Spectroscopy of Hydrogen, Helium, Neon and Mercury Low-Pressure Discharge and a Barcode-like Periodic Table Based on Energy Levels

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Strong spectral lines in the visible range are obtained from luminescence generated by low-pressure gas discharge tubes of hydrogen, neon, helium, and mercury. Although the spectrum of neon is complicated at first glance, the energy levels are degenerate and clustered; this means that the level statistics differ from the Wigner surmise, which is closely related to level repulsion and quantum chaos. We present a visualization of the lower 99 energy levels of each atom in a barcode-like periodic table.

Key words: Gastube, Discharge, Periodic Table, Energy Level

1. Introduction

One of the authors (YM) has studied “secondary real images” in the framework of the Super Science High School (SSH) project [1], which aims to nurture talented Japanese students in the field of science and technology. The secondary real image, which is distinct from the universal real image, is formed by multiple reflections and refractions inside the lens. This image is formed near the lens, and may provide a method of ghost photography. Such interests in the research field of geometrical optics are hereafter expanded to spectroscopy.

Luminescence was generated by applying 5000 V across glass tubes containing low-pressure hydrogen, helium, neon, and mercury gas. The pressure of each gas was about 1/100 atmospheres. The resulting luminescence is shown in Fig. 1.

It is well established that the geometric construction of phase space for classical dynamical systems (*islands* of periodicity embedded in a *sea* of chaos) is reflected in the statistical property of energy levels in quantum systems [2]. It may be considered as a *Science on Form*. Wigner introduced random matrices to describe nuclei of heavy atoms [3]. He compared the spacings between the lines in the spectrum of a heavy atom nucleus to the spacings between the eigenvalues of a random matrix. The level spacings of neon, which is not so heavy though, are somewhat complicated, as shown later. In this study, we first obtained a distribution of the nearest-neighbor energy level spacings of neon and compared these with spacing distribution calculated according to the Wigner surmise [3]. With the help of an atomic-spectroscopic database, we then illustrate energy levels near the ground states as barcodes in the periodic table.

Fig. 1. Luminescence of H, Ne, He, and Hg (from left to right).

In the second section, luminescence of hydrogen, helium, neon, and mercury is spectroscopically analyzed. The spectrum of neon is compared with the Wigner surmise. In the third section, a barcode-like periodic table is presented. The final section is devoted to concluding remarks.

2. Luminescence of H, He, Ne, and Hg

A visible-light spectrometer supplied by Kyoto Nijikoubou LLP was used to obtain the wavelength and relative intensity of strong spectral lines. The wavelength calibration accuracy for the instrument is about 2 nm in the vicinity of 600 nm wavelength, and the wavelength resolution $\lambda/\Delta\lambda$ is nearly equal to 300. The results are shown in Fig. 2. As expected, the Balmer series is observed in the case of hydrogen.

In the case of neon, a relatively complicated spectrum is obtained as shown in Fig. 2. Figure 3 compares our data with a neon spectrum from *The Basic Atomic Spectroscopic Data* [4], supplied by the National Institute of Standards and Technology (NIST), U.S. Department of Commerce.

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