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# LASER-INDUCED FLUORESCENCE IN MINERALS: PRELIMINARY RESULTS

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## ABSTRACT

Visible radiation from an argon-ion laser used on mineral samples can induce fluorescence. One hundred and fifty-five mineral samples, representing 70 mineral species, were tested; sixty-one (29 species) produced visible fluorescence. Most minerals known to fluoresce in ultraviolet light also fluoresce under the 488 nm line of the argon-ion laser, but the colors commonly differ. Differently colored specimens of the same mineral may fluoresce in different colors.

*Keywords:* laser, fluorescence, mineral.

## SOMMAIRE

La radiation d'un laser émis par l'argon ionisé peut induire la fluorescence dans certains minéraux. Nous avons examiné 155 échantillons minéralogiques; des 70 espèces étudiées, 29 (61 échantillons) produisent une fluorescence visible. La plupart des minéraux qui réagissent à la lumière ultraviolette montrent aussi une réaction à la longueur d'onde de 488 nm de ce laser, mais les deux fluorescences sont généralement de couleurs différentes. Des échantillons d'une même espèce mais de couleurs différentes peuvent réagir différemment au point du vue couleur.

(Traduit par la Rédaction)

*Mots-clés:* laser, fluorescence, minéral.

## WARNING

Laser radiation is dangerous. Exercise proper precautions at all times while making observations of the type mentioned in this paper.

## INTRODUCTION

In this work, we report preliminary results of a study of laser-induced fluorescence in minerals. We have used a Spectra Physics model 162A argon-ion laser, which produces several visible lines in the blue-green region. In this study, we have used the 488 nm blue-green line, the same as used in forensic investigations. Laser Gard LGS–A safety goggles were used to screen out the laser light. A theoretical discussion of the operation of lasers and a presentation of the theory of fluorescence are beyond the scope of the present report, which is limited to a presentation of the results of our study and their possible applications. Research is continuing on this interesting topic.

Fluorescence induced by ultraviolet radiation is well known in mineralogy, and is used to identify and characterize different types of minerals. However, there is one serious drawback to UV-induced fluorescence, namely that the specimen cannot be mounted in glass since short-wave ultraviolet radiation cannot pass through glass. This opacity greatly limits the usefuless of the technique, since mineral and rock specimens are usually mounted on glass for microscopy. The usefulness of fluorescence as a diagnostic tool in mineralogy and petrology would be greatly expanded if fluorescence were excited by visible radiation transmitted through lenses and cover slips.

For a variety of reasons, practical use of visible-light-induced fluorescence was not possible until the invention of the laser, and, specifically, the development of the argon-ion laser, which produces blue-green light. Short-wavelength light is necessary to excite fluorescence, which always has a longer wavelength than the exciting radiation, a relationship known as Stokes Law. The most common lasers produce red light (the HeNe laser produces a 632.8 nm line, for example). Common lasers, therefore, produce fluorescence in the infrared range, which would not be visible and hence would have quite limited application.

The other necessary part of a system designed to utilize visible-light-induced fluorescence is an efficient blocking filter to screen out the exciting radiation, so that the weaker fluorescent radiation becomes visible. Of course, filters are not necessary for UV-induced fluorescence, since the exciting radiation is invisible to the human eye. Fortunately, the safety hazard represented by lasers has led to the development of remarkably efficient safety filters which effectively screen out the laser lines while allowing other visible light to pass. All the equipment necessary to produce and observe laser-induced fluorescence is thus available off-the-shelf. One needs only illuminate a sample with blue or green light and observe the sample through the proper safety goggles. Any observed luminescent effect is due to laser-induced fluorescence. A somewhat more complex arrangement is necessary to use the technique with a microscope.

Fluorescence excited by a visible-light laser has, up to now, been used in the fields of forensic science and botany. In forensic science the argon-ion laser has been used to make fingerprints visible (Menzel 1979, 1982, Menzel & Duff 1979, Dalrymple 1979). In some cases, clear prints were made visible which could not be obtained in any other way. Even in cases where ultraviolet light detected fingerprints, the argon-ion laser can commonly reveal more detail.

More recently, D.C. Mortimer (pers. comm., 1983), of the Ecotoxicology Section, National Research Council in Ottawa, has used the 488 nm line on an argon-ion laser to excite fluorescence in a newly discovered organic compound isolated from chloroplasts in plants. This compound, which may be important in photosynthesis, was missed by conventional techniques. Curiously, coherent light from the laser produces a different fluorescence than incoherent light of the same wavelength, a rather unexpected result. It is not known, at the present time, if this phenomenon also occurs in minerals.

## Observations

The observations reported here were obtained using the blue-green 488 nm line of an argon-ion laser. The light beam from the laser was expanded by a negative lens to a diameter of about 14 cm. The mineral specimens were placed in the beam, and any fluorescence was observed through safety goggles. The blue-green light from the argon-ion laser is quite dangerous, both because of the level of power and the high sensitivity of the eye to this radiation. Care was taken at all times to ensure that no specular reflection of the beam entered the observer's eye. All observations were made in a darkened room. *Anyone wishing to duplicate these results should take proper safety precautions at all times while using a laser.*

One hundred and fifty-five mineral samples representing 70 different mineral species obtained from the Museum collection at Queen's University were used in this study. Two examples of laser fluorescence are shown in Figures 1 and 2. Figure

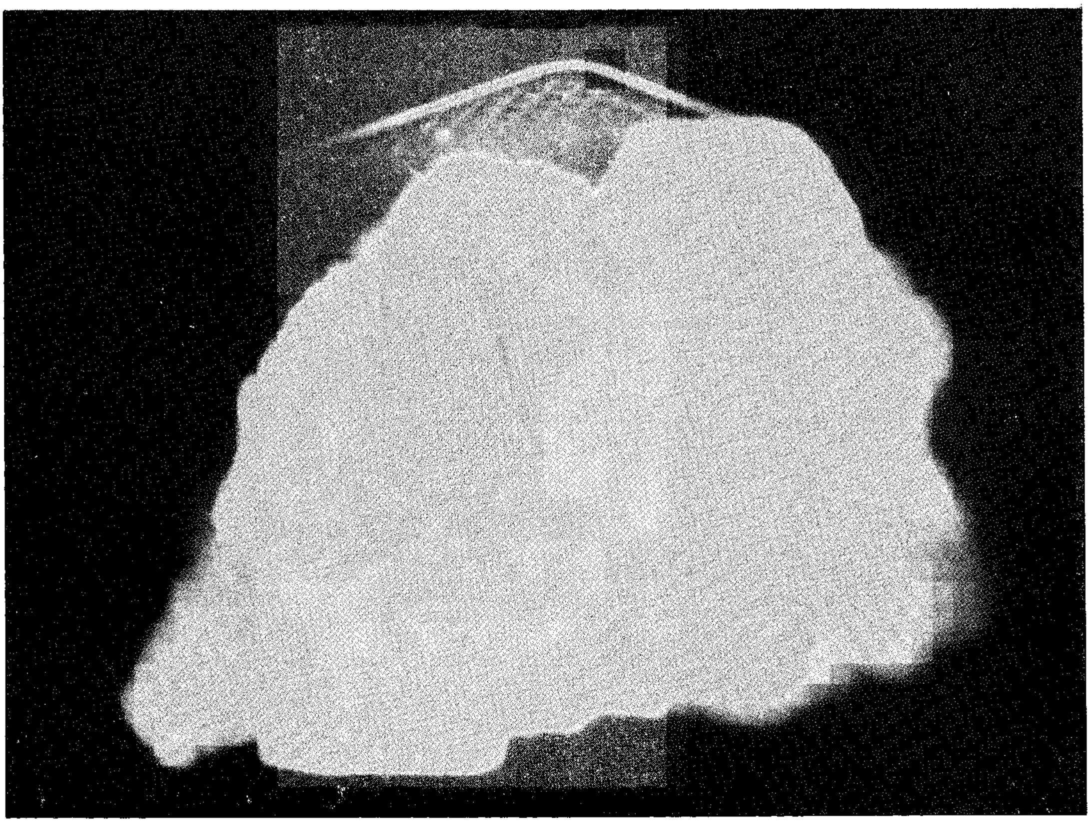

FIG. 1. Sample of aragonite (M795) from Sicily (exact locality unknown). Bright red laser-fluorescence excited by 488 nm line of an argon-ion laser. The UV-fluorescent color for this mineral is white (short-wave UV). Aragonite from Agrigento, Sicily is known to fluoresce white (short-wave UV) or pink (long-wave UV). Photographed in a darkened room. Specimen width is 9 cm.

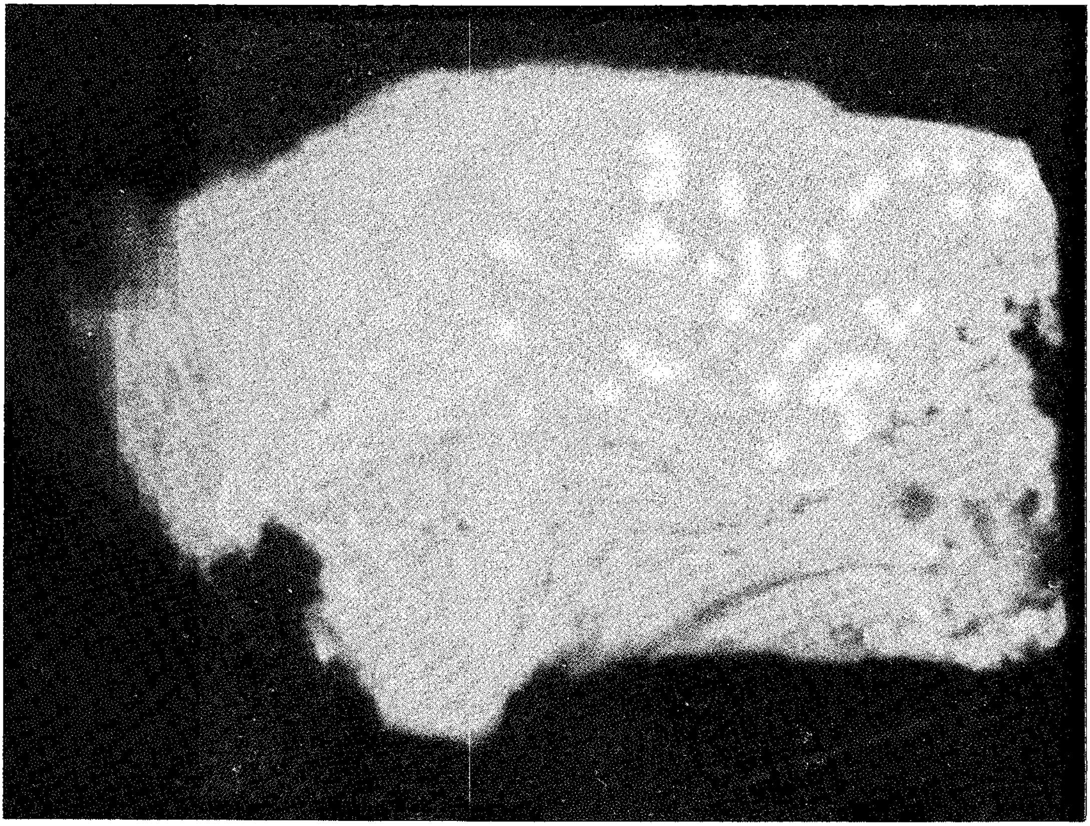

FIG. 2. Sample of pectolite (M1447) from Paterson, N. J. Bright yellow laser fluorescence excited by the 488 nm line of an argon-ion laser. The UV-fluorescent color for this mineral is orange. Photographed in a darkened room. Specimen width is 7 cm.

1 shows aragonite fluorescing a brilliant red under excitation of the argon-ion 488 nm blue-green line. Figure 2 shows pectolite fluorescing a bright yellow under the same circumstances. Both were photographed in a darkened room. The results of this work are presented in Table 1. The observed fluorescence is indicated along with the Museum number and the usual fluorescent color noted with short-wave ultraviolet radiation (where known). Sixty-one of the samples, representing some twenty-nine mineral species, showed noticeable fluorescence. Most minerals known to fluoresce under ultraviolet light also fluoresce when exposed to the 488 nm line of the argon-ion laser. Note that the fluorescent colors produced by the two techniques are typically different. We think that this is due mainly to the different exciting radiation rather than to a coloring effect of the safety goggles.

## DISCUSSION

In this work, we have demonstrated, for the first time, the efficacy of visible light from an argon-ion laser in producing visible fluorescence in common minerals. The wavelength of fluorescence so produced is different from that obtained using ultraviolet radiation for excitation, an aspect considered worthy of more study, as it may have value in identifying and characterizing minerals. Although we have used hand specimens, laser fluorescence will likely be found most useful in microscopy (because glass is opaque to ultraviolet radiation but not to visible laser radiation).

For further work, it would appear that a deep blue laser line, such as the 442 nm line from a Liconix HeCd laser, would be convenient. Using this radiation, almost all visible colors could be produced by fluorescence. Although the human eye is extremely sensitive to colors and is able to recognize about 10,000 different hues, languages seldom have more than ten words describing color. Verbal descriptions are therefore, of necessity, somewhat imprecise. Therefore, the use of a recording spectrograph, with resulting observations of chomaticity (Henry 1980,

TABLE 1. LASER FLUORESCENCE OF SELECTED MINERALS

| MINERAL | LASER COLOR | UV COLOR | # | LOCATION |
|---|---|---|---|---|
| anglesite | green | white | M2248 | N.S. Wales |
| anhydrite | pale green | ? | M2249 | Mound House, Nev. |
| apatite | orange | yellow | M973 | Eganville, Ont. |
| aragonite | bright red | white | M795 | Sicily |
| autunite | yellow-orange | green | M999 | Black Hills, S.D. |
| benitoite | yellow-orange | blue | M1465 | San Benito Co., Ca. |
| brucite | green | white | M537 | Wood's Mine, Pa. |
| calcite | bright yellow | red or pink | M723 | Templeton, P.Q. |
| chabazite | dull green | ? | M1237 | Thul Ghat, India |
| chalcedony | orange | yellow | M1070 | Tampa, Fla. |
| chrysoberyl | faint red | red to pink | M638 | Takovaja R., U.S.S.R. |
| chrysotile | faint orange | ? | M1283 | Carolina, Transvaal |
| colemanite | yellow and orange | white | M872 | Inyo Co., Ca. |
| corundum | brilliant red | red | M445 | Clay Co., N.C. |
| fluorite | light green | blue | M696 | Madoc?, Ont. |
| gypsum | light green | yellow, green | M906 | Brantford, Ont. |
| nepheline | light orange | red to orange | M1195 | location unknown |
| opal | yellow | yellow, green | M1123 | Bohemia |
| pectolite | bright yellow | orange | M1447 | Paterson, N.J. |
| pitchblende | faint yellow | ? | M861 | location unknown |
| scapolite | orange | orange, yellow | M1184 | Haliburton, Ont. |
| scheelite | red | white | M1019 | Aunor Gold Mine, Ont. |
| serpentine | yellow-orange | ? | M1273 | Colorado R. |
| spodumene | yellow | orange | M1433 | San Diego Co., Ca. |
| ulexite | orange | ? | M870 | San Bernardino Co., Ca. |
| uraninite | faint orange | ? | M535 | Comray Mines, Ont. |
| wernerite | orange | orange, yellow | M1178 | St. Lawrence Co., N.Y. |
| willemite | green | green | M1557 | Franklin, N.J. |
| witherite | yellow-orange | white | M808 | Cumberland, Eng. |

Newsome & Modreski 1981), would place observations on a more quantitative basis.

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