STUDY OF AND CALCULATION OF FWHM OF SODIUM SPECTRUM USING ATOMIC BEAM TECHNIQUE

M. ATIF*

Physics and Astronomy Department, College of Science, King Saud University, Riyadh, Saudi Arabia, National Institute of Lasers and Optronics, Islamabad, Pakistan

The atomic beam apparatus has been employed to observe the Sodium spectrum using two step laser excitation schemes. The first dye laser pumped by the second harmonic generation (SHG) 532nm excites the atom from the 3s $^2S_{1/2}$ ground state to the 3p $^2P_{1/2}$ or 3p $^2P_{3/2}$ multiplets of the first excited state which are further ionized by a photon from the third harmonic 355nm of the Nd-YAG laser. The ions are directed to the channeltron by applying a positive voltage to the lower ion deflecting plate. The ions signal from the channeltron has been recorded on a computer after processing through a box car averager. The ionization peaks and the calculation of Full width Half Maximum (FWHM) of Sodium are studied by varying the voltage on the lower ion deflecting plates.

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1. Introduction

The first experiment was conducted on sodium atom. Ten out of the eleven electrons of the normal sodium atom are interlocked in closed shells. They contribute nothing to the angular momentum of the atom. We have to consider only the states of the eleventh electron in the spectrum of neutral sodium ($1S^2$, $2S^2$, $2P^6$, $3S^1$). The sodium D-line belongs to principal series. Lines of the principal series are due to transitions from a P state to S state. For the upper state, L = 1, J = L ± S = 3/2 or 1/2. Hence the possible two terms are: $^2P_{1/2}$ and $^2P_{3/2}$. For the lower S state, L = 0, J = 1/2 so that only one term $^2S_{1/2}$ is possible. Energy level diagram is shown in Fig.1. They are (i) $^2P_{1/2} \rightarrow {}^2S_{1/2}$ which results in the D_1 line of wavelength 5896 A^0 and (ii) $^2P_{3/2} \rightarrow {}^2S_{1/2}$ giving the D_2 line of wavelength 5890 A^0 . Applying the selection rules $\Delta l = \pm 1$ and $\Delta J = \pm 1$ or 0 (excluding $0 \rightarrow 0$), both the transitions are allowed. This explains the doublet fine structure of the sodium D-line. The relative intensity of the $^2P_{1/2} \rightarrow {}^2S_{1/2}$ or $^2P_{3/2} \rightarrow {}^2S_{1/2}$ are in the ratio of 1:2 [1].

In this study an atomic beam apparatus has been used to study the Sodium spectrum using two step laser excitation schemes. The ionization peaks and the calculation of Full width Half Maximum (FWHM) of Sodium are calculated by varying the voltage on the lower ion deflecting plates.

* Corresponding author: atifhull@gmail.com

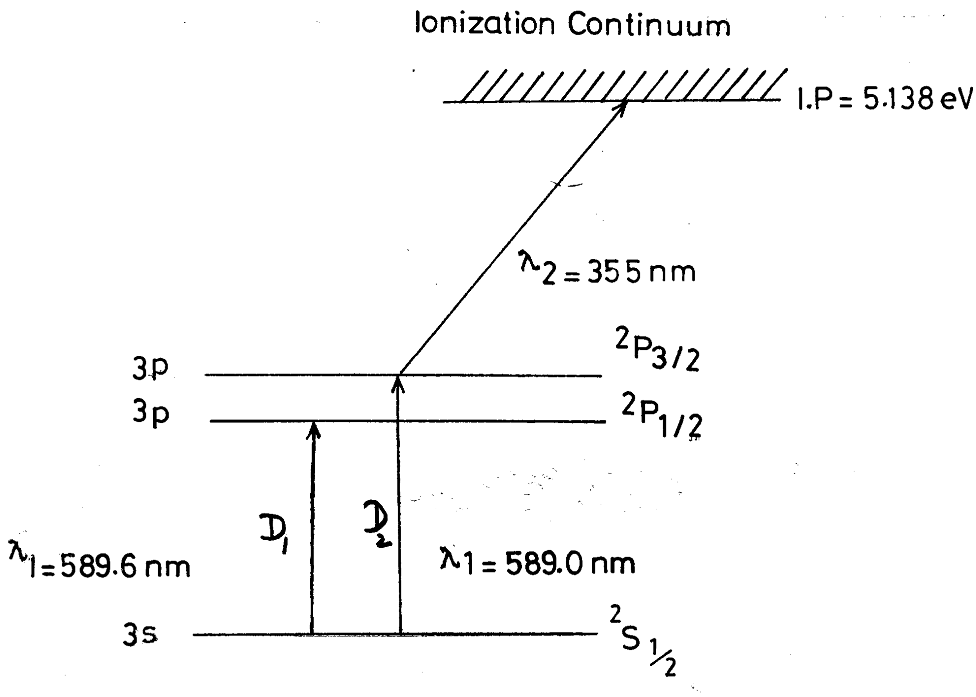


Fig. 1. Energy level diagram of sodium

2. Experimental Arrangement:

The experimental arrangement consists of atomic beam apparatus (Fig.2), a pulsed Nd-YAG laser, 100 Hz storage oscilloscope, box car averger and the computer as shown in Fig.3.

First of all we created a vacuum of the order of 10^{-6} torr by using a rotary pump and an oil diffusion pump in the vacuum chamber. The channeltron was installed across the ion deflecting plates for the detection of ions. The constructed oven having 50 mm in length with diameter 0.5 mm was placed in the vacuum chamber and a sample of sodium was loaded in it. The sodium was heated in the oven at 200^0c by applying a voltage of 12.5 volts and a sample of sodium atom emerged through an aperture of 0.5 mm diameter into a high vacuum chamber. A DC voltage ranging between -1.8→-2.0 kV was applied to the channeltron and a voltage of 5 volts was applied to the lower ion deflecting plates. The experiment was conducted using two step laser excitation schemes. The first dye laser pumped by the 2nd harmonic (532nm) of the Nd:YAG laser having 10ns pulse width and 10 Hz repetition rate promotes the atom from the ground state to the resonance lines. The second laser was the third harmonic 355nm of the Nd:YAG laser which ionizes the atom from the 3p excited state. The observed signal was fed to boxcar averager model SR-250. The signal was processed through a boxcar averger. The boxcar was synchronized with the laser. The output signal from the boxcar averger was finally fed to computer to record the spectrum for subsequent analysis.

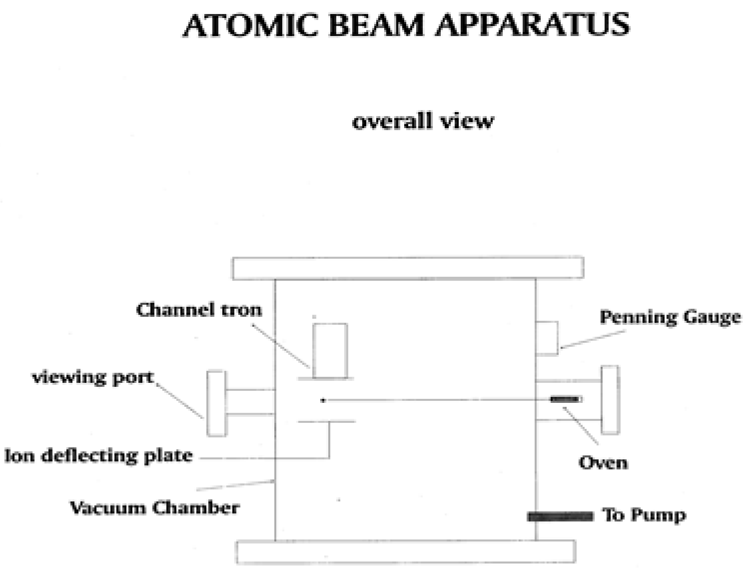
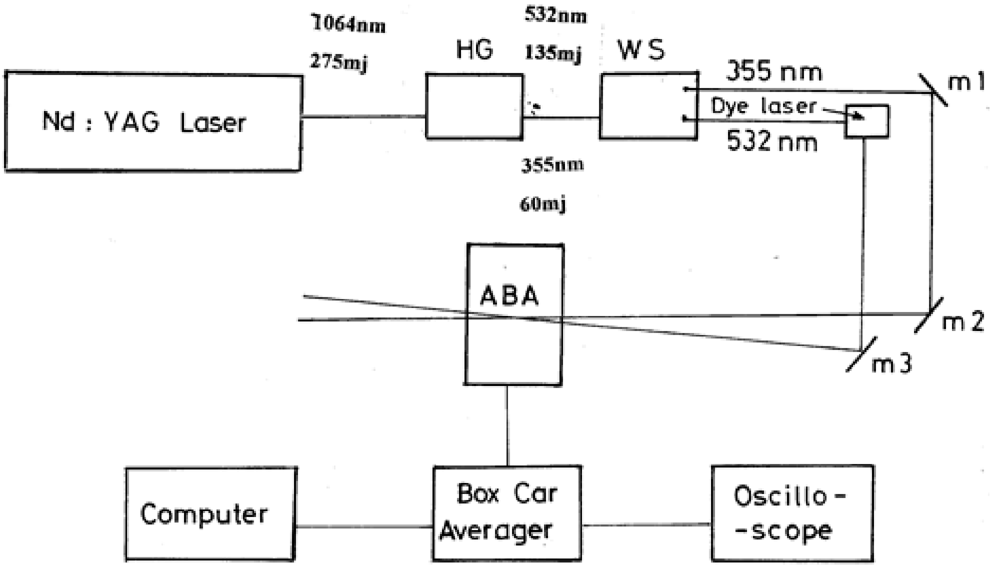


Fig. 2



Experimental set up for Laser Spectroscopic Studies.

HG = Harmonic Generator
WS = Wavelength separator
ABA= Atomic beam apparatus

Fig.3

3. Results and Dicussion

The experiment was conducted on sodium atom using two step laser excitation schemes. The sodium was heated in the oven at about 200^0c. The sodium atomic beam is generated from the oven with a divergence angle of 11^0. The R6G dye laser pumped by the 2nd harmonic 18796.99 cm^{-1} (532nm) of the Nd:YAG laser [2-5] promotes the atom from the ground state to the resonance lines at 16956.17 cm^{-1} ($5890A^0$) and 16973.366 cm^{-1} ($5896A^0$) as shown in Figs.4, 5 & 6. The second laser was the third harmonic 28169.01 cm^{-1} (355nm) of the Nd:YAG laser which ionizes the atom from the first excited state as shown in Fig.1. The second laser is a fixed frequency whereas the first dye laser is scanned between 580 to 590nm. The laser beam is focused in the interaction region using a 20 cm focal length quartz lens. The observed spectrum showed two well defined peaks corresponding to the transitions

$$3s\ ^2S_{1/2} \rightarrow 3p\ ^2P_{1/2} \rightarrow 3p\ ^2P_{3/2}$$

The energy difference between two peaks is 17.25 cm^{-1} . The experimental term resonance energies are calculated as the sum of the laser energy and the energies 16956.17 cm^{-1} or 16973.366 cm^{-1} for the 3p $^2P_{1/2}$ or 3p $^2P_{3/2}$ intermediate states as given by Moore(1971) [6]. The experimental results are shown in Figs. 4, 5 & 6.

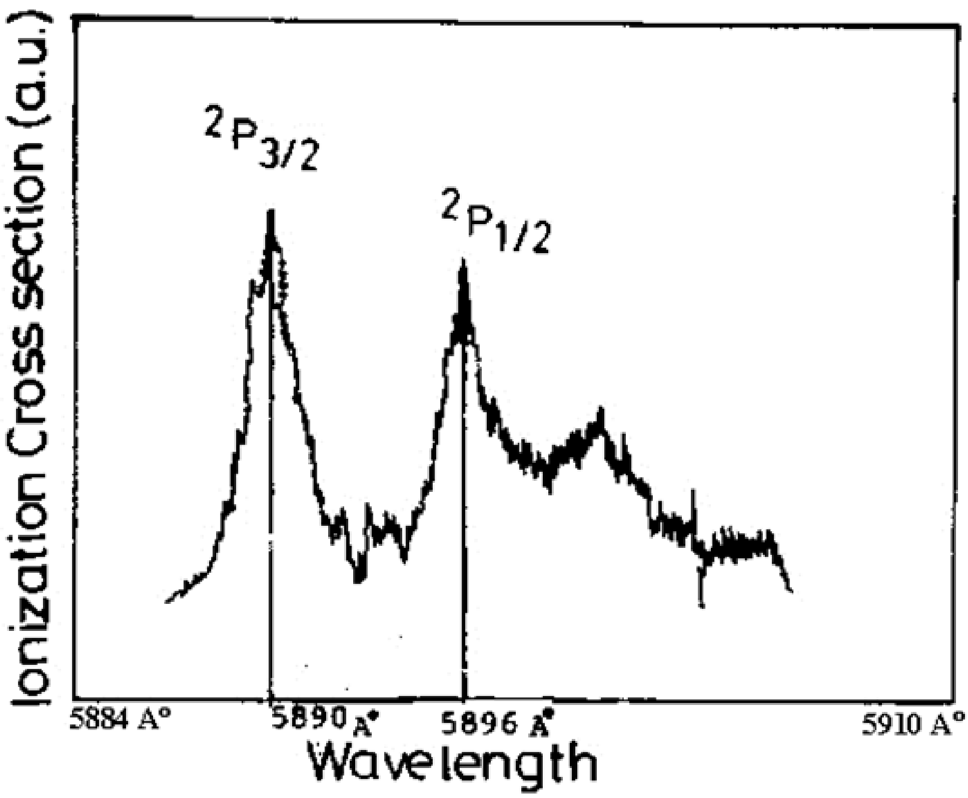


Fig. 4 Observed data of sodium atom
Oven Voltage = 12.5 V
CH = 2 Kv
Lower Plate 0v
Vacuum 3 x 10^{-6} mbar
Laser shots were three and motor steps 1.

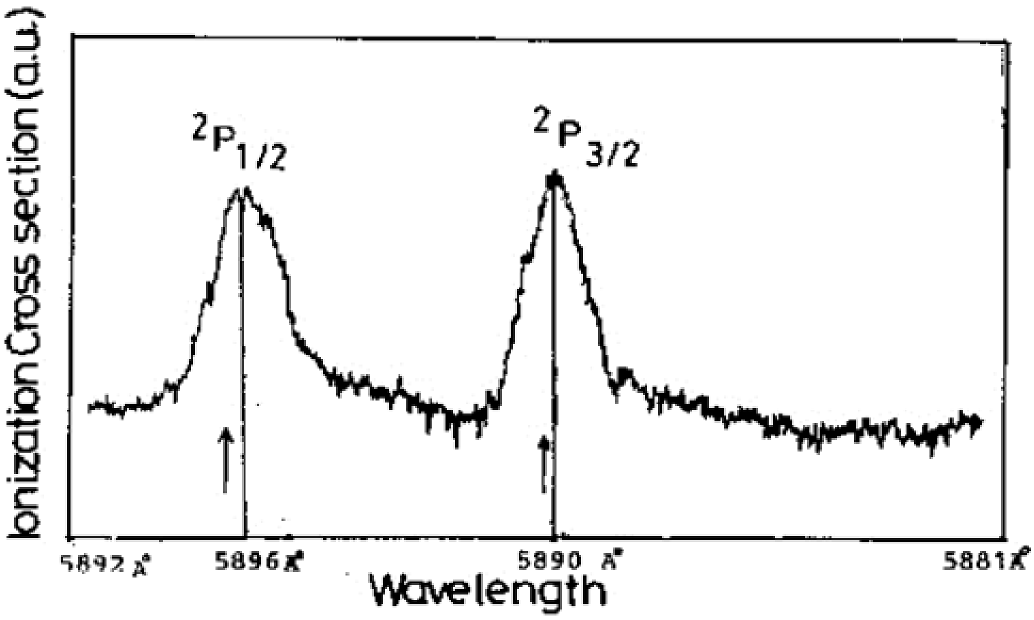


Fig. 5 Observed data of sodium atom.
Oven Voltage = 12.5 V
CH = 2 Kv
Lower Plate = 3v
Vacuum = 3×10^{-6} mbar
Laser shots were three and motor steps 1.

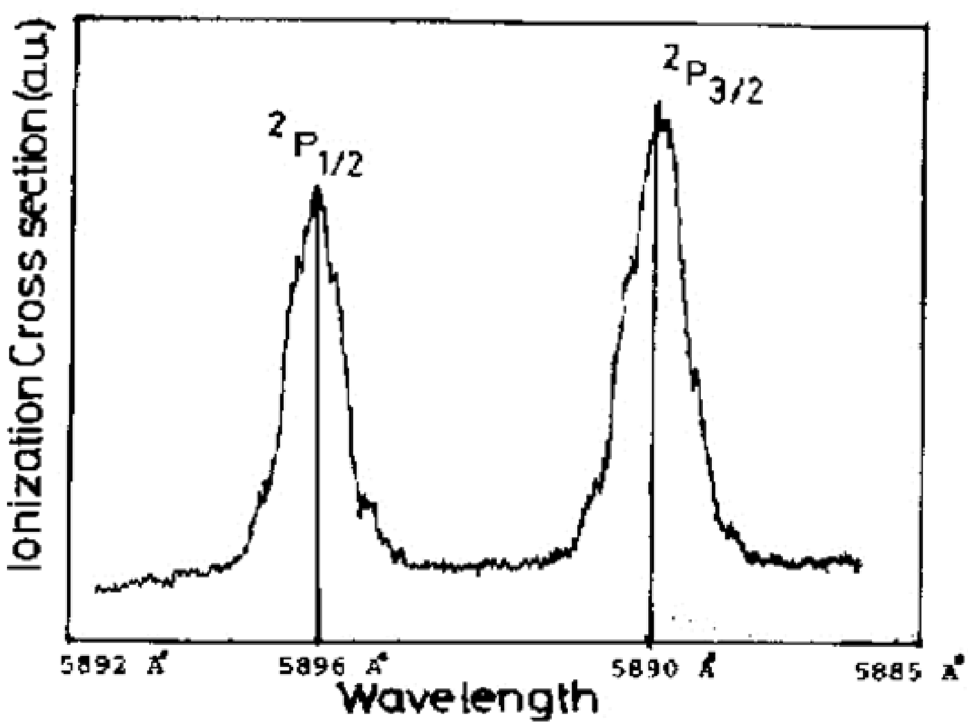


Fig. 6 Observed data of sodium atom.
Oven Voltage = 12.5 V
CH = 2 Kv
Lower Plate = 5v
Vacuum = 3×10^{-6} mbar
Laser shots were three and motor steps 1.

In all the figures we have kept constant the vapour densities, laser energies, the channeltron applied voltage whereas the voltage at the lower plate of the ion deflecting plates was varied from 0 to 5 volts. In Fig. 4 there are two well defined peaks which correspond to ionization signal from the 3p $^2P_{1/2}$ and 3p $^2P_{3/2}$ respectively. The signal is bit noisy because there is no field deflecting potential between the plates which reduces the sensitivity of the detection system. Since the energy difference between two peaks is 17.25 cm^{-1}, the corresponding width of the lines are,

FWHM (full width half maximum) for the first peak =4.5±0.5 cm^{-1}

FWHM (full width half maximum) for the second peak = 4.8 ± 0.5 cm^{-1}

The ionization peaks shown in Fig.5, were recorded by applying 3 volts on the lower ion deflecting plates. The observed peaks shows better signal to noise ratio. The width of the peak is determined as

FWHM (full width half maximum) for the first peak = 4.0 ± 0.3 cm^{-1}

FWHM (full width half maximum) for the second peak = 4.4 ± 0.3 cm^{-1}

For the results reproduced in Fig 6, the applied potential across the ion deflecting plates is 5 volts and the observed peaks shows excellent signal to noise ratio. The width of the peak is determined as

FWHM (full width half maximum) for the first peak = 3.5 ± 0.3 cm^{-1}

FWHM (full width half maximum) for the second peak = 3.9 ± 0.3 cm^{-1}

4. Conclusion

It is observed that with the increase of the applied voltage at the lower ion deflecting plates, the photoionization signal show a better signal to noise ratio. Secondly the width of the observed peaks also decreases gradually. This fact can be attributed to the better sensitivity achievements at higher potentials. However as we further increase the potential, the electric field effects on the observed structure will also begin to emerge.

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