Frequency Narrowed Lasers for Spin Exchange Optical Pumping

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Introduction

Spin exchange optical pumping (SEOP) places demanding requirements on its laser source, requiring as high power as possible within the collisional broadened Rubidium absorption profile. The absorption linewidth of Rubidium atoms in a typical SEOP experiment is of the order of ~ 20 GHz / bar [1]. Some means by which to frequency narrow the typically very broad spectral ~ 1000 GHz (~ 2 nm) of a high power laser diode array is thus required in order to achieve efficient SEOP [2,3]. The gains made by using frequency narrowed lasers for Rb SEOP of ^{3}He [4] and ^{129}Xe [5] are considerable. Our Hyperpolarised Technologies Consortium [6] is exploring the various technologies for frequency narrowing of high power laser bars for ^{3}He and ^{129}Xe SEOP. We have made a direct comparison of a 60W Nuvonyx laser bar mounted in both an ECDL as per the design described in [3] and using a Volume Holographic Grating (VHG) manufactured by PD-LD Inc. [7]

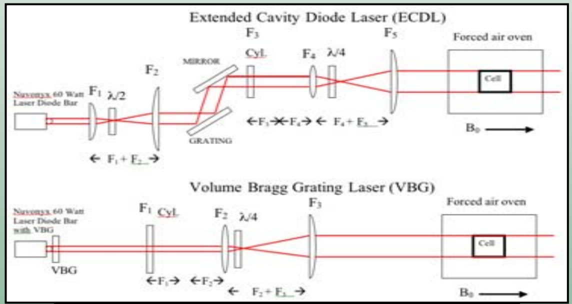

Figure 1 Schematic of ECDL and VBG laser cavities

ECDL and VHG Lasers

Our extended cavity diode laser (ECDL) uses a newly developed 3-D holographic grating formed in glass known as a Volume Holographic Grating (VHG) [8] or Volume Bragg Grating (VBG) [7]. The cavity arrangement used for our conventional ECDL [2,3] and the new VHG is shown in Figure 1. For the VHG cavity a micro collimating lens is attached on the front of the laser bar to collimate the laser output along its fast axis. The VHG is placed immediately after this micro lens and acts as the frequency selective feedback element. For the VHG cavity, Lens F1 is a cylindrical lens that collimates the divergence of the laser output in the slow axis. Lens F2 and F3 act as a conventional telescope to allow beam expansion to a size that covers our SEOP cell, typically 5 cm diameter. Between lens F2 and F3 is a quarter wave plate to create the circularly polarised light from the linear polarised output of the laser diode array.

ECDL Results with a 60 Watt Laser Diode Array

Figure 2 (LHS) shows data for the Nuvonyx 60 Watt laser diode with and without feedback in a ECDL cavity. Data from a conventional Coherent 30 Watt FAP system is shown in comparison to the narrowed ECDL and shows just how effective the ECDL arrangement is in both narrowing the spectra to ~ 0.1 nm and suppressing out-of-band emission > 20 dB. Spectral power density of the narrowed ECDL is in excess of ten times that of both the Coherent FAP and bare Nuvonyx laser diode at > 100 watts / nm. Using an identical laser bar and ECDL arrangement, Babcock and co-workers [3] have achieved 81% nuclear polarisation in a small 3 bar ^{3}He cell, the highest ever with a laser diode array.

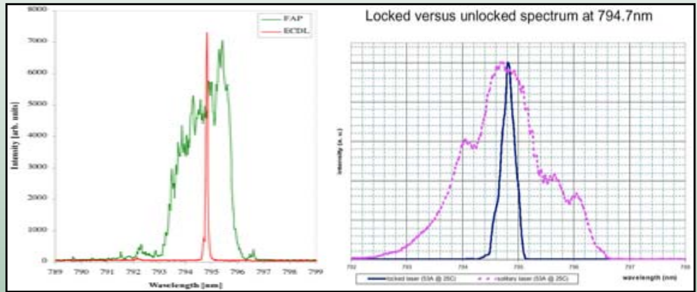

Figure 2 Comparison of un-narrowed & narrowed ECDL and VBG

VHG Results with a 60 Watt Laser Diode Array

Unlike the ECDL [2,3] the VHG does not have mechanical tuning capability by changing the angle of the grating relative to the laser bar. PD-LD Inc. literature for the VHG suggests a small residual temperature tuning coefficient of ~ 0.01 nm / Deg. C (compared to 0.30 nm / Deg. C for the bare laser diode). Data for a laser bar before and after integration of the VHG is shown in Figure 2 (RHS). Data taken with a PD-LD VHG show that the locked wavelength tunes with current ~ 0.0125 nm / Amp. This is a direct result of the laser light heating the VHG [8]. The residual temperature tuning of the VHG as a function of laser power allows enough adjustment for inaccuracies in wavelength manufacture as well as the Rb wavelength variation as a function of pressure.

Figure 3 Photo of the new Ultra-high power 320 Watt VBG laser

VHG frequency Narrowing with P > 200 Watt

Even with the frequency narrowing of the 60 Watt ECDL and VHG lasers, SEOP of ^{3}He for large volume neutron spin filters and hyperpolarised ^{129}Xe production still shows that we are photon limited [4,9]. Some careful consideration has to be given in extending SEOP to multi-hundred Watt pumping levels due to heating of the Rb by the laser leading to Rb "runaway" [10]. Hersman [9] is able to avoid this problem in his low pressure ^{129}Xe SEOP by generating his Rb vapour before entry into the optical pumping cell. Our group is currently building a new VBG frequency narrowed laser (Figure 3) using a "state of the art" single laser bar capable of in excess of 320 Watts (Figure 4). This system will use a new tunable "chirped" VBG grating allowing optimal tuning at the highest power levels available from this new laser diode. This system will have the highest optical power density per nm at 794.7nm of any system reported to date [11].

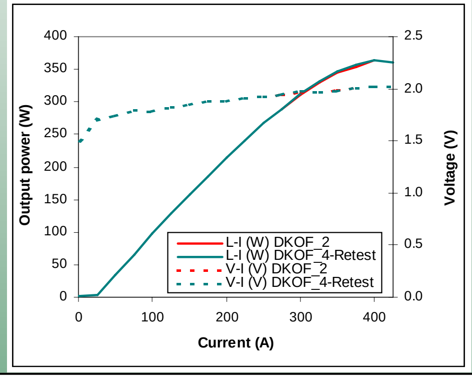

Figure 4 Optical Power vs Current for nLight 795nm 320 Watt laser

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