Development of a Compact 1.55 µm Acetylene Standard, using a Widely Tunable DSDBR Diode Laser

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Abstract

A compact acetylene-stabilised laser system is under development at NPL using a digital supermode distributed Bragg reflector diode laser. This tunable laser source offers complete spectral coverage of the ITU C-band (1528-1563 nm) and, when frequency-stabilised to acetylene transitions, can give many absolute frequency references in that spectral region. The system is very promising for development as a robust, high precision portable standard. In this paper we will present preliminary data relating to the standard's frequency stability and spectroscopic performance.

Introduction

Since the first demonstration of Doppler-free acetylene features in the 1.5 µm region [1], there has been considerable international interest in the development of acetylene-stabilised semiconductor lasers as frequency reference standards for the optical telecommunications C-band [1-8]. The frequency of line P(16) of the $\nu_1 + \nu_3$ band of $^{13}C_2H_2$ has been added to the CIPM list of recommended radiations [9], and measured at several laboratories [3-8]. Of the systems reported to date, most make use of an enhancement cavity [1, 3-5, 8] and others use an erbium-doped fibre amplifier [2, 6]. The experimental complexity of these systems makes them unpromising candidates for development as compact portable standards. However, a simpler system using a 40 mW DFB diode laser has also been reported [7], with encouraging performance. This paper reports a simplified and compact acetylene standard under development at NPL.

Experimental Set-Up

The laser source used for this work is an Oclaro digital supermode distributed Bragg refractor diode laser (DSDBR DL). This device has twelve active sections, comprising a semiconductor optical amplifier, eight front grating sections, a gain section, a phase section and a rear Bragg section. It incorporates two integral optical isolators, giving 40 dB total isolation prior to the fibre pigtail. The manufacturer's specification for this device is an output power of 20 mW in a typical full-width-at-half-maximum (FWHM) spectral linewidth of 1 MHz (maximum linewidth of 5 MHz). The device used in this work was selected for higher power, giving approximately 30 mW available output power. The laser can be frequency tuned through either the phase section or the gain section, with tuning sensitivities of approximately +10 GHz/mA and -0.8 GHz/mA respectively. With appropriate settings of the grating currents, complete spectral coverage of the C-band is achievable.

The experimental arrangement for acetylene spectroscopy is shown in Fig. 1. The output from the 1 x 2 fibre coupler is collimated and then focused to a beam waist w_0 of about 0.5 mm at the mirror. The coupler was chosen to give 90% of the available power for the acetylene spectroscopy and the remainder is available as an output and for diagnostic purposes. The gain section current is modulated at 540 Hz to give frequency modulation on the laser output with a peak-to-peak modulation depth of 5 MHz. Two cells are used in this work. A 6.7 kPa cell is used to obtain pressure-broadened features. The second, lower pressure cell is 200-mm long with Brewster windows. It contains acetylene at a pressure of 3 Pa. yielding a single pass absorption of approximately 5×10^{-4}. It is planned to use third harmonic phase sensitive detection to recover a Doppler-free acetylene signal for use as a locking discriminant. An integrator can used to servo the DSDBR diode laser frequency via its gain section injection current. The relative stability (σ/f)), lock-point repeatability and parametric dependencies of the compact standard will be investigated by heterodyne beat frequency comparison with the existing NPL standards [5].

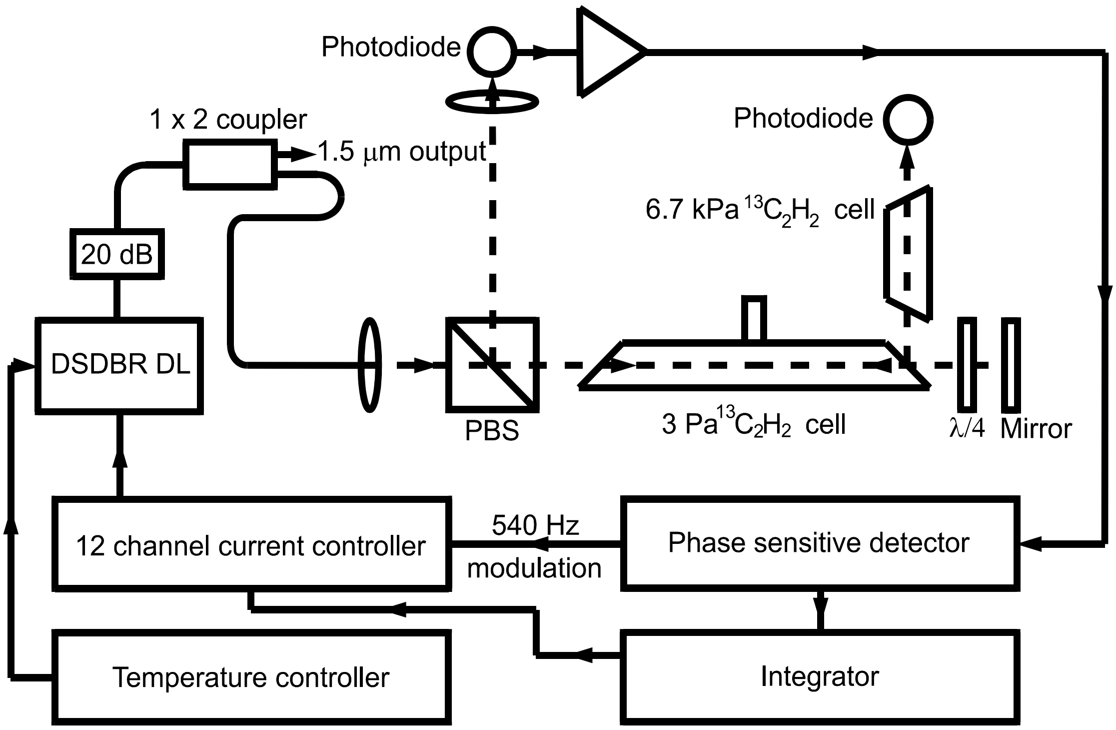

Fig. 1. Experimental arrangement for acetylene spectroscopy

Preliminary Results

A pressure-broadened line profile of P(16) is shown in Fig. 2. The observed signal-to-noise ratio is very good. indicating the laser's technical noise should not be a major limitation in stabilising to acetylene features. The plot also demonstrates the smooth tuning of the laser, suggesting there are no major parasitic interference effects. To date, we have not observed Doppler-free spectra.

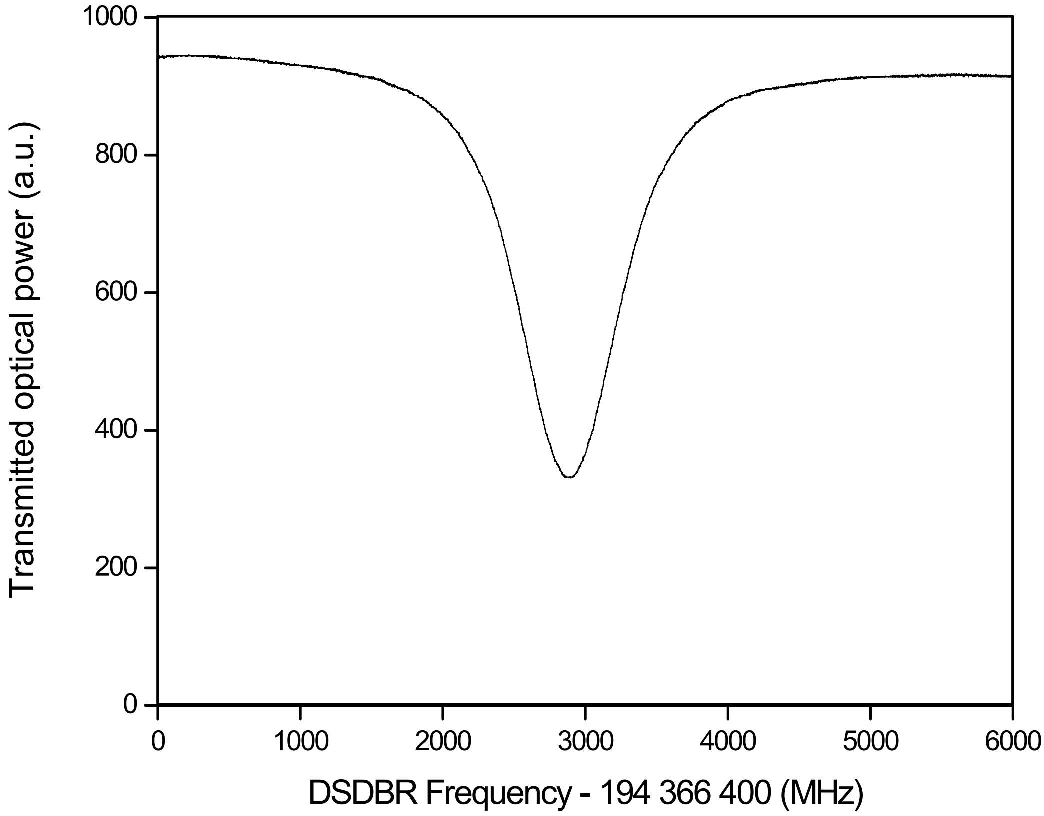

Fig. 2 Pressure-broadened line profile of line P(16) of the $v_1 + v_3$ band of $^{13}C_2H_2$.

Conclusion

A simple and compact acetylene standard is under development at NPL. The fractional lock-point repeatability of the system is expected to be better than 1 part in 10^{10}. The system should be readily adapted as a portable standard, permitting *in situ* calibration of test equipment in the field.

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