%, which would be enough gas to perform more than 350 MR images on human lungs.

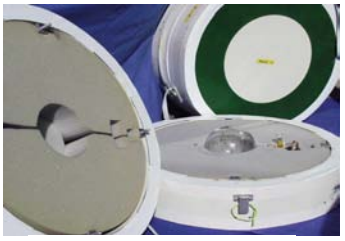


Figure 2: Spin case and ^{3}He storage vessel

Furthermore we have developed a unit which administers a preselected bolus of ^{3}He precisely during the breathing cycle and triggers the MRT scanner. It is particularly useful for quantification of functional imaging. In this context we have also developed various methods to measure the polarisation at high accuracy during the polarisation process as well as after transport.

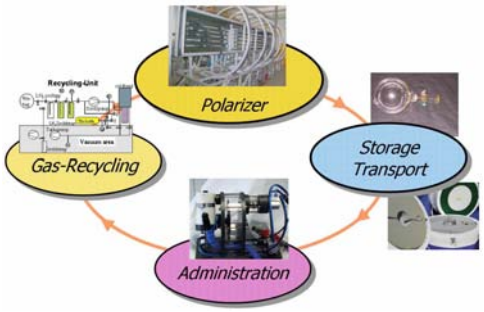


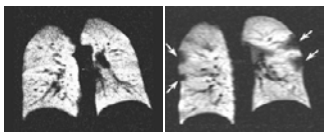
Figure 4: ^{3}He Cycle

Results and Discussion:

Since 2002 our Apparatus is the most powerful Polarizer worldwide concerning the achievable Polarisation and production rate. It has reached a level that made it possible to rebuild the system on a commercial base. This new machine which is used at the neutron source FRM II in Munich provides comparable performance characteristics but has improved handling and safety features. The system has been approved recently by the local health authority to meet the demands of the new German Medicines Law. During the last years a big step was taken by identifying and eliminating the main relaxation source that is responsible for the loss of polarisation while storing the gas inside the transport vessels. This allows us now to provide highly polarized ^{3}He (P>60%) independent from the distance of the measuring site to the polarizer. Besides solving the problems of production, storage, transport and administer polarised ^{3}He we developed a purifying unit to extract ^{3}He from the exhaled Air/^{3}He mixture with high efficiency to reduce costs and avoid wasting the gas. By adding this last step we have closed the cycle (Fig.4) and the purified and sterilized gas can be polarized again. We hope that the now possible easy access to highly polarized ^{3}He will significantly widen its use in experiments and medical applications.

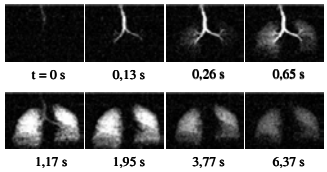
Our polarized ^{3}He was regularly used at the University Clinics Mainz, the Royal Hallamshire Hospital at Sheffield (GB) and the Danish Research Centre for Magnetic Resonance, Copenhagen (DK) in an EU funded research program for assessing the diagnosis of pulmonary diseases by ^{3}He MRT and some other smaller studies. Some results are shown below.

Morphological High Resolution Lung Imaging

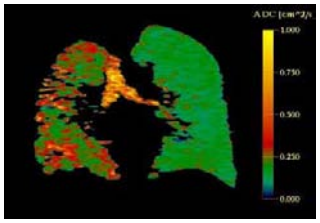


Nonsmoker — Smoker, 30 years old with venitlation defects

Ultrafast MRT of Pulmonary Ventilation



Imaging of Apparent Diffusion Coefficient



left: fibrotic lung; right: transplanted healthy lung
yellow: large air spaces; blue: small airspaces

Measurement of Oxygen Partial Pressure and Decrease during Breathhold

- Experiment with anesthetized pig
- Double Acquisition, variable time interval (1 s, 7 s)
- Linear decrease of oxygen pressure: $p_{O2} = p_0 - R * t$