A Compact Counter-flow Xenon Polarizer for Clinical Applications

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Abstract
Hyperpolarized xenon offers extraordinary potential as a contrast agent for MRI. The University of New Hampshire's Center for Hyperpolarized Gas Studies is the undisputed leader in xenon polarization technology and methods. A polarizer is installed in Boston's Brigham and Women's Hospital, where polarized xenon for MRI experiments is produced, on a continuous basis. Further partnering with outside hospitals is anticipated. In collaboration with UNH, Xemed LLC is developing a compact version of the polarizer. This paper presents progress improving the properties while reducing the size of the magnetic subsystem, increasing the efficiency and capacity of the freezeout and scaling up the laser of the compact polarizer.

Introduction

The counter-flow xenon polarizer developed at the University of New Hampshire[1] has been scaled op in capacity and reduced in size to fit in a standard 19" rack. The project was divided in three parts: 1) Isolation of the uniform polarizing magnetic field and the NMR region from the high-strength freezeout magnet required detailed design and precise implementation. 2) The freezeout/thaw system needed greater capacity and automated operation, and 3) The laser needed to be reduced in size and cost, and equipped with an external cavity.

Figure.1. The rackmount xenon polarizer

Permanent magnet subsystem

Figure 1 shows the polarizer. The two-meter polarization column and 16 coil solenoid are mounted inside the green shield cage, which also functions as a return yoke. A laser beam [3] enters from the side, and is directed down via a 45° dielectric mirror. Xenon gas enters from the bottom of the column, flows opposite to the direction of the laser beam, and exits at the top, into the permanent magnet subsystem [2]. It consists of a field rotator, a uniform field for NMR measurement, an exponential field ramp and a 4 Kgauss freezeout region. The NMR operates at 83 gauss for xenon and 23 gauss for calibration.

Freezeout subsystem

The freezeout consists of a quartz multitube heat exchanger with optimized surface-to-volume ratio, an X-Y actuator controlled LN2 dewar, a warm water thaw-bath, an automated LN2/water switcher (figure 2) and a 10 liter LN2 supply dewar. The system automatically raises the LN2 level, dependent on the xenon flow rate, leaving a thin layer of frozen xenon in the freezeout. It then lowers the LN2 dewar, and replaces it with the warm water, which thaws the xenon into a plastic bag in a uniform field. The bag is internally coated to reduce relaxation, and can be removed for MRI experiments.

Figure 2. LN2/water freezeout/thaw unit

Laser subsystem

Two new lasers allow us to explore the operational range of the polarizer. The presently installed laser system consists of a 9 bar 795 nm 540W wavelength narrowed laser diode array [3]. We set the maximum power with narrowing at 270W. A low modulation grating and an afocal telescopic lens system form an external wavelength narrowing cavity. The space between bars (figure 3) is eliminated by a segmented mirror. The beam is then shaped to fit the polarizing column with cylindrical lenses. The beam divergence in the polarizing column is less than 0.5 degrees. A recently acquired 12 bar 1.2KW laser is being evaluated. The optimal laser for our commercial clinical polarizer will balance cost, capacity, and longevity.

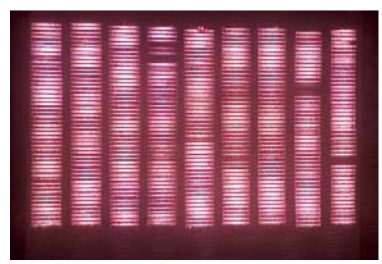

Figure 3: 9-Bar laser illumination pattern

Results

The compact polarizer contains a 100 ppm permanent magnet NMR, an automated freezeout/thaw system, which does not require human intervention, and a compact high power laser, wavelength narrowed to better than 0.5 nm. Software for complete system control and user friendly interface is in development. Power requirement is 3000 W. Weight is approximately 400 kg. The performance characteristics will be presented on the meeting, including details on unattended operation and the latest polarization figures. The polarizer should be able to run for hundreds of hours without servicing other than refilling the LN2 and water bath.

Summary and outlook

The UNH xenon polarizer has been producing over a liter per hour at 40% polarization, operating for hundreds of hours at the Brigham and Women's Hospital without major breakdown or maintenance. Xemed has developed a prototype compact commercial polarizer with lower environmental requirements (power, heat load, space) and potentially improved performance (polarization rate, capacity, mean time between maintenace). Measured performance parameters will be presented.

Acknowledgements
This work was supported by the National Institute of Health under STTR contracts R42 RR20200-02, R42 HL78295-02 and R41 ES14005-01.

References

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