Using laser frequency narrowing techniques to improve production of hyperpolarized Xe for imaging and surface analysis.

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INTRODUCTION

Hyperpolarized ^{129}Xe is xenon gas whose spin polarization has been increased by four to five orders of magnitude through optical pumping. This gain in spin polarization directly translates to a signal gain in MRI and MRS. Hyperpolarized gas (^{129}Xe and ^{3}He) has been used for imaging of lungs, particularly the air spaces of the lung which has typically resisted conventional MRI techniques in the past. Early results on animals as well as on humans have indicated that hyperpolarized noble gas MRI can have profound diagnostic and therapeutic implications for diseases of the lung. The high Xe solubility in the blood and tissues may also open possibilities of imaging other organs such as the brain, kidney and heart using hyperpolarized (HP) ^{129}Xe. The large chemical shift of Xe makes HP ^{129}Xe NMR suitable for studying, for example, surface structure of bulk polymers.

METHOD

HP^{129}Xe is produced using the spin-exchange optical pumping (SEOP) method. As a laser source for SEOP, diode lasers are the most popular choice because of the low cost and small footprint. The use of diode lasers, however, does bring a disadvantage. The spectral output of diode lasers is typically a couple of nm wide and this makes the optical pumping less efficient. Our research has been directed toward efficient, cheap production of HP^{129}Xe by optically optimizing the pumping process. We frequency narrow a 30W LDA (CEO ARR26C030) using optical feedback from a diffraction grating[1-3], and employ the laser for SEOP of ^{129}Xe. Figure 1 shows an illustration of the feedback technique where a grating is used to select the wavelength of the light returned to the diode. The laser is induced to run at the wavelength of the light that is fed back and as the grating only returns a small part of the spectral range the laser is narrowed.

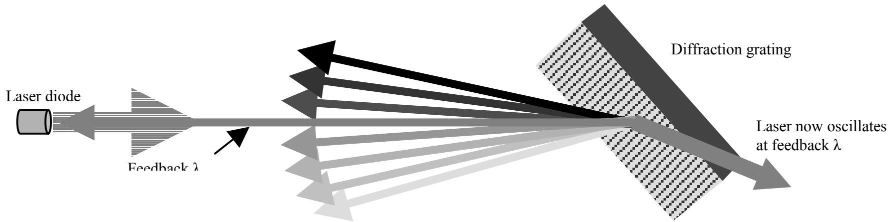

Figure 1 Diagram showing the reflected spectrum from the grating being fed back to the laser diode. Only a small part of the spectrum returns to the diode inducing it to operate over a narrower wavelength range.

RESULTS AND DISCUSSION

Using low field NMR, we compare signal strengths obtained with (a) the narrowed laser and (b) the free-running laser at the same operating current. Figure 2 shows the NMR spectra obtained for each case.

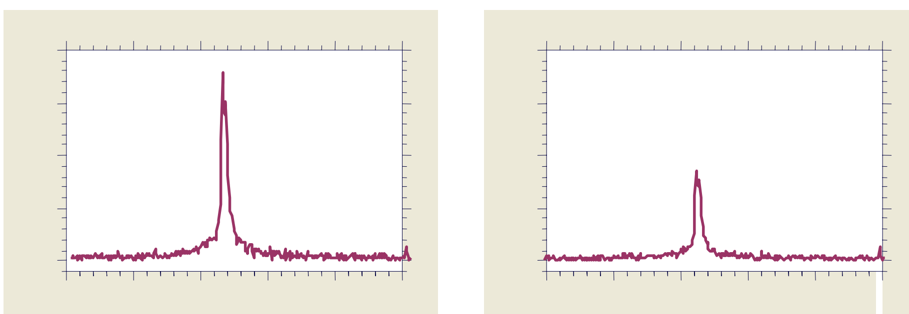

Figure 2 Low field NMR spectra of HP129Xe produced by SEOP with (a) frequency narrowed LDA (b) free-running LDA, at the same operating current.

We compared signal strength by integrating the NMR spectrum, and found that frequency narrowing the LDA improved signal strength by factor of 2, as summarized in table 1. As signal strength is directly proportional to polarization, this indicates a 195% increase in spin polarization.

Optical Pumping Source	Signal strength	Relative signal strength
Frequency Narrowed LDA	5.26×10^{6}	1.95
Free-running laser	2.70×10^{6}	1.0

Table 1 Signal strength calculated from integral of NMR spectrum

The HP^{129}Xe produced in this manner was used for xenon NMR spectroscopy of silica nanoparticles. The Xe chemical shift was used to 'visualise' the dehydration of the particle surface as a mixture of Xe, N_2 and ^{4}He flowed over the sample. By using feedback to narrow the laser, we were able to significantly increase the level of hyperpolarisation of xenon and thus increase its sensitivity as a diagnostic tool.

REFERENCES

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