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# The teaching tools; light traces in uranium-glass lenses with use of luminescence under purple laser-light excitation

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**Abstract**

Two luminescent materials were newly developed to visualize light traces in a convex lens or a concave lens clearly: an infusion of quercus (quercus water) and uranium-glass lenses. A laser pointer that provides a 405-nm purple-light emission was used as the excitation source for luminescence. The aforementioned materials were assembled for the apparatus as follows. (1) A uranium-glass lens was placed in the quercus water, or (2) a uranium-glass lens was placed between two uranium-glass prisms, and then the following light traces were visualized; the incident light, the refracted light in the uranium-glass lens and the transmitted light that passes through the quercus water or uranium-glass prisms.

Keywords: uranium glass; quercus; lens; teaching tools; luminescence; laser pointer

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## 1. Introduction

In the school education, luminescence phenomenon is popular in Japan. For example, luminescent minerals derive curiosity in the class of earth science of high school. From this reason, various kinds of teaching tools using luminescence could be expected to develop. Actually in the classes of chemistry and physics, luminescent materials were developed as teaching tools. Yamashita, Sidikeand Nakagawa (2001) verified the teaching tools "black light" and "luminescent materials" on the market. Toyama and Asai (2011) synthesized calcium carbonate phosphors activated with nitric acid cerium, manganese chloride and chlorination teribium. Sidike Aierkin and Yamashita (2003) synthesized luminescent salt activated with Pb and Mn. For showing luminescence from these phosphors, ultraviolet (UV) light is used as the excitation source. If visible light is utilized instead of UV light, it would be easy to handle because of its safety. Luminescent teaching tools excited by visible light have been proposed as follows. In biological education, Deguchi, Onodera and Namikawa (2013) developed the educational tool with green luminescent protein (GFP). In earth science education, Kohno and Nakano (2011) developed new tools for understanding birefringence of calcite, and Kohno, Zaiatsu, nakano and Yamashita (2013) made materials using birefringence as colorful materials. Taga, Kohno and Nakano (2015) made new tools for understanding birefringence of calcite in combination of calcite, uranium glass and an infusion of quercus in water (quercus water).

As the previous research of teaching tools showing a light trace through a lens, Sakuma *et al*. (2011) used a red laser light and the acrylic lens to develop educational materials of light trace with use of the Tyndall phenomenon and examined understanding of the students concerning real image by the convex lens. But there is no previous study of teaching tools with luminescence trace passing through a lens. The present report develops new luminescent teaching tools for tracing light passing through a convex lens or a concave lens by using uranium-glass lens, uranium-glass prisms and the quercus water mentioned above.

## 2. Luminescent materials

Taga *et al*. (2015) made progress in teaching tools of calcite birefringence with luminescence under the purple light from a laser pointer. These teaching tools have three kinds of luminescent materials, that is, calcite, uranium glass and the quercus water. A laser pointer that provides a 405-nm purple light was used as the excitation source for luminescence. The aforementioned materials were assembled for the apparatus as follows. (1) A calcite crystal was placed in the quercus water, or (2) a calcite crystal was placed between two uranium-glass prisms, and then the light traces were observed. The following light traces were visualized; the incident light, the refracted light in the calcite crystal, and the transmitted light that passes through the quercus water or a uranium-glass prism (Taga *et al*., 2015).

The 405-nm purple light from the laser pointer was used as the excitation source for luminescence (Kohno and Nakano, 2011). This laser pointer has the maximum output less than 1 mW for totally eliminating the risk of blindness by looking directly into the laser pointer and it is necessary to be careful for students in observation.

More details of the luminescent materials proposed by Taga *et al*. (2015) are as follows.

### *2.1. Quercus water*

It has been known that an infusion of certain plants in water fluoresces upon irradiation with UV rays or visible light. According to Brenii (2007), Nicolas Monardes noticed in the 16th century that an infusion of lignum nephriticum showed a peculiar bluish color by irradiation of UV light. In the 18th century, other liquids such as petroleum, as well as the tinctures of sandalwood, quassia wood and horse-chestnut bark were found to show similar phenomena, though no explanation was made

(Brenii, 2007). It is well known that dissolved organic matter (corrosive materials, etc.) fluoresce (Yoshioka and Mostofa, 2010). Kohno *et al*. (2010) and Taga *et al*. (2011) provided the possibility of organic material derived from plants as the luminescence origin of gypsum from the salt lake.

The colorless quercus water is made by putting quercus (Fagaceae) branches into water bucket for a few hours. It has a few advantages; the blue luminescence under the visible light excitation, safe for the skin, and inexpensive (Taga *et al*. 2015).

Taga *et al*. (2015) revealed the understandings of the students about the nature of the light such as rectilinear propagation, reflection and refraction of light in demonstration experiment. (1) By using the purple laser pointer as the excitation source of luminescence, the quercus water shows a visible luminescence trace that is teaching tools for rectilinear propagation of light (Fig. 1(a).). (2) With use of mirror in the quercus water, the luminescence trace shows reflection of light (Fig. 1(b).). (3) The beam from the laser pointer is passing through a uranium-glass prism (5 cm×3 cm×3 cm) in the quercus water. The luminescence trace demonstrates refraction of the beam at the surface of prism (Fig. 2(a).). In addition, Taga *et al*. (2015) presented new teaching tools showing calcite birefringence with a combination of calcite, quercus water and uranium-glass prism (Fig. 2(b).).

As the causative agents of the luminescence phenomenon of infusion by the plant, Shimada (1938; 1940; 1952a; 1952b) proposed esculetin (Aesculetin) and fraxin (Fraxin) in Oleaceae Fraxinus (eg ash, Fraxinus lanuginosa). As for the quercus water used in the present report, the causative agent has not been revealed yet.

### *2.2. Uranium glass*

The uranium glass used in the present report was made by *Yousei no Mori* (Fairy Wood) *Glass Museum* of Okayama Pref. in Japan. It contains uranyl ($UO2^{2+}$) ion less than or equal to 0.1 wt%, and emits green luminescence under the purple laser-light excitation. Its radiation dose was 0.14 µSv / h (1.2 mSv / y) at the surface of the uranium glass. Effect of radiation from uranium glass was confirmed to be comparable to the value of the natural radiation dose (0.15 µSv / h (1.3 mSv / y)) (Taga *et al*., 2015).

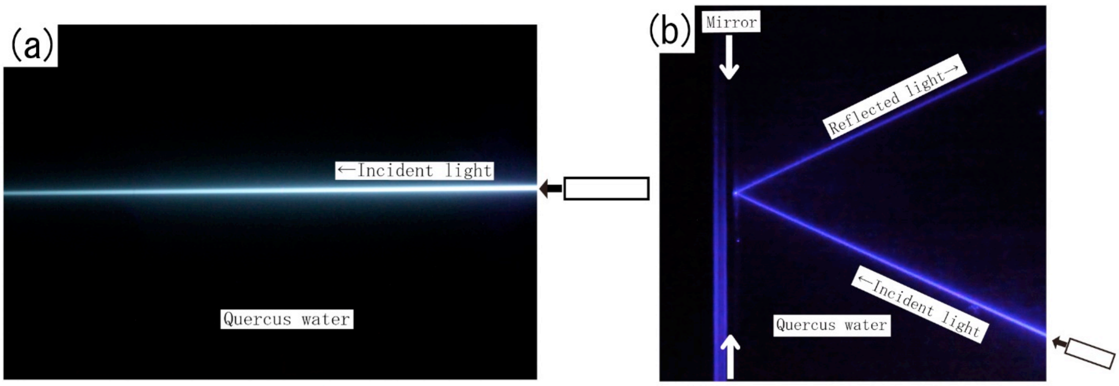


**Figure 1. (a) Luminescence trace of rectlinear light in the quercus water modified after Taga *et al*.(2015); (b) Luminescence trace of light reflection in the same water modified after Taga *et al*.(2015).**

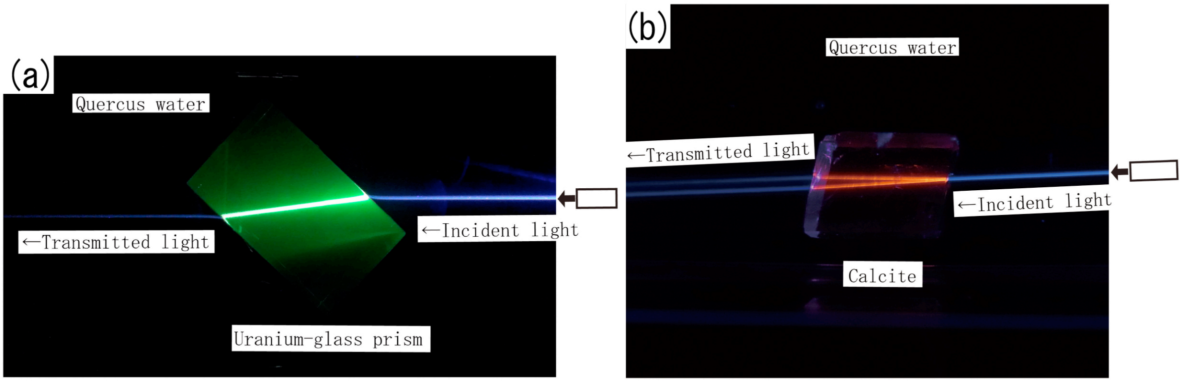


**Figure 2. (a) Luminescence trace of refraction of light at the boundary between the quercus water and the prism modified after Taga *et al*.(2015); (b) Teaching tools about calcite birefringence with luminescence modified after Taga *et al*.(2015) .**

A convex lens and a concave lens were made of uranium glass mentioned above (2. (2)). Uranium-glass lenses in the present report (uranium-lens) were made by molding uranium-glass prisms of 6.5 cm × 6.5 cm × 2.7 cm. It was entrusted to the lens production company. The size of the convex lens is 6.4 cm in diameter, 2.7 cm in thickness of the center and 9.4 cm as the focal distance in air. The size of the concave lens is 6.4 cm in diameter, 0.4 cm in thickness of the center and -14.2 cm as the focal length in air. Both lenses were cut off into semicircles, for observing luminescence traces through the cut surface (Fig. 3.).

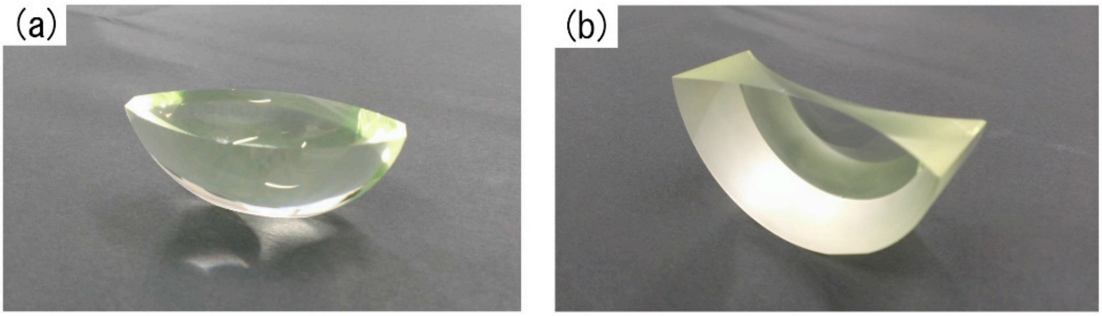


**Figure 3. (a) A uranium-glass convex lens (6.4 cm in diameter); (b) A uranium-glass concave lens (6.4 cm in diameter).**

## 4. Methodology

The aforementioned materials were assembled for the educational tools as follows. (1) A uranium-lens was placed in the quercus water, or (2) a uranium-lens was placed between two uranium-glass prisms, and then the light traces were observed. The following light traces were visualized; the incident light, the refracted light in the uranium-lens and the transmitted light that passes through the quercus water or uranium-glass prisms (Fig. 4(a), 4(b), 5(a), 5(b)).

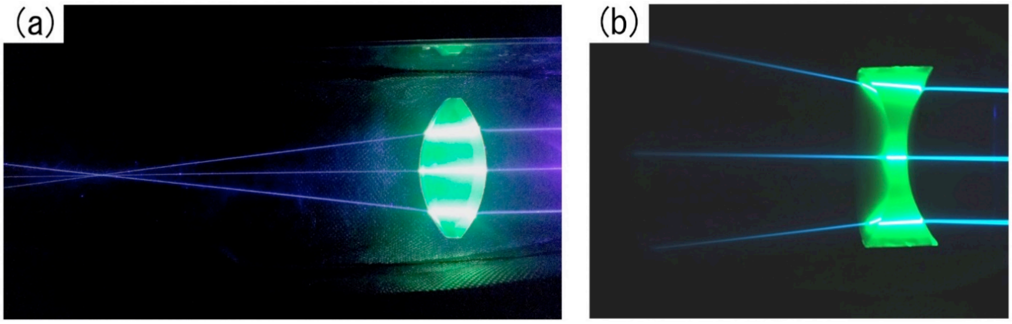


**Figure 4. (a) Light trace passing through the quercus water and a convex uranium-lens; (b) Light trace passing through the quercus water and a concave uranium-lens.**

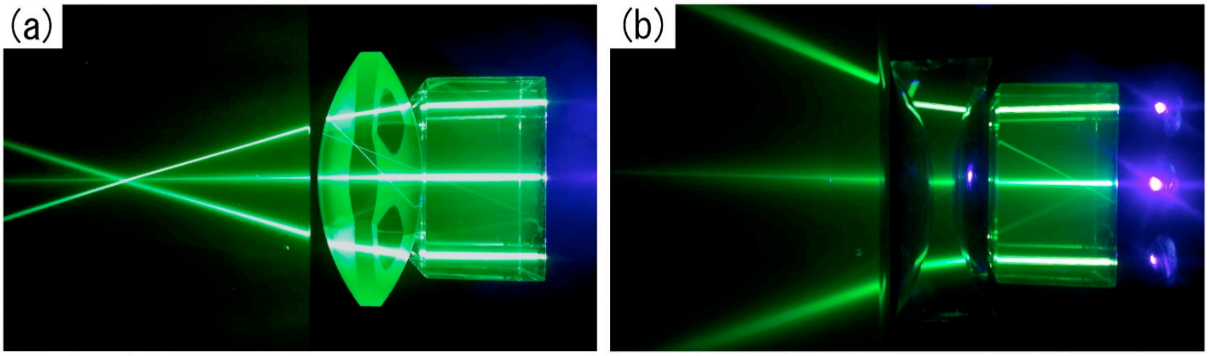


**Figure 5. (a) Light trace of uranium-glass prisms and a convex uranium-lens; (b) Light trace of uranium-glass prisms and a concave uranium-lens.**

## 5. Discussion

### *5.1. Educational effect of luminescence*

Students in junior high school in Japan study the nature of lens in science class. In study, reflection, refraction, total internal reflection and the nature of convex lens are treated. As the nature of lens, they study focus point, focal length and light traces refracted by the lens. After that they learn the real image and virtual image of a convex lens by drawing figures. If new tools for light trace of lens are developed, the nature of lens would become more understandable for the students. Taga *et al*. (2015) revealed that practical application of luminescence traces that demonstrated rectilinear propagation, reflection, and refraction of light could result in better understanding of light propagation among the high school students. From this result, luminescence trace might be a big help for students to understand the light trace. In the present report, it is characterized that new teaching tools uses only luminescence traces, which would be expected to contribute to better understanding of the nature of lenses for students.

### *5.2. Reflected light inside uranium-lenses*

In Fig. 5(a) and Fig. 5(b) the refracted light traces are observed inside uranium-lens. Japanese junior high school students do not study the refracted light traces as the nature of lens in curriculum, but from this observation they could come to know that not only the light transmit through lens, but a part of light reflect repeatedly in the lens. In science text book of junior high school of Japan, students learn one light trace passing through lens by drawing figures. But the proposed observation would provide that there are complicated actual light traces inside the lens, and that the fact might become an opportunity to further understanding of the lens for students.

### *5.3. Focal length of uranium-lens*

Refraction of light between uranium glass and the quercus water is different with that between uranium glass and air. The reason is due to the difference between the refractive index of water (~1.33) and that of air (1.00). Uranium glass in the present report contains uranyl ($UO_2^{2+}$) ion less than or equal to 0.1 wt%, and because of the quantity, the uranyl ions would not affect the refractive index (n = 1.54 of Na glass in air). Similarly it is supposed that there is no difference between the refractive index of water and that of the quercus water. The relative refractive index between uranium glass and the quercus water n ′ would become 1.16 ( n ′≃ 1.54/1.33 = 1.16), approximately. The focal length f of thin lens with the curvature radii of R and R′ in air is expressed by

$$1/\mathrm{f} = (\mathrm{n}-1)((1/R) + (1/R')). \qquad (1)$$

And it is modified as

$$\mathrm{f} = k/(n-1)\,. \qquad (2)$$

On the other hand, focal length f ' of the same uranium-lens in the quercus water is

$$\mathrm{f}' = k/(n'-1)\,. \qquad (3)$$

Assign a refractive index of n and n', the ratio of the focal lengths is

$$\mathrm{f}'/\mathrm{f} = (1.54-1)/(1.16-1) = 3.4 \qquad (4)$$

By placing the uranium-lens in the quercus water, its focal length is understood to be more than three times, compared with that in air. The actual focal length of convex uranium-lens in the quercus water was measured. The focal length in the quercus water (18.8 cm) is approximately 3.7 times that in air (5.1 cm), which provides similar result of Eq. (4). In observation, it is necessary to point out that the actual focal length of the lens in air is shorter.

## 6. Conclusion

New teaching tools were developed to demonstrate the light traces in a convex lens or a concave lens with use of two luminescent materials; an infusion of quercus (quercus water) and uranium-lenses. Feature of the teaching tools is that all the light traces are visualized by luminescence, and they would be more effective for students to understand light traces and the nature of lens.

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