

# Automated Hyperpolarized $^{129}\text{Xe}$ Gas Generator for Biomedical MRI/MRS Applications

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## Introduction

The hyperpolarization (HP) technique can increase the signal sensitivity of nuclear magnetic resonance (NMR) ten thousand times for  $^3\text{He}$  and  $^{129}\text{Xe}$ , and thus it enables instantaneous imaging of cavity gases [1, 2]. This technology has been expected to be a practical technology for the development of medical equipment that enables instantaneous evaluation of lung functions, and the early diagnosis and prevention of cerebral infarction based on the high-accuracy and high-speed imaging of blood flow in the brain [3]. To investigate such biomedical applications of HP Xe, a practical HP Xe gas generator has been required. In this report, we propose the improvement of an HP Xe generator which works under atmospheric pressure and applies a batch method to provide a continuous supply of HP Xe gas by utilizing the technologies for a highly pure gas supply, a gas control system, cleanliness at the semiconductor production equipment level, and highly accurate pressure control. The device was evaluated through long-term experimental operation for the continuous collection of 30ml syringes of HP Xe gas, using a 2T-MRI scanner. The performance of this device for the polarization of naturally abundant Xe and  $\text{N}_2$  gas mixture was evaluated.

## Apparatus

Figure 1 shows the developed automated HP Xe manufacturing device. This device is composed of a cylinder storage part for the Xe and  $\text{N}_2$  gas mixture which is the raw material, along with high-purity nitrogen gas for purging, a pressure control component, a HP Xe formation component and a system control component. The system control component incorporates an interactive touch-screen panel designed for error-free operational control. Atmospheric gas purging, conducted after changing the gas cylinders or cells, was fully automated. Cell positioning could be altered according to the direction of the NMR/MRI magnetic field, and the equipment for generating a magnetic field specifically for polarization could be installed on a separate frame if necessary. Figure 2 shows the Pyrex glass cell fabricated to include rubidium metal. The glass cell has two valves which become the entrance for the Xe and  $\text{N}_2$  gas mixture that is used as the raw material and the exit for the hyperpolarized gas from a cylinder-shaped glass cell of 60mm diameter and 100mm length with a flat window for irradiation. The rubidium was inserted under a vacuum to prevent its oxidation on the internal wall of the Pyrex glass cell and to prevent it from air contamination. The Xe and  $\text{N}_2$  gas mixture with a pressure of approximately 1.2 atm is enclosed, when the rubidium is transferred to the wall of the cell.

## Experiments

The stray field of a horizontal superconducting magnet (2T) was used for optical pumping processes. The cell was heated to  $\sim 120^\circ\text{C}$  in a magnetic field of approximately  $\sim 12\text{mT}$  and irradiated using a 30W semiconductor laser light of  $794.7 \pm 1\text{nm}$  wavelength (Coherent: B1-79-40.0C-19-30-A; 40W), then circularly polarized through a quarter-wave plate (CVI: QWPO-795-08-4-R10). After 30 minutes, the HP Xe gas was produced at a polarization rate of 2~3%. All MRI experiments were performed using the 2T MRI system (Bruker Biospec with Oxford 2T/31cm SCM). We prepared a surface coil for the  $^{129}\text{Xe}$  frequency at 2T ( $\sim 23.56\text{MHz}$ ) with  $50\Omega$  matching circuits.

## Results

We achieved a 2~3% polarization of  $^{129}\text{Xe}$  for the Xe (98%) and  $\text{N}_2$  (2%) gas mixture. The HP Xe gas was transported to plastic syringes and 14 days of long term experimental operation in AIST allowed the continuous collection of more than one hundred 30ml syringes of HP xenon gas at a polarization rate of 2~3%. We have performed MRI on the Xe gas in the syringes. Figure 3 shows the image acquired using the echo planer imaging sequence. By diluting Xe gas with He and  $\text{N}_2$  buffer gas (30:50:20), approximately a 20% polarization rate of  $^{129}\text{Xe}$  was obtained.

## Conclusion

We successfully developed a practical device that uses a batch method to provide a continuous supply of HP Xe gas with a sufficient rate of polarization for practical NMR/MRI experiments. This research should facilitate further work on NMR/MRI to shorten measurement times, obtain more diverse data, and increase its accuracy. The research should also facilitate the development of technologies suitable for biomedical applications including the instantaneous evaluation of lung functions, and of medical technologies for the early diagnosis and prevention of cerebral infarction based on high-accuracy and high-speed imaging of the blood flow in the brain.



Fig.1 Practical device for the automated manufacture of hyperpolarized Xe gas.



Fig.2 Rubidium enclosed in a Pyrex glass cell.

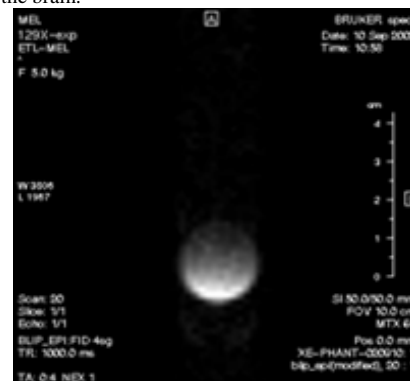


Fig.3 MRI image of hyperpolarized Xe gas extracted in a syringe (NEX=1, 64X64, Number of segments = 4, TE=9.68ms, THK=50mm).

## References

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