Luminescent materials in €uro banknotes

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Introduction

In €uro banknotes several authenticity features are incorporated to protect them from counterfeiting. One feature is the use of luminescent materials (so-called phosphors). The topic of this poster is to understand which phosphors are used by the European Central Bank (ECB) in the new 5 Euro banknotes.

Method

Emission, excitation and decay measurements were taken.

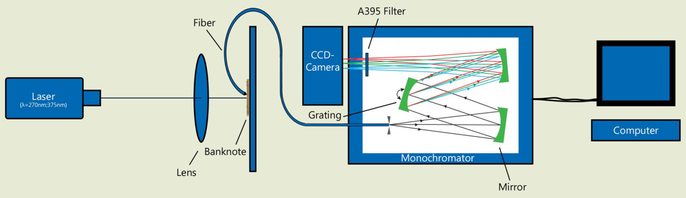


Figure 1: Schematic view of measurments [1]

Results

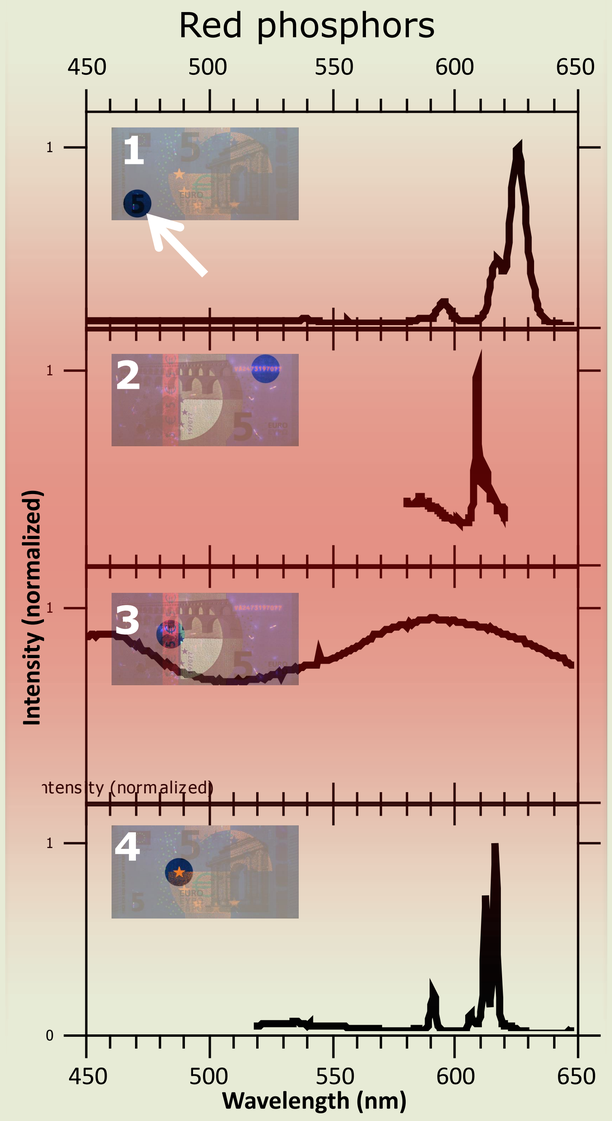
The new banknotes light up differently under long- and short-wave UV light.

Figure 2: frontside banknote, short-wave UV light

Figure 3: frontside banknote, long-wave UV light

Figure 4: backside banknote, short-wave UV light

Figure 4: backside banknote, long-wave UV light



The red phosphors

1. Red Fiber: **Eu^{3+}** in an β-diketon complex. Eu^{3+} is **coordinated by three O=C-(CH_2)-C=O groups**[2].
2. Serial number: **Eu^{3+} in Y_2O_2S.** Also found in the green quadrant, see 6 and 7.
3. Red band: **organic dye**, possibly Rhodamine 6G[3].
4. Star: a mixture of both red and green phosphors (see 9 for green phosphor). The red part, which is visible on short UV light is probably a **Eu^{3+} complex.**

The blue phosphor

5. Blue fiber: **Eu^{2+}** in $(BaO)_x \cdot 6Al_2O_3$[2]. This is the same as in the old banknotes.

The green phosphors

6 and 7. Light and dark quadrant: **organic dyes** (decay time: ns-scale); possibly Coumarins[3].
8. Green fiber: a mixture of two phosphors which contains possibly **Eu^{2+}** or an organic dye.
9. Star: a mixture of both green and red phosphors; see also 4. The green part is **organic** as well (decay time: 5.9 ns). Probably another Coumarin dye
10. Green circle: possibly **Eu^{2+}**, but more measurement are required.

Conclusion

We discovered that the ECB has used many more different phosphors to protect the new series of euro banknotes from counterfeiting. Instead of three lanthanide complexes in the old banknotes, the new banknotes contain at least 10, both organic and inorganic, phosphors.

Frozen banknotes

During our measurements, we discovered something interesting which is not mentioned on the ECB website. By cooling down the banknotes with liquid nitrogen, the banknote light up bright green. This luminescent material is incorporated in the whole banknote, and is a special phosphor with a quenching temperature around 0°C.

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References:
[1]: Czerny-Turner configuration. Applications of gratings. [Cited 26 juni]. Available at www.zeiss.de.
[2]: Suyver, F. Meijerink, A. Chemisch 2 Weekblad 4, 12 (2002).
[3]: Brackmann, U. Lambdachrome Laser Dyes. First Edition. Göttingen, West Germany. Lambda Physik 1886.