Quantum Light Dimmer

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Abstract. The absorption of sodium lamp light by the flame spiced with table salt is a cause of the shadow cast by the flame. When the magnetic field is applied, the shadow fades a little due to the Zeeman effect. The experiment and its analysis are of didactical interest because they allow students to observe several aspects of quantum theory and the application of interferometry in an intriguing effect.

Introduction

If you put a flame with table salt added in front of a vapor sodium lamp, the flame casts a shadow. The shadow can become lighter if the flame is put into a strong magnetic field [1]. Our group investigated this phenomenon to participate in the Young Physicists' Tournament—a scientific competition between teams of secondary school students [2] that provokes students to become researchers, encourages teamwork, and teaches how to present and defend the obtained results.

Theory

In light of a sodium lamp, the candle's flame will not leave a shadow because it is a gas. However, when we add table salt to the candle, it casts a shadow, for light emitted by the sodium lamp is absorbed by the sodium atoms present in the area of the flame.

When the flame is placed in a strong magnetic field, more sodium lamp light will pass through the flame due to the splitting of the spectral lines, known as the Zeeman effect.

In this case, the anomalous Zeeman effect given by the formula (1) as follows

$$\Delta E_m = \mu_B \cdot B \cdot (m_l + 2m_s) \quad (1)$$

is observed as orbital angular momentum is non-zero.

The diagram in Fig.1 illustrates the disappearance of energy gaps corresponding to the sodium doublet when the magnetic field is applied, causing the lightening of the flame shadow.

The described effects are visually attractive and applicable for spectroscope measurements, while the explanation of the observed phenomena requires an understanding of non-trivial, especially for teenagers, theoretical models.

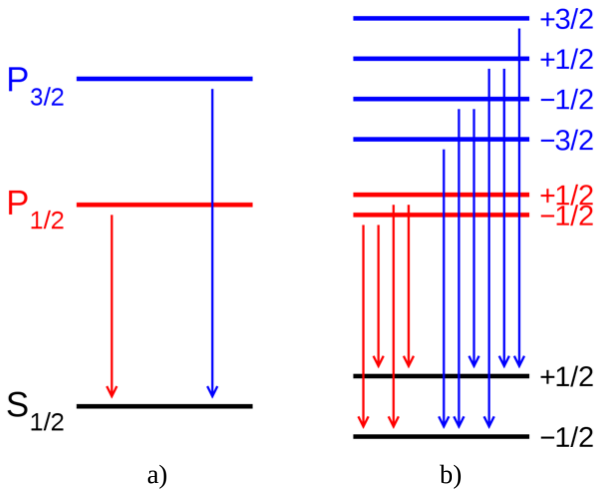


Fig. 1. Sodium doublet a) no magnetic field, b) magnetic field.

Implementation

Experimental setup (Fig. 2) consisted of:

- sodium vapor lamp that produced wavelengths of 589,0 nm and 589,6 nm
- gas burner to which table salt was added
- filter
- spectrometer
- electromagnet

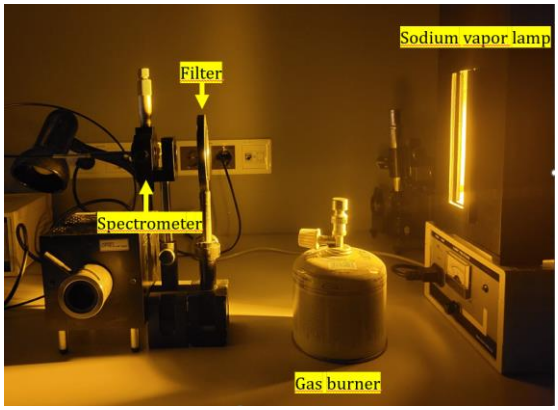
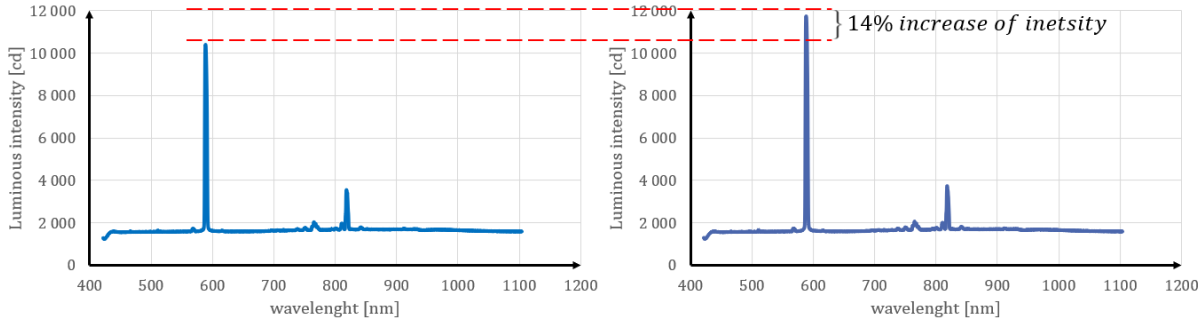


Fig. 2. Experimental setup.

In the first part of the experiment, the spectrum of the sodium lamp was detected, and the clear peak on the wavelength 589 nm was observed.

When the flame with a table salt was placed between the lamp and the spectrometer, the intensity of the described peak dropped dramatically.

When the magnetic field was applied, the intensity of the 589 wavelength increased, and the shadow slightly softened, providing evidence of the energy shifts of the electrons in a magnetic field, called the Zeeman effect. The results of the experiment are presented on Fig. 3.



a) b)

Fig. 3. Results of the experiment: a) sodium lamp, salt b) sodium lamp, salt, magnetic field.

Conclusion

Inspired by the International Young Physicists' Tournament, students explained the quantum properties of particles and energy states of an electron in an atom, explained the sodium doublet and its dependence on the spin, showed how the magnetic field affects the energy states, explained why the flame shadow occurs when the salt is added to it and why it fades in the magnetic field, performed experiments and observed absorption and emission of 589 nm wavelength in a flame with salt and shadow softening in a magnetic field.

References

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