碘分子穩頻雷射之研究

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摘要

碘分子的超精細躍遷，在光譜學上時常提供來做穩定的頻率參考標準。它窄小的超精細結構成分(hyperfine structure components)也廣泛地被使用在穩頻雷射上。靠近532 nm 波段的碘分子躍遷比紅光躍遷來得強些，並且這些波段的躍遷很容易被半導體雷射泵浦 Nd:YAG 雷射(diode-pumped, Nd:YAG laser)之倍頻光所涵蓋。此外，在 2001 年長度諮詢委員會議(Consultative Committee for Length)也建議532 nm 波段的碘分子躍遷(R(56) 32-0 transition of $^{127}I_2$)中之 a_{10} 超精細結構成分成為光頻標準。

對於這個 a_{10} 超精細結構成分來說，壓力和功率對它造成的頻率漂移量已經被報導過了，但是，對於它的另一些特性包含線寬、壓力和功率所造成的線寬變化至今還沒有系統地被研究。為了更深入研究上述的特性，我們使用三次微分訊號的最高振幅和調制線寬之間的關係來決定出 a_{10} 的線寬。我們也使用這個相同的方法來研究出壓力和功率對 a_{10} 所造成的線寬變化。

一般而言，超精細結構的間距是以拍頻的方法量得。但是，不是每一間實驗室都有這個經費來架設兩套穩頻雷射系統。因此，我們研究出一個只需要一套穩頻雷射系統的方法來取代拍頻技術的量測。這套穩頻雷射系統需具備一個聲光調制移頻器。我們以 532 nm(R(56) 32-0 transition)這條碘分子躍遷為例子做此實驗。我們已經成功地量測到這條躍遷中超精細結構分

子之間的間距。以 a_{10} 當一個參考基準，我們實驗所得的超精細結構的間距和長度諮詢委員會議(Consultative Committee for Length)的值來比較，差距在 20 kHz 內。

除了半導體雷射泵浦 Nd:YAG 雷射(diode-pumped, Nd:YAG laser)之倍頻光 532 nm 波段外，對於用二極體雷射來作穩頻，我們也同樣感到有興趣，這是因為二極體雷射擁有較小的尺寸、較寬廣的調頻範圍、較大的功率和輕巧的重量。使用腔外的碘蒸氣室將外腔二極體雷射穩頻在碘的超精細結構成分上，這個方法已經被廣泛地研究和報導。

657 nm 波段的二極體雷射比起 633 nm 波段的二極體雷射擁有較低的費用和較高的功率，因此，我們使用 657 nm 波段的外腔二極體雷射來研究 657.483 nm 波段之碘分子躍遷(P(84) 5-5 transition of $^{127}I_2$)，並將我們的外腔二極體雷射穩頻在此躍遷的超精細結構成分上。我們得到了此躍遷超精細結構成分的訊噪比是 1000(在 1 秒的時間常數)；此二極體雷射穩頻在 o 超精細結構成分上，所得到的頻率穩定性優於 10 kHz。我們的實驗設計可以應用在其他波長的外腔二極體雷射上。

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Studies of Laser Stabilization Using Molecular Iodine

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ABSTRACT

Optical transitions in molecular iodine often provide stable references for precision spectroscopy and their hyperfine structure components have also been widely used in laser frequency stabilization. The molecular iodine lines near 532 nm have stronger absorption than red transitions and readily are carried out by diode-pumped, frequency-doubled solid-state Nd:YAG lasers. Moreover, the 2001 meeting of Consultative Committee for Length led the a_{10} component of R(56) 32-0 transition of $^{127}I_2$ at 532 nm for the optical frequency standard.

Its pressure shift and power shift has been reported. However, the characteristics of the a_{10} component including linewidth, pressure broadening, and power broadening have not been investigated systematically. To further investigate the above-mentioned characteristics, we use the dependence of the peak amplitude of the third-derivative signal on the modulation width to determine the linewidth of the hyperfine structure a_{10} component of R(56) 32-0 transition. We also use the same method to investigate pressure broadening and power broadening of the a_{10} component.

In general, the hyperfine splitting is measured by heterodyne technique. However, not every laboratory could set up two iodine-stabilized lasers for measuring hyperfine splitting.

Therefore, we study a method in which uses only one laser with a double-passed acousto-optic modulator frequency shifter replacing heterodyne technique. We use the R(56) 32-0 transition of $^{127}I_2$ at 532 nm as an example. We have successfully measured the hyperfine splitting. Using the a_{10} component as a reference, the difference of the hyperfine splitting between Consultative Committee for Length and our results is within 20 kHz.

Besides the diode-pumped, frequency doubled Nd:YAG laser at 532 nm, we are also interesting in using diode lasers for frequency stabilization because of their smaller size, larger tuning range, higher power, and compactness. Frequency stabilization of the external cavity diode laser to the iodine hyperfine structure components using extra-cavity iodine cell has been extensively studied and reported.

The diode laser at 657 nm has the characteristics of lower cost and higher power than that at 633 nm. Therefore, we use the 657 nm ECDL to investigate the saturation spectrum of the hyperfine structure components of P(84) 5-5 transition of $^{127}I_2$ at 657.483 nm for frequency stabilization of our ECDL laser. We have obtained the hyperfine structure components of P(84) 5-5 transition with a SNR of 1000 at 1 s time constant. The diode laser is frequency stabilized to the hyperfine component *o* of the saturated absorption signal. The frequency stability better than 10 kHz is achieved. Our scheme can be applied to ECDL at other wavelengths.

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