B8 | Irradiation Device for Neutron-Autoradiography

The instrument B8 allows to irradiate and activate artistic, technical or geological items (foils, stones etc.) and other materials with cold neutrons and to investigate them by imaging plate technique and/or to analyse it by gamma-spectroscopy. In the main the instrument is used for paintings but also for other purposes (neutron activation analysis). External cooperation partners for joint research projects are the Painting Gallery of the Berlin State Museum (Staatliche Museen Preussischer Kulturbesitz, Gemäldegalerie zu Berlin) and the Prussian Palaces and Gardens Foundation Berlin-Brandenburg (Stiftung Preussischer Schlösser und Gärten Berlin-Brandenburg) in Potsdam.

Instrument description

The painting is fixed on a support in front of a neutron guide end with an open area of 3.5 x 12.5 cm². The surface of the painting is adjusted under a small angle (< 3°) with respect to the axis of the guide. Thus a 12.5 cm wide strip of the painting is illuminated by the neutrons. The main free path of the neutrons within the paint layer is much longer than in the case of perpendicular transmission. The support is moved up and down with a velocity of a few cm/s in order to receive a uniform activation of the total area of the panel.

The facility is installed in a secure closed container. The basic area of the container is 250 x 450 cm². On a special table in a shielded room in the basement the film exposure and the gamma spectroscopy can be performed for the suitable times (up to more than 4 weeks) depending on the half-lives of the isotopes.

Application of autoradiography to paintings

After irradiation, the neutron-induced radioactivity decays with time. About a dozen different light and heavy isotopes – emitting β- (electrons) and ϒ-radiation – are created (the most important isotopes and their half-lives are presented in the table). The induced β-decay is used to blacken highly sensitive films or imaging plates to reveal the spatial distribution of the pigments. It is a big advantage of neutrons that different pigments can be represented on separate films. This is due to a contrast variation created by the differences in the half-life times of the isotopes. The ϒ-spectroscopy via a Ge-detector provides information about the element composition of the pigments. The image plate technique allows for direct digital analysis and processing. With this method conceptual changes and corrections ("pentimenti") during the creation of the painting become visible. In some cases decisions about the authenticity can be made. The art historian or restorer receives valuable information about the brush technique of the artist and the actual condition of the painting.

Advantages of the method

- Activation cross-section (n,β) depends on the isotope
- Different pictures depending on the half-lifetimes of the isotopes
- Less ϒ-rays (cold source)
- Non-destructive

Selected examples

Neutron autoradiography is capable of revealing different paint layers piled-up during the creation of the painting, whereas different pigments can be represented on separate films due to a contrast variation created by the differences in the half-life times of the isotopes. Thus, in many cases the individual brushstroke applied by the artist is made visible, as well as changes made during the painting process, so-called pentimentis. When investigating paintings that have been reliably authenticated, it is possible to identify the particular style of an artist. By an example - a painting from the French Nicolas Poussin, belonging to the Berlin Picture Gallery - the efficiency of neutron autoradiography is demonstrated as a non-destructive method.

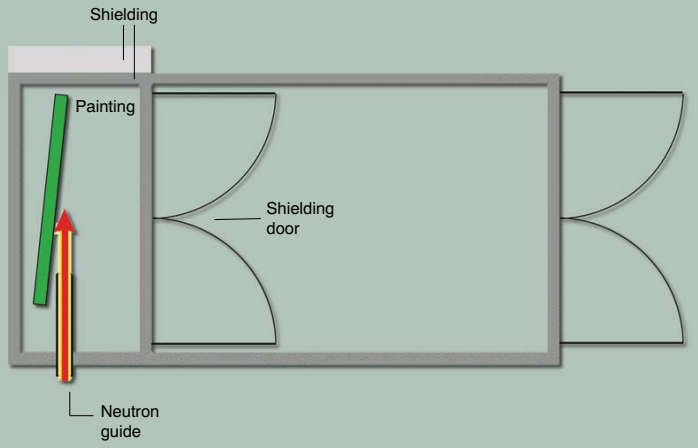

Fig. 1

Fig. 2

"Armida abducts the sleeping Rinaldo"

The illustrations in this painting of the French Painter Nicolas Poussin (1594–1665) show scenes from the bible and from classical antiquity. In 1625 the legend of the sorceress Armida and the crusader Rinaldo had inspired Poussin to a painting named "Armida and Rinaldo", now owned by the Dulwich Picture Gallery in London, that has been identified as an original. In contrast, the painting from the Berlin Picture Gallery "Armida abducts the sleeping Rinaldo" (Fig. 1) shows a different but similar scene, and was listed in the Berlin Gallery's catalogue as a copy. To clarify the open question of the ascription a neutron radiography investigation was carried out. In figure 2, one of the autoradiographs is depicted. Already this first record, showing the distribution of the short-lived isotope ^{56}Mn contained in the brown pigment umber, revealed surprising pentimenti as conceptual changes: additional trees (highlighted in Fig. 2) not present in the final painting. These trees fit in the composition of the painting and contain the same pigments as the other structures. Obviously, these pentimenti are corrections made by the artist himself. A copyist would not have been aware of these changes. Therefore, these pentimenti are strong and important hints that this painting can possibly be attributed to Nicolas Poussin himself.

Instrument Data

Neutron guide	NL1A
Neutron guide cross section	35 mm x 125 mm
Wavelength	white beam (cold spectrum)
Typical flux	$1 \cdot 10^{9}$ n/cm²s
Instrument responsible	B. Schröder-Smeibidl schroeder-smeibidl@hmi.de

Isotope	Half life	Pigment
^{56}Mn	2.6 h	Brown colours, Umber, Ocre
^{64}Cu	13 h	Azurite, Malachite
^{76}As	1.1 d	Smalt, Realgar, Auripigmente
^{122}Sb	2.7 d	Naples-Yellow
^{124}Sb	60 d	
^{32}P	14 d	Bone-black
^{203}Hg	47 d	Vermilion
^{60}Co	5.3 a	Smalt

Fig. 1: Nicolas Poussin, Replica, "Armida abducts the sleeping Rinaldo", (c. 1637), Picture Gallery Berlin, 120 x 150 cm², Cat No. 486

Fig. 2: Nicolas Poussin, "Armida abducts the sleeping Rinaldo", 1st neutron autoradiography assembled from 12 image plate records: in order to investigate the whole picture, two separated irradiations were carried out and finally recomposed.

References

Elemental dispersion and stable isotope fractionation during reactive fluid-flow and fluid immiscibility in the Bufa del Diente aureole, NE-Mexico: Evidence from radiographies and Li, B, Sr, Nd, and Pb isotope systematics.
Rolf L. Romer, Wilhelm Heinrich, Birgit Schröder-Smeibidl, Anette Meixner, Carl-Otto Fischer, and Cathrin Schulz in Contributions to Mineralogy and Petrology (2005) 149, p. 400-429