

用微扰增强双共振对 Na_2 $2^3\Pi_g$ 和 $3^3\Pi_g$ 能级进行新观测*

崔成哲, 陈 峥, 刘耀明, 李 丽**

(清华大学物理系和原子分子纳米科学重点实验室, 北京 100084)

摘 要: Na_2 $2^3\Pi_g$ 和 $3^3\Pi_g$ 态在 34860 cm^{-1} (相对基态 T_e) 和 $3s+3d$ 解离限之间的 $\Omega=0, 1, 2$ 能级进行了脉冲激光微扰增强双共振探测. 观测到两个态之间强烈的相互微扰. 给出忽略微扰情况下 $\Omega=0$ 能级的 T_v 和 B_v .

关键词: Na_2 ; $2^3\Pi_g$ 态; $3^3\Pi_g$ 态; 三重态; 里德堡态; PFOODR

中图分类号: 0643.3 文献标识码: A

New Observation of the Na_2 $2^3\Pi_g$ and $3^3\Pi_g$ States by Pulsed

Perturbation Facilitated Optical-Optical Double Resonance Spectroscopy*

Cui Chengzhe, Chen Zheng, Liu Yaoming, Li Li**

(Department of Physics and Key Lab of Atomic and Molecular Nanosciences, Tsinghua University, Beijing 100084)

Abstract The $\Omega=0, 1, 2$ levels of the Na_2 $2^3\Pi_g$ and $3^3\Pi_g$ states in the energy region between 34860 cm^{-1} above the T_e of the ground state and the $3s+3d$ atomic limit have been probed by pulsed laser perturbation facilitated optical-optical double resonance (PFOODR) spectroscopy. Strong mixing of these two states has been observed. The T_v and B_v values are given for the $\Omega=0$ component without deperturbation.

Keywords Na_2 , $2^3\Pi_g$ state, $3^3\Pi_g$ state, Triplet states, Rydberg states, PFOODR

1 Introduction

The Na_2 $2^3\Pi_g$ state has received much attention since the 1970's because it is the origin of the strong violet emission band peaking at $436\text{ nm}^{[1]}$. Fig. 1 gives the potential energy curves of these two states and several other states and the excitation scheme. The lower energy part of the $3^3\Pi_g$ state locates at the same energy region with the high- v levels of the $2^3\Pi_g$ state. These two states were first directly observed and as-

signed by perturbation facilitated optical-optical double resonance (PFOODR) spectroscopy with continuous wave (CW) lasers in 1983 by Li and Field^[2] and many more theoretical and experimental works have been devoted to these two states since then^[3-17]. The $2^3\Pi_g$ state is the lowest $n=3$ member of the $nd\pi_g$ Rydberg series and dissociates to the $3s+3d$ atomic limit. The $3^3\Pi_g$ state is the $n=4$ member of this $nd\pi_g$ Rydberg series and dissociates to $3s+4p$ atomic limit^[3, 4, 18]. The vibrational numberings of these two states

* Project supported by the National Natural Science Foundation of China (10174042, 20173029) and NKBRFSF of China.

This paper is dedicated to Prof. Zhu Qihe for his 80's birthday and his contribution on molecular dynamics.

** Corresponding author, E-mail: lili@mail.tsinghua.edu.cn Received 4 January 2004; in final form 26 April 2004.

are determined by resolved fluorescence of the bound-free transitions to the $a^3\Sigma_u^+$ state, and preliminary molecular constants have been obtained^[6,7].

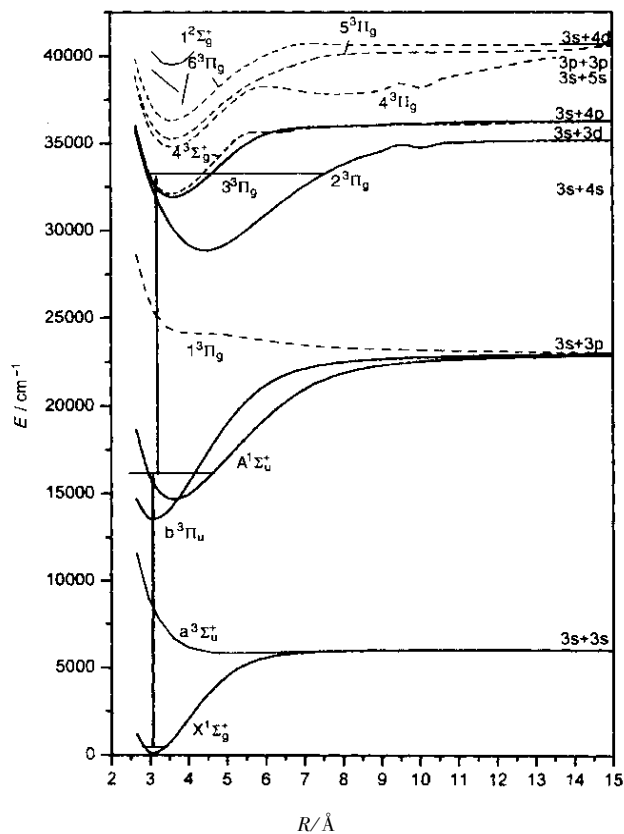


Fig. 1 Potential energy curves of several electronic states of Na_2 ^[4]

The $2^3\Pi_g \sim 3^3\Pi_g$ perturbation is due to electronic interaction of two states with the same symmetry^[6,14]. This interaction is very strong and a band-by-band deperturbation is not suitable. A global deperturbation including the interactions from all vibrational levels as well as the continuum is required. This deperturbation becomes even more complicated because both states are triplet states.

In order to obtain reliable deperturbed molecular constants and interaction parameters, with which the eigen energies of any vibrational rotational levels of these two states can be accurately calculated, the data fields of these two states should cover as many vibrational rotational levels as possible for all three Ω components. The previous CW experiments have observed many levels with the sub-Doppler resolution. The pulsed PFOODR excitation experiments have observed many

high- v levels of these two states and the strong predissociation of the $3^3\Pi_g$ state above the $3s + 3d$ atomic limit. But the probe laser linewidth of previous pulsed experiment is 0.2 cm^{-1} and the accuracy is not high enough for the deperturbation. Besides, most previous data are $\Omega = 0$ component. In this work, we observe more high- v levels of $\Omega = 0, 1$, and 2 components by pulsed PFOODR excitation spectroscopy with higher accuracy.

2 Experiment

The experimental setup has been described in our previous publications^[14]. Briefly, sodium vapor was generated in a crossed heatpipe oven. Argon was used as the buffer gas and its pressure was about $80 \sim 133 \text{ Pa}$. The temperature of the sodium vapor at the equilibrium temperature was about 500°C at 133 Pa . A Lambda Physik EMG 202MSC excimer laser simultaneously pumped two LP FL 3002E dye lasers, which served as the PUMP and PROBE lasers. The PUMP and PROBE laser beams counterpropagated and overlapped at the center of the heatpipe. The PUMP laser was operated with DCM or Rhodamine 6G dyes and the linewidth was about 0.04 cm^{-1} with an intracavity etalon. The PROBE laser was operated with Coumarin 307 or 153 dyes and the linewidth was also about 0.04 cm^{-1} with an intracavity etalon. The absolute frequencies of both lasers were calibrated using the standard iodine calibration^[19]. While the PUMP laser frequency was held fixed to a desired transition from the ground $X^1\Sigma_g^+$ state to an $A^1\Sigma_u^+ \sim b^3\Pi_u$ mixed intermediate level, the PROBE laser was scanned to excite from the intermediate mixed level to the $2^3\Pi_g$ and $3^3\Pi_g$ states. The OODR excitation signals were recorded by monitoring molecular fluorescence or/and atomic $3d \rightarrow 3p$ fluorescence. A Hamamatsu R212U photomultiplier tube (PMT) with color glass filters was used to detect the $2^3\Pi_g/3^3\Pi_g \rightarrow a^3\Sigma_u^+$ UV-violet molecular fluorescence. A Hamamatsu R928 PMT and three filters (an interference filter, and two short wavelength cut-off color glass filters) were used to monitor the atomic $3d \rightarrow 3p$ fluorescence. The outputs of the R928 and R212U PMTs and laser-induced fluorescence

(LIF) of I_2 were simultaneously monitored by a three channel SR250 Boxcar and recorded by a computer.

3 Results and discussion

The intermediate levels we used in this PFOODR excitation experiment are

$$A^1\Sigma_u^+ v=8 \sim b^3\Pi_{0u} v=14, J=8, 10, 12, 14^{[20, 21]}$$

$$A^1\Sigma_u^+ v=7 \sim b^3\Pi_{0u} v=13, J=31$$

$$A^1\Sigma_u^+ v=7 \sim b^3\Pi_{1u} v=13, J=26^{[22]}$$

$$A^1\Sigma_u^+ v=26 \sim b^3\Pi_{2u} v=28, J=16^{[23]}$$

A total of 192 and 38 vibrational rotational levels have been observed for the $2^3\Pi_g$ and $3^3\Pi_g$ states, respectively. The highest $2^3\Pi_g$ level observed is the $v=116, J=11$ level, which is less than 1 cm^{-1} below the $3s+3d$ dissociation limit.

Table 1 and Table 2 list our observed levels for the $2^3\Pi_g$ and $3^3\Pi_g$ states, respectively. Fig. 2 shows a portion of the OODR excitation spectra near the $3s+3d$ limit via the $b^3\Pi_{0u} v=14, J=10$ intermediate level. The upper spectrum is obtained by monitoring atomic $3d \rightarrow 3p$ fluorescence, and the lower spectrum is recorded by monitoring molecular UV fluorescence. The $3s+3d$ atomic limit is marked in the spectra. The $2^3\Pi_g$ spectra below $3s+3d$ limit have four rotational lines for each vibrational level: two stronger lines and two weaker lines. In the $^3\Pi_{\Omega g} \leftarrow b^3\Pi_{\Omega' u}$ excitation spectra, the

strongest OODR signals correspond to $\Delta\Omega=0, \Delta J=\pm 1$ transitions. Normally, only the two $\Delta\Omega=0$ lines are observed for the lower vibrational levels of the $2^3\Pi_g$ state. In Fig. 2, weaker $\Delta\Omega=+1, \Delta J=\pm 1$ transitions into the $2^3\Pi_g$ levels are also observed near the $3s+3d$ atomic limit. The assignment of the weaker $\Delta\Omega=+1$ transitions is uncertain until they can be precisely predicted from the $\Delta\Omega=0(^3\Pi_{1g} \leftarrow b^3\Pi_{1u})$ transitions. The signals into the $2^3\Pi_g v \geq 110$ levels not only are observed by detecting molecular fluorescence, but also by detecting atomic fluorescence. The sensitivity of the atomic detection is even higher than the molecular fluorescence detection near the $3s+3d$ limit. There are two possible reasons why atomic fluorescence detection is more sensitive than molecular fluorescence detection near the $3s+3d$ limit in our experiment: ① when the $2^3\Pi_g$ levels near the $3s+3d$ limit are excited, the long- λ portion of the $2^3\Pi_g \rightarrow b^3\Pi_u$ fluorescence can pass through the filters and be detected by PMT R928; ② under our experimental condition, collision can effectively induce molecular dissociation to produce $3d$ atoms^[14].

Strong perturbations have been observed between the $2^3\Pi_g$ and $3^3\Pi_g$ states. The $3^3\Pi_g v=3 \sim 31$ levels are strongly perturbed by the $2^3\Pi_g v \geq 43$ levels^[2, 6, 7]. Strong predissociation of the $3^3\Pi_g v > 31$ levels due to

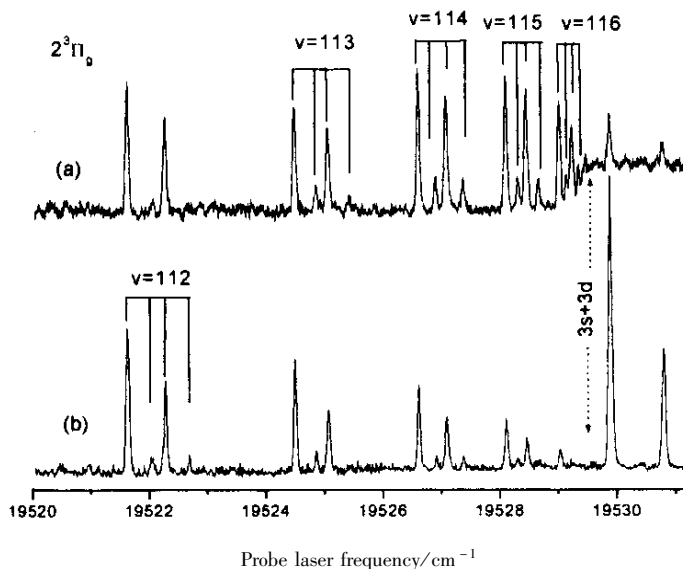


Fig. 2 A portion of the OODR excitation spectra near the $3s+3d$ limit via the $b^3\Pi_{0u} v=14, J=10$ intermediate level

(a) Monitoring atomic $3d \rightarrow 3p$ fluorescence. (b) Monitoring molecular UV fluorescence.

Table 1 OODR excitation data of the $2^3\Pi_g$ state

Intermediate $b^3\Pi_u$ levels			Probe frequency /cm ⁻¹	OODR term value/cm ⁻¹	$2^3\Pi_g$ energy levels		
v'	J'	Ω'			v	J	Ω
13	26	1	19243.01	34859.27	91	25	1
13	26	1	19247.98	34864.24	91	27	1
13	26	1	19270.76	34887.02	92	25	1
13	26	1	19275.37	34891.63	92	27	1
13	26	1	19310.33	34926.59	93	25	1
13	26	1	19315.30	34931.56	93	27	1
28	16	2	17340.30	34907.61	93	15	2
28	16	2	17343.49	34910.80	93	17	2
14	8	0	19263.57	34921.87	94	7	0
14	8	0	19264.97	34923.27	94	9	0
14	10	0	19257.79	34923.32	94	9	0
14	10	0	19259.53	34925.06	94	11	0
14	12	0	19253.54	34925.05	94	11	0
14	12	0	19255.57	34927.08	94	13	0
14	14	0	19248.32	34927.05	94	13	0
14	14	0	19250.68	34929.41	94	15	0
13	31	0	19310.39	34957.33	94	30	0
13	31	0	19315.89	34962.83	94	32	0
13	26	1	19332.06	34948.32	94	25	1
13	26	1	19336.52	34952.78	94	27	1
28	16	2	17365.76	34933.07	94	15	2
28	16	2	17368.65	34935.96	94	17	2
14	8	0	19320.98	34979.28	96	7	0
14	8	0	19322.28	34980.58	96	9	0
14	10	0	19315.11	34980.64	96	9	0
14	10	0	19316.70	34982.23	96	11	0
14	12	0	19310.72	34982.23	96	11	0
14	12	0	19312.63	34984.14	96	13	0
14	14	0	19305.38	34984.11	96	13	0
14	14	0	19307.64	34986.37	96	15	0
13	31	0	19372.88	35019.82	96	30	0
13	31	0	19379.85	35026.79	96	32	0
13	26	1	19391.21	35007.47	96	25	1
13	26	1	19397.12	35013.38	96	27	1
28	16	2	17422.81	34990.12	96	15	2
28	16	2	17425.78	34993.09	96	17	2
14	8	0	19343.62	35001.92	97	7	0
14	8	0	19344.88	35003.18	97	9	0
14	10	0	19337.71	35003.24	97	9	0

Intermediate $b^3\Pi_u$ levels			Probe frequency / cm^{-1}	OODR term value/ cm^{-1}	$2^3\Pi_g$ energy levels		
v'	J'	Ω'			v	J	Ω
14	10	0	19339.24	35004.77	97	11	0
14	12	0	19333.25	35004.76	97	11	0
14	12	0	19335.05	35006.56	97	13	0
14	14	0	19327.82	35006.55	97	13	0
14	14	0	19329.91	35008.64	97	15	0
13	31	0	19387.36	35034.30	97	30	0
13	31	0	19393.03	35039.97	97	32	0
13	26	1	19409.48	35025.74	97	25	1
13	26	1	19413.60	35029.86	97	27	1
28	16	2	17444.55	35011.86	97	15	2
28	16	2	17447.42	35014.73	97	17	2
13	31	0	19406.59	35053.53	98	30	0
13	31	0	19410.92	35057.86	98	32	0
13	26	1	19429.83	35046.09	98	25	1
13	26	1	19433.55	35049.81	98	27	1
28	16	2	17465.06	35032.37	98	15	2
28	16	2	17467.78	35035.09	98	17	2
14	8	0	19392.42	35050.72	100	7	0
14	8	0	19393.63	35051.93	100	9	0
14	10	0	19386.44	35051.97	100	9	0
14	10	0	19387.98	35053.51	100	11	0
14	12	0	19381.99	35053.50	100	11	0
14	12	0	19383.87	35055.38	100	13	0
14	14	0	19376.62	35055.35	100	13	0
14	14	0	19378.89	35057.62	100	15	0
13	31	0	19442.41	35089.35	100	30	0
13	31	0	19446.85	35093.79	100	32	0
13	26	1	19463.50	35079.76	100	25	1
13	26	1	19468.46	35084.72	100	27	1
28	16	2	17494.04	35061.35	100	15	2
28	16	2	17497.22	35064.53	100	17	2
14	8	0	19410.75	35069.05	101	7	0
14	8	0	19411.80	35070.10	101	9	0
14	10	0	19404.61	35070.14	101	9	0
14	10	0	19405.94	35071.47	101	11	0
14	12	0	19399.97	35071.48	101	11	0
14	12	0	19401.50	35073.01	101	13	0
14	14	0	19394.26	35072.99	101	13	0
14	14	0	19396.10	35074.83	101	15	0
13	31	0	19466.15	35113.09	101	30	0

Intermediate b $^3\Pi_u$ levels			Probe frequency /cm $^{-1}$	OODR term value/cm $^{-1}$	$2^3\Pi_g$ energy levels		
v'	J'	Ω'			v	J	Ω
13	31	0	19471.14	35118.08	101	32	0
13	26	1	19489.49	35105.75	101	25	1
13	26	1	19493.06	35109.32	101	27	1
28	16	2	17510.37	35077.68	101	15	2
28	16	2	17512.75	35080.06	101	17	2
13	31	0	19479.53	35126.47	102	30	0
13	31	0	19483.16	35130.10	102	32	0
13	26	1	19504.11	35120.37	102	25	1
13	26	1	19507.12	35123.38	102	27	1
28	16	2	17527.03	35094.34	102	15	2
28	16	2	17529.17	35096.48	102	17	2
13	31	0	19492.53	35139.47	103	30	0
13	31	0	19495.66	35142.60	103	32	0
28	16	2	17542.29	35109.60	103	15	2
28	16	2	17544.41	35111.72	103	17	2
14	8	0	19464.35	35122.65	104	7	0
14	8	0	19465.45	35123.75	104	9	0
14	10	0	19458.28	35123.81	104	9	0
14	10	0	19459.72	35125.25	104	11	0
14	12	0	19453.73	35125.24	104	11	0
14	12	0	19455.55	35127.06	104	13	0
14	14	0	19448.30	35127.03	104	13	0
14	14	0	19450.55	35129.28	104	15	0
14	8	0	19476.38	35134.68	105	7	0
14	8	0	19477.23	35135.53	105	9	0
14	10	0	19470.05	35135.58	105	9	0
14	10	0	19471.13	35136.66	105	11	0
14	12	0	19465.16	35136.67	105	11	0
14	12	0	19466.47	35137.98	105	13	0
14	14	0	19459.23	35137.96	105	13	0
14	14	0	19460.84	35139.57	105	15	0
13	26	1	19542.27	35158.53	105	27	1
14	8	0	19487.72	35146.02	106	7	0
14	8	0	19488.46	35146.76	106	9	0
14	10	0	19481.29	35146.82	106	9	0
14	10	0	19482.22	35147.75	106	11	0
14	12	0	19476.23	35147.74	106	11	0
14	12	0	19477.36	35148.87	106	13	0
14	14	0	19470.12	35148.85	106	13	0
14	14	0	19471.43	35150.16	106	15	0

Intermediate $b^3\Pi_u$ levels			Probe frequency / cm^{-1}	OODR term value/ cm^{-1}	$2^3\Pi_g$ energy levels		
v'	J'	Ω'			v	J	Ω
13	26	1	19553.84	35170.10	106	25	1
13	26	1	19557.04	35173.30	106	27	1
14	8	0	19497.79	35156.09	107	7	0
14	8	0	19498.47	35156.77	107	9	0
14	10	0	19491.29	35156.82	107	9	0
14	10	0	19492.15	35157.68	107	11	0
14	12	0	19486.16	35157.67	107	11	0
14	12	0	19487.15	35158.66	107	13	0
14	14	0	19479.91	35158.64	107	13	0
14	14	0	19481.08	35159.81	107	15	0
13	26	1	19560.46	35176.72	107	25	1
13	26	1	19562.87	35179.13	107	27	1
13	26	1	19566.31	35182.57	108	25	1
13	26	1	19568.17	35184.43	108	27	1
14	8	0	19519.73	35178.03	110	7	0
14	8	0	19520.32	35178.62	110	9	0
14	10	0	19513.15	35178.68	110	9	0
14	10	0	19513.84	35179.37	110	11	0
14	8	0	19524.49	35182.79	111	7	0
14	8	0	19525.08	35183.38	111	9	0
14	10	0	19517.91	35183.44	111	9	0
14	10	0	19518.59	35184.12	111	11	0
14	12	0	19512.61	35184.12	111	11	0
14	12	0	19513.36	35184.87	111	13	0
14	8	0	19528.23	35186.53	112	7	0
14	8	0	19528.80	35187.10	112	9	0
14	10	0	19521.63	35187.16	112	9	0
14	10	0	19522.28	35187.81	112	11	0
14	10	0	19522.06	35187.59	112	9	1
14	10	0	19522.69	35188.22	112	11	1
14	12	0	19516.30	35187.81	112	11	0
14	12	0	19516.99	35188.50	112	13	0
14	14	0	19509.74	35188.47	112	13	0
14	14	0	19510.47	35189.20	112	15	0
14	8	0	19531.17	35189.47	113	7	0
14	8	0	19531.67	35189.97	113	9	0
14	10	0	19524.50	35190.03	113	9	0
14	10	0	19525.07	35190.60	113	11	0
14	10	0	19524.86	35190.39	113	9	1
14	10	0	19525.42	35190.95	113	11	1

Intermediate b $^3\Pi_u$ levels			Probe frequency /cm $^{-1}$	OODR term value/cm $^{-1}$	$2^3\Pi_g$ energy levels		
v'	J'	Ω'			v	J	Ω
14	12	0	19519.08	35190.59	113	11	0
14	12	0	19519.69	35191.20	113	13	0
14	14	0	19512.45	35191.18	113	13	0
14	14	0	19513.06	35191.79	113	15	0
14	14	0	19512.82	35191.55	113	13	1
14	8	0	19533.38	35191.68	114	7	0
14	8	0	19533.78	35192.08	114	9	0
14	10	0	19526.62	35192.15	114	9	0
14	10	0	19527.08	35192.61	114	11	0
14	10	0	19526.92	35192.45	114	9	1
14	10	0	19527.39	35192.92	114	11	1
14	12	0	19521.09	35192.60	114	11	0
14	12	0	19521.58	35193.09	114	13	0
14	14	0	19514.37	35193.10	114	13	0
14	14	0	19514.87	35193.60	114	15	0
14	14	0	19514.64	35193.37	114	13	1
14	8	0	19535.00	35193.30	115	7	0
14	8	0	19535.27	35193.57	115	9	0
14	10	0	19528.11	35193.64	115	9	0
14	10	0	19528.46	35193.99	115	11	0
14	10	0	19528.31	35193.84	115	9	1
14	10	0	19528.66	35194.19	115	11	1
14	12	0	19522.46	35193.97	115	11	0
14	12	0	19522.82	35194.33	115	13	0
14	14	0	19515.59	35194.32	115	13	0
14	14	0	19515.95	35194.68	115	15	0
14	14	0	19515.77	35194.50	115	13	1
14	8	0	19535.98	35194.28	116	7	0
14	8	0	19536.18	35194.48	116	9	0
14	10	0	19529.02	35194.55	116	9	0
14	10	0	19529.23	35194.76	116	11	0
14	10	0	19529.14	35194.67	116	9	1
14	10	0	19529.35	35194.88	116	11	1

the perturbation of the continuum of the $2^3\Pi_g$ state has also been observed^[14]. Although the vibrational spacings and rotational constants are quite different in the same energy region, the $2^3\Pi_g$ vs. $3^3\Pi_g$ assignment can become ambiguous for the strongly mixed levels. Similar to Ref. [6], preliminary T_v and B_v values for

these vibrational levels of the $\Omega=0$ component are given from a linear least-squares fit ignoring the mutual perturbation between the $2^3\Pi_g$ and $3^3\Pi_g$ states:

$$T = T_v + B_v J(J+1)$$

where T_v is the vibrational energy above the T_e of the ground state, and B_v is the rotational constant. Table 3

Table 2 OODR excitation data of the $3^3\Pi_g$ state

Intermediate $b^3\Pi_u$ levels			Probe frequency / cm^{-1}	OODR term value/ cm^{-1}	$3^3\Pi_g$ energy levels		
v'	J'	Ω'			v	J	Ω
14	8	0	19284.29	34942.59	29	7	0
14	8	0	19286.15	34944.45	29	9	0
14	10	0	19279.00	34944.53	29	9	0
14	10	0	19281.27	34946.80	29	11	0
14	12	0	19275.28	34946.79	29	11	0
14	12	0	19277.91	34949.42	29	13	0
14	14	0	19270.67	34949.40	29	13	0
14	14	0	19273.61	34952.34	29	15	0
13	26	1	19377.15	34993.41	29	25	1
13	26	1	19382.41	34998.67	29	27	1
28	16	2	17389.03	34956.34	29	15	2
28	16	2	17392.37	34959.68	29	17	2
14	8	0	19376.15	35034.45	30	7	0
14	8	0	19377.87	35036.17	30	9	0
14	10	0	19370.69	35036.22	30	9	0
14	10	0	19372.86	35038.39	30	11	0
14	12	0	19366.88	35038.39	30	11	0
14	12	0	19369.52	35041.03	30	13	0
14	14	0	19362.26	35040.99	30	13	0
14	14	0	19365.34	35044.07	30	15	0
13	31	0	19454.83	35101.77	30	30	0
13	31	0	19460.69	35107.63	30	32	0
13	26	1	19475.21	35091.47	30	25	1
13	26	1	19480.05	35096.31	30	27	1
28	16	2	17481.02	35048.33	30	15	2
28	16	2	17484.54	35051.85	30	17	2
14	8	0	19453.51	35111.81	31	7	0
14	8	0	19455.00	35113.30	31	9	0
14	10	0	19447.81	35113.34	31	9	0
14	10	0	19449.66	35115.19	31	11	0
14	12	0	19443.67	35115.18	31	11	0
14	12	0	19445.8	35117.31	31	13	0
14	14	0	19438.55	35117.28	31	13	0
14	14	0	19440.92	35119.65	31	15	0
13	26	1	19546.99	35163.25	31	25	1
13	26	1	19550.49	35166.75	31	27	1
28	16	2	17555.25	35122.56	31	15	2
28	16	2	17557.69	35125.00	31	17	2

gives these values for the $2^3\Pi_g$ and $3^3\Pi_g$ states. Neither the vibrational intervals nor the B_v values vary regularly with v for both states. When a $2^3\Pi_g$ vibrational level is close to a $3^3\Pi_g$ level, not only these two levels repel each other, but also make B_v values irregular. The strong perturbation between $2^3\Pi_g$ and $3^3\Pi_g$ states makes it impossible to obtain precise molecular constants without a systematic multilevel deperturbation. Such a global deperturbation with all data by CW and pulsed PFOODR excitation spectroscopy is underway and the results will be published elsewhere.

Table 3 Unperturbed T_v and B_v values of the vibrational levels

	v	T_v	$(1\sigma)^a$	B_v	(1σ)
$2^3\Pi_g$	94	34919.64	(04)	0.04074	(09)
	96	34975.90	(25)	0.04764	(53)
	97	34999.75	(10)	0.03766	(22)
	98	35021.57		0.03437	
	100	35047.71	(20)	0.04403	(43)
	101	35064.70	(50)	0.05090	(107)
	102	35099.68		0.02881	
	103	35116.37		0.02484	
	104	35120.55	(07)	0.03596	(44)
	105	35133.17	(03)	0.02650	(18)
	106	35144.77	(02)	0.02249	(12)
	107	35154.98	(02)	0.02017	(16)
	110	35177.06	(06)	0.01760	(62)
	111	35181.91	(05)	0.01651	(46)
	112	35185.82	(07)	0.01446	(48)
	113	35188.86	(07)	0.01260	(46)
114	35191.18	(06)	0.01042	(37)	
115	35192.94	(05)	0.00754	(32)	
116	35193.94	(07)	0.00629	(07)	
$3^3\Pi_g$	29	34939.72	(08)	0.05303	(50)
	30	35028.29	(71)	0.07644	(154)
	31	35109.49	(06)	0.04271	(39)

a. Standard error is given only when more than three different levels are observed.

4 Conclusions

High vibrational levels of the $2^3\Pi_g$ and $3^3\Pi_g$ states of Na_2 have been studied by pulsed PFOODR

spectroscopy. Provisional T_v and B_v values for these vibrational levels of the $\Omega = 0$ component are obtained without considering mutual perturbation between the $2^3\Pi_g$ and $3^3\Pi_g$ states.

References

- [1] Pichler G, Bahns J T, Sando K M, Stwalley W C, Konowalow D D, Li L, Field R W, Muller W. *Chem. Phys. Lett.*, 1986, **129**:425, and the references there in.
- [2] Li L, Field R W. *J. Phys. Chem.*, 1983, **87**:3020
- [3] Jeung G H. *Phys. Rev. A*, 1987, **35**:26, and the references there in.
- [4] Magnier S, Millie Ph, Dulieu O, Masnou-Seeuws F. *J. Chem. Phys.*, 1993, **98**:7113, and references there in.
- [5] Jones K M. Ph. D. Thesis, Stanford University, Stanford, California 1983.
- [6] Li L, Field R W. *J. Mol. Spectrosc.*, 1986, **117**:245
- [7] Xie X, Field R W, Li L, Lyyra A M, Bahns J T, Stwalley W C. *J. Mol. Spectrosc.*, 1989, **134**:119
- [8] Li L, Field R W. *J. Mol. Spectrosc.*, 1987, **123**:237
- [9] Li L, Lyyra A M, Stwalley W C, Li M, Field R W. *J. Mol. Spectrosc.*, 1991, **147**:215
- [10] Whang T-J, Stwalley W C, Li L, Lyyra A M. *J. Chem. Phys.*, 1992, **97**:7211
- [11] Whang T J. Ph. D. Thesis, University of Iowa, Iowa City, Iowa 1992.
- [12] Li L, Li M. *J. Mol. Spectrosc.*, 1995, **173**:25
- [13] Li L, Field R W. Chapter 7 of Book *Molecular Spectroscopy and Dynamics by Stimulated Emission Pumping*, World Scientific Co., Singapore, 1995
- [14] Liu Y, Li J, Gao H, Chen D, Li L, Field R W, Lyyra A M. *J. Chem. Phys.*, 1998, **108**:2269
- [15] Li L, Liu Y, Li J, Chen D, Lyyra A M, Antonova S, Lazarov G. *Chin. J. Chem. Phys.*, 1998, **11**:500
- [16] Li L, Lyyra A M. *Spectrochimica Acta Part A*, 1999, **55A**:2147
- [17] Li H, Gao H. *Chin. J. Chem. Phys.* 2001, **14**:647
- [18] Li J, Liu Y, Dai X, Li L, Field R W. *J. Chem. Phys.*, 2001, **114**:7859
- [19] Gerstenkorn S, Luc P. Atlas du Spectre D'Absorption de la Molecule d'Iode, CNRS, Paris, 1978.
- [20] Shimizu K, Shimizu F. *J. Chem. Phys.*, 1983, **78**:1126
- [21] Katô H, Otani M, Baba M, *J. Chem. Phys.*, 1988, **89**:653
- [22] Ji B. Ph. D. Thesis, University of Iowa, 1995.
- [23] Li M, Wang C, Wang Y, Li L. *J. Mol. Spectrosc.*, 1987, **123**:161