Spectrally-narrowed external-cavity high power diode laser arrays for optical pumping of hyperpolarized xenon

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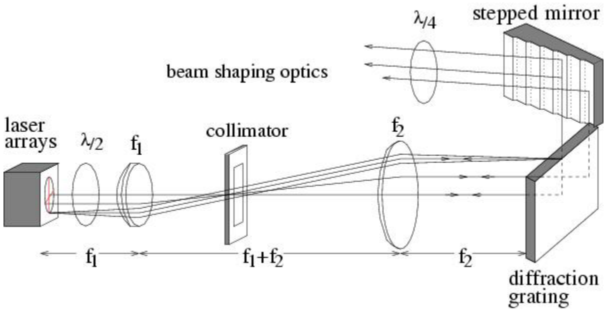
Abstract

We describe a laser for optical pumping of hyperpolarized xenon that makes use of an external cavity to narrow the spectral linewidth of a multi-bar stack of diode laser arrays. For a commercially available 279 watt free running 5-bar stack of diode laser arrays running at 60 A, we narrow the spectral linewidth to 0.40 nm (FWHM) with 115 watt of CW output power. This technique leads to high efficiency, low cost production of hyperpolarized ^{129}Xe for magnetic resonance imaging.

Introduction

Recent developments in production of large volume hyperpolarized xenon for magnetic resonance imaging through spin-exchange optical pumping increasingly demand for high power and narrow bandwidth laser light[1]. Low cost high power diode laser arrays (LDAs) can yield powers in the kilowatt regime, but with spectral width of typically about 2-4 nm which limits the power that can be absorbed by the alkali atoms during spin-exchange optical pumping. Recently it has been demonstrated that appropriately designed external cavities can be used to frequency narrow a single high power diode laser array bar[2]. The technique increases the spectral power density at the wavelength where the optical pumping takes place. With much higher power available from multi-bar LDAs, it is clearly of interest to narrow its frequency linewidth and further increase the effectiveness of optical pumping process.

Apparatus and Method



A typical stack of high power LDAs, such as Nuvonyx PA-332[3], consists of 5 LDAs with 2.2 mm array pitch distance. Each array has 49 optically independent emitters, each 100 micron wide on 200 micron center, spaced in an approximately straight line across a 1 cm wide bar. It is capable of delivering full power of 335 watt at current of 70 A. The principle behind using an external cavity to frequency narrow LDAs is that light from each emitter needs to be approximately collimated, reflected off a diffraction grating at a uniform angle and imaged back onto the emitter with high efficiency. For this purpose, a telescope with magnification of 2 is constructed to reduce the laser angular spread. Followed by a holographic diffraction grating with 1800 lines/mm provided the optical feedback to the LDAs. The grating has a Littrow angle of 45.7 degree for 795 nm needed for Rb optical pumping. We have tested three innovations with this arrangement: First, we used large focal length lens and low magnification telescope to reduce the effect of the field of depth on linewidth narrowing. Second, we implemented a collimator in the intermediate focal point of the external cavity to reduce divergence and increase brightness. Third, we invented and fabricated a gold plated stepped mirror for increased intensity and beam uniformity. The stepped mirror provides individual reflective element for each of the laser light arrays from the zero order diffraction off the grating such that the dark areas are substantially removed with minimum loss of laser power. Laser light from external cavity is linearly polarized in the P-plane at maximum power output. The output power is maximized by adjusting the output coupling through orientation variable λ/2 plate in the cavity.

Results

Figure 1 shows a comparison of the spectral linewidth between the external cavity laser and the free running laser. The linewidth of all five arrays combined is 0.31 nm FWHM at 15 A, broadens to 0.40 nm at 60 A. A maximum of 115 watt of spectrally narrowed power is coupled out of the cavity from a 279 watt free running laser at 60 A. Wavelength tunability is also of interest for applications in spin-exchange optical pumping. Our external cavity allows as many as 10 nm tuning, as shown in Figure 2. With appropriate beam shaping optics and applying the spectrally narrowed laser to our xenon polarizer, it is capable of producing hyperpolarized xenon gas at a rate of typically 1.2 liters/hour with polarization over 45%[1].

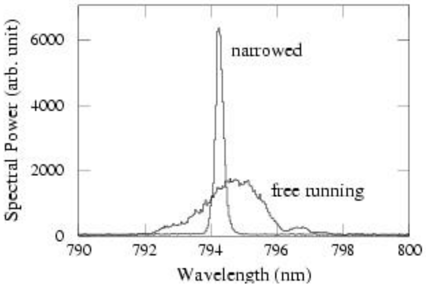


Figure 1: Comparison between free running and spectrally narrowed linewidth

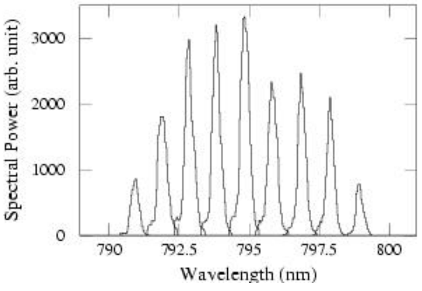


Figure 2: Tuning range and the spectral power of the external cavity laser

Outlook

Our near term future is to increase the power output efficiency of the external cavity by replacing the high modulation diffraction grating with a low modulation one, and by replacing the gold coating of the stepped mirror with dielectric coating. We expect 25% more power output. The work is currently in progress.

Acknowledgement s

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References

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