

# Laser cleaning in French museums: towards instating a methodology

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## Abstract

This communication aims at taking stock of French museum practice regarding the use of laser cleaning, and it summarises a few reflections and interrogations, from the art historian's and archaeologist's, rather than the scientist's, standpoint. Our conclusions owe a lot to discussions with restorers and scientists<sup>1</sup>. © 2003 Éditions scientifiques et médicales Elsevier SAS. All rights reserved.

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## 1. Introduction

Restoration in museums is not subject to the constraints imposed on large monumental sites or to the restricted options left by open-air localisation. It is rarely conditioned by the obligation to preserve the usage value of the object, its decorative function within a compound sculpture or architectural setting. On the other hand, the context of museum collections imposes other obligations: displaying pieces with a very close-range view, weight of the presentation aspect in restoration decisions, collection consistency and priority to preserve the traces of history, as imposed by the museum's conservatory function.

Laser has only been used in France to restore museum pieces on a one-off, occasional basis, without any global approach. Institutions in charge of public collections have shown a reserved attitude to the apparent uncertainties, except for the sculpture department of the Louvre museum. Some curators in charge of art pieces are reluctant to adopt a method that apparently precludes any modulation of the end result. Nevertheless, a survey initiated this year by the Centre de Recherche et de Restauration des Musées de France (C2RMF) with sculpture conservator-restorers has revealed that a large number of professionals working for museums have had specific training and have been using

laser to clean a significant number of museum sculptures. The survey questionnaire was sent to approximately 60 restorers, half of whom replied. Eleven have never used laser (no training = 5). Sixteen use it occasionally or regularly (on one to several tens of art pieces in their collection), preferably for archaeology; fewer use it for sculpture. The majority use it mainly for registered monuments, some exclusively so. Pieces are essentially made of stone, except in a few cases (plasters)<sup>2</sup>.

However, laser cleaning has recently been chosen within C2RMF for several major art pieces. By analysing these early experiments, C2RMF expects to deepen its methodologic approach to the entire spectrum of cleaning issues, reconsidered according to the type, requirements and consequences of the use of laser. From these experiments, it is led to reconsider the technical, documentation, ethical and aesthetical issues, which are seen in a new light following the introduction of this new technique. We will review them as they are raised in the course of any restoration approach: studies and analyses, development of a cleaning protocol, selection of a process and the presentation dimension.

These reflections were elaborated on during the processing of major pieces, including the *Pilier des Nautes*, which will serve as the main illustration of this presentation. A monument of worship dedicated to Jupiter by Paris boatmen under Tiberius (14–37 AD), it was discovered beneath the

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<sup>1</sup> Especially with M.-E. Meyohas, who took the time to partake in our reflections.

<sup>2</sup> J. Délivré, on plasters; R. Coignard, trials on raw clay and varnished clay; G. Barthe, on terra cotta and plaster. Some have used it for models and for composite art pieces (C. Goubert and C. Cordier).

choir of Notre-Dame-de-Paris in 1711, in foundation masonry. Since 1843, it has been on display in the frigidarium of the National Medieval Museum, an outstanding space included in the Gallo-Roman baths of Lutecia.

The Museum decided to study and restore it in 1998. The Eight-God block was deemed the most representative and was chosen for study. Soon, the problem of black crusts and surface grey wash emerged. After trials, and in consideration of the condition of the stone (marked presence of salts, degradation and extreme brittleness of the sculpted skin), it appeared that the only method possible was laser cleansing. The block was thus cleaned in April of 2001<sup>3</sup>.

## 2. Study and analysis

It is the links between historical documentation, restorers' observations and laboratory analyses that determine the understanding of the object and hence all the decisions to be taken about it. Any intervention, even the slightest dusting, will destroy something of the historical condition the piece was in when first admitted to the collection. Any element removed, even a layer of dirt, is a piece of information. It is therefore necessary, before any undertaking, to document the piece.

That process begins before any restoration plan, when the curator decides on the museographic programme. Collecting the most documented record as possible will help not only in locating the art piece historically and aesthetically but also in collecting precise data on its material history, which will help curators, conservators-restorers and scientists in reaching a correct diagnosis by making the right choices. This documentary concern is somewhat new in sculpture; it is sometimes misunderstood or even evaded as an unnecessary complication by communities involved in urgent restoration projects. It is nonetheless necessary, as was the principle and the implementation of restoration reports. It is only then that studies by restorers will take place, followed by laboratory analyses, in that order, which is vital. The study of the material remnants left on the piece, with binocular magnifier examination, must precede the selection of sampling areas. These analyses must be interpreted jointly by the scientists and the restorer, to result in mapping and stratigraphy and, whenever possible, a chronological history of the depositions and interventions detected, in relation with historical documentation.

In the case of the *Pilier des Nautes*, the exceptional character of the piece justified protracted studies [1], which elicited layered stratigraphy whose limits are not easy to define: black scabs of variable thickness, with locally greasy

aspect<sup>4</sup> and grey wash. These studies were supplemented by four series of analyses [2–7] to identify the type of material, the black scabs, mortars, pigments and salts. These procedures were carried out over 2 years, were validated at each stage by a scientific committee<sup>5</sup> and are expected to undergo new developments in the coming months.

The ongoing experiment should lead us to systematise more sophisticated characterisation analyses, for any future laser cleaning, to understand the structure of deposits and define alteration morphology more precisely, as follows.

*Stratigraphic analyses on specimens collected at various places.* The insufficient response obtained so far, in our view, argues in favour of refining studies and tests of the superficial layers of the stone, so as to shed more light on the composition of the dirt marks, their stratification and surface heterogeneity, and to better predict and understand what the aspect of the piece will be after cleaning. The studies conducted so far have often revealed a degree of complexity in layer stratification (strata inside the black crusts; alternation of gypsum layer and carbonate matrix), which leads us to consider that surface deposits on the stone are to be treated as a polychromy, whose stratigraphy may be informative on the various stages of the material history of art pieces.

*Salt analyses, whose results may be crucial for later choices.* The purpose of these tests is not only to guide the methodological choice but also to possibly provide indications about the origin of the salts [8].

More sophisticated tests on the black crusts would also be more necessary if the hypothesis of the partial redeposition of dirt marks due to laser use were to be confirmed by studies. It is indeed important to be able to define the risks associated with the side-effects of laser cleaning.

Lastly, all this naturally leads us to recommend, as for polychrome sculptures, that one leave some signs of the surface condition as it was before conservation treatments. Investigation methods are rapidly evolving, and the information contained in the dirt marks so preserved may prove of capital importance in 10 or 50 years. This approach would more easily apply to museum pieces, which are better protected from climatic variations and whose surface layers have been less exposed to recent modifications, except incidentally.

In the case of the *Pilier des Nautes*, grey washes were found to date back to the XIXth and XXth centuries [5–7], and there was no ambiguity at all in that respect. In contrast, it is currently impossible to accurately date the black crusts, approximately timed “during the pre-industrial era” simply because they do not contain any markers from the industrial period: this merely indicates that they probably date back to

<sup>3</sup> By restorers C. Aballéa, R. Lambert, M.-E. Meyohas and C. Pariselle, in consultation with the curators of the National Medieval Museum, V. Huchard (Manager) and G. Andreu (in charge of archaeological collections).

<sup>4</sup> Tests did not evidence the presence of oxalate. It is therefore impossible at this stage to determine whether the brown layer otherwise visible is in continuity with dirt or if it pertains to something else.

<sup>5</sup> V. Huchard and G. Andreu, museum curators, C2RMF, LRMH, LISA, Sculpture Department, Louvre museum.

before the second half of the XIXth century. Conservators noticed that they overlap the cracks and alterations and that they are present on the upper faces of the blocks, which were not visible when the *Pilier* was in place (thus, they are not ancient and probably date back to the period when the *Pilier* was dismantled). Preserving information was important. It was decided to leave two signs and also to keep the cleaning residues.

### 3. Importance of cleansing tests; protocol; cleaning level: the example of the *Pilier*

It appears crucial, for any cleaning method, to carry out analyses to assess the results obtained with varying cleaning levels. With laser cleaning, can the “laser effect” be measured and controlled, and how? Although the procedures are already well known to laser specialists, it was important that the curator could see that the laser could be used as another method.

#### 3.1. The tests

With the *Pilier des Nautes*, tests were carried out in December 2000 with a Q-switched Nd:YAG laser fitted with an articulated arm (Thomson-Thales NL 102) according to the following procedure. Before use, the energy delivered by the laser was measured with a calorimeter. The average power delivered was calculated from the latter, using data on pulse duration (ca. 7 ns) and spot diameter (6 mm), which remained the same during all experimentation: average laser power was measured with a calorimeter to find the correspondences with the grading numbers written on the light intensity potentiometer and the measuring unit (watts per square centimetre)<sup>6</sup>. Thirteen tests were carried out on the A, B and C surfaces of the Eight-God block as well as on the upper surface (Fig. 1), which corresponded to all surface conditions that could be found on the sculpture. The stone surface was very slightly moisturised. Each surface was only scanned by the light beam once. Test areas were photographed before and after processing. In certain areas, half of the surface had previously been dusted off by microsanding, using a Rivolta device (1 mm nozzle, pressure 0.2 bar, pumice stone powder, 90 µm diameter). The cleaned areas were observed with the naked eye and with a binocular magnifier.

#### 3.2. The cleansing level issue

The choice of several cleaning levels offered to curators gives them a margin for appreciation: it enables them, as with other methods, to negotiate with conservators and agree



Fig. 1. Paris, musée de Cluny, *Pilier des Nautes*, inv. Cl 1461, the Eight-God block, the five tests of the C face.



Fig. 2. Paris, musée de Cluny, *Pilier des Nautes*, inv. Cl 1461, the Eight-God block, the C face during laser cleansing.

on a level of reference according to the requirements of archaeology or art history. The heterogeneity of the pillar surface shows that modalities will have to be regularly adapted to obtain a good overall legibility. But the tests carried out by restorers revealed that levels 5–9 (about 21–29 W cm<sup>-2</sup>) were deemed excessive in all cases, a comment that was validated by the scientific committee. The acceptable level is generally in the vicinity of power level 4 (about 17 W cm<sup>-2</sup>) and frequency 1 (30 Hz). That result level does not make the pillar surface even, but it ensures a relatively homogeneous aspect of the block (Fig. 2).

### 4. Choosing the method

In recent years, the following cases were handled by C2RMF<sup>7</sup>: the stone collection of the future Gallo-Roman

<sup>6</sup> The ratio between potentiometer numbers and power intensity is as follows: 1 = 3.5 W; 2 = 3.5 W; 3 = 4.5 W; 4 = 4.84 W; 5 = 5 W; 6 = 6 W; 7 = unstable; 8 = 7 W; 9 = 8 W.

<sup>7</sup> By the following conservators: Périgueux: J. Butterfass, M. Prieur, E. Desroches, P. Jallet, D. Faunières and C. Goubert; Nantes: F. Berson;



Fig. 3. Toulouse, musée des Augustins, *Reliefs de la Daurade*, inv. Ra 542, XIIIth century, restoration by Sophie Reynard-Dubis.

museum of Périgueux (125 sculptures), two Gallo-Roman sculptures from the Nantes museum (Dobrée museum) and a Gallo-Roman sculpture from the Rouen museums (musée des antiquités de Seine maritime), Amiens (musée de Picardie, cathedral consoles, XIIIth century), Douai (collection of marbles, limestones and plasters), Toulouse (Fig. 3, musée des Augustins, *Reliefs de la Daurade*, XIIIth century), and Paris (musée national du Moyen Âge, *Pilier des Nautes*).

#### 4.1. The criteria: by elimination or documented choice?

Whenever C2RMF has validated the choice of laser, the prevailing criterion has been the highest safety of the skin and constituent material, after it had been ensured by prior studies that nothing stood in the way. That choice was made exclusively for very altered and porous limestone art pieces, the integrity of which would have been jeopardised even more with wet techniques or microabrasion: comparing the “yellowish aspect” with maximal surface preservation was most favourable to the latter.

The collection consistency criterion may weigh in the option chosen. If a series of statues of the same monument are preserved, solutions consisting in cleaning some by dabs and others by laser should be ruled out. In any event, artificially introducing aesthetical differences should be

avoided. In Périgueux, the limestone Gallo-Roman sculptures, which were for a long time displayed in the cloister, were nearly all in poor condition: they showed black crusts, ascribable to air pollution, desquamation and uprisings, powdering and craters. The entire set was therefore processed by laser. In contrast, with the *Reliefs de la Daurade* in Toulouse, two possibilities were approved by the scientific committee, who validated these choices because they involved two types of material: marble which had lost all its polychromy and five extremely degraded limestones.

However, this “collection consistency” principle should not be construed as a rule but as a mere guideline. Experience shows, with the consoles of the Amiens museum, the *Reliefs de la Daurade* of the Toulouse museum and the *Pilier des Nautes* of the National Medieval Museum, that the material protection criterion prevails.

But current criteria are not satisfactory, because laser is chosen only when other methods cannot be. It would certainly be of interest to systematically perform laser tests when tests have been carried out with other methods (wet techniques, microblasting, etc.). Laser is turned down because of the cost and implementation difficulties: self-employed restorers cannot afford to rent equipment solely for tests. We therefore have to question our current methods. C2RMF is currently considering the purchase of a unit that would be made available to restorers in the Ateliers de Flore (inside the Louvre museum) and would ensure better methodology. The question remains, however, of the point from which we are ready to accept the laser option, even if we do not fully understand all the phenomena induced.

#### 4.2. The methodological mix issue

It has sometimes been proposed to modulate the visual results obtained with laser by applying other cleansing methods (microabrasion or wet methods). Comparative studies conducted, in particular, by the Laboratoire de Recherche des Monuments Historiques clearly demonstrated how microscopic observations of the stone upper layer argued for laser. If it is chosen, it thus appears that supplementation by microabrasion or wet methods is ruled out. However, with particularly thick black scabs, and only when the stone can withstand it without prior consolidation, microabrasion could help reduce the thickness of black crusts and perhaps reduce the effects of partial redeposition and alteration.

Likewise, using wet methods to reduce the yellow aspect after laser treatment appears hardly acceptable when laser was chosen specifically to avoid additional humidity and ensure the utmost preservation of the skin. When using swabs is compatible with the condition of the stone, they might be used, but only subject to the material removed being analysed (gypsum or partially redeposited dirt).

## 5. Conclusion: questions and prospects

Even if phenomena involving stone are beginning to be better understood, unresolved issues still bar the use of laser in museums.

### 5.1. Stone

It has been admitted, following the work of V. Vergès-Belmin, G. Oriol and P. Bromblet, in particular, that the yellow aspect seen on stone after laser cleaning is mainly due to the transformation of the stone superficial layers (or epigenic layer containing hydrosoluble organic compounds and iron oxides and oxalates, although these cannot be called a “patina”, a term that carries a different meaning in art history [9–11]). But does it explain everything? All the interactions that occur during laser ablation have yet to be identified. What of the issue of possible redeposition and its consequences? It will be a major parameter to be considered for the choice of method (because it is linked to the integrity of the piece), for the necessary refining of tests and for studying processes that would permit reduction of that effect.

### 5.2. The plaster problem

In the case of plaster, whereby a yellow aspect is obtained after artificial spoilage and laser cleansing, the explanations that may possibly be valid for stone do not apply. With the current state of knowledge, we recommend ruling out that method with plasters (see the experiments conducted by Jean Délivré in Douai on *L'Amérique du Sud* by Houssin [12], and Anne Liégey with tests). It could be envisaged that C2RMF could initiate a study on the subject, because plaster pieces constitute about 30–50% of the sculpture collections in French museums.

### 5.3. Understanding interactions with polychromies

Using laser on polychromatic sculpture is out of the question. There is no need to elaborate on that decision, which has been generally accepted and will stand for as long as the optical alteration phenomenon has not been understood and controlled. Arrangements could be made in extreme cases where the piece would be endangered by other methods and would retain minute traces that have been accurately mapped in a highly sophisticated previous study by a restorer. Those traces would then be “avoided” during cleaning operations; but such a trade-off would be best avoided if possible.

The diversity of surface aspects obtained in the above cases leaves us wondering. In the case of *La Daurade*, the relief surface, beneath dirt, displayed some yellow–brown

discolouration, even reddish-brown. The Amiens consoles<sup>8</sup>, evenly coated with sometimes very thick black crusts, now evenly display that strong caramel colour. On the *Pilier*, various aspects can be seen within the same block, which reflect the heterogeneity noted before processing. It is now acceptable to speak of the various “yellow aspects” rather than “yellow discolouration”, although it would be interesting to understand which parameters make those colour nuances vary. But they do not vary only according to the type of stone, and the colouration degree and the type of dirt appear to be linked. Colour enhancement beneath thick black crusts is not inherent to the laser method (e.g., it is also seen on marbles, beneath black scabs treated by microabrasion, see James Pradier, *Prométhée enchaîné*, 1827, Louvre<sup>9</sup>, as well as by laser, see Pierre Lepautre, *Aria et Poetus*, 1691, Louvre, Département des sculptures [13]). Other hypotheses like material impregnation by various substances can sometimes be verified: in Toulouse, the analysis performed by S. Pagès for the *Reliefs de la Daurade* revealed the existence of a coloured preparation that accounted for that aspect, which was not sensitively modified by laser cleaning [14]. But with the *Pilier des Nautes*, nothing like that could be evidenced (unmoulding agent?) in the brownish areas noted before and after treatment, and tests did not detect any oxalates (uncompleted studies; additional analyses planned).

### 5.4. Visual uniformity, or the “laser aspect”

Beyond the colour difference between a piece processed by the wet method and one that is laser-cleansed, the excessive evenness produced by laser is, in some curators’ opinion, perceived as hampering proper reading of sculpted volumes, which appear flattened (no aspect difference is seen between crack planes and a preserved skin area).

### 5.5. The dot effect

A criticism sometimes worded is that of the dot effect. A halo effect sometimes occurs around the point of impact, not easily corrected on subsequent passages because the contrast between the halo and the stone is no longer sharp enough. That phenomenon could depend on the impact diameter. Studying this specific point could lead to recommendations on the choice of material and on the specification of an optimal laser beam.

### 5.6. Prospects

In museums, laser cleaning has so far been reserved for particularly delicate pieces—for which the yellow aspect is acceptable as a minor drawback in relation to the risks

<sup>8</sup> Musée de Picardie, curators M. Pinette and F. Lemoux; consoles with animal figures, XIIIth century, inv. MP 997.4 (1–9).

<sup>9</sup> Département des sculptures; restored by H. Susini, 2001.

carried by other methods. But trials carried out on the *Pilier des Nautes*, although they raised many questions and led to the prescription of more constraining preparatory steps, also warranted better understanding of the technique: the quality approach proposed by restorers (stages and tests) provided an opportunity to validate procedures of reference. Tests tended to indicate that the use of laser could be more subtly modulated and that the technique allows for some flexibility in cleaning levels, at least equal to that of other methods.

In that context, new light was also shed on the growing interest in dirt mark studies<sup>10</sup> and in the issue of stone epigenic layer preservation [15]. But it appears that museum stone collections were not cleansed as much as previously thought in the XIXth century, or at least not systematically, but instead were repainted or whitewashed (as in the musée Guimet in Paris and the musée des Augustins in Toulouse [16]). Stone collections in museums, put away before industrial pollution, are therefore an outstanding source of data in that respect, and one that is rather well preserved.

By feedback from these two issues, understanding the phenomena induced by laser should lead us to reassess in a more critical perspective the effects induced by each cleansing method. The methodological choice (microabrasion, wet method or laser) may determine marked differences in aspect, raising the question: how can we remedy that? This interrogation is a reminder that any restoration is above all a historical intervention that modifies the aspect of a piece from what it was before. This can only warrant increased prudence before (more sophisticated prior studies; more stringent conditions to be met) and during (more systematic control procedures) processing.

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<sup>10</sup> For example, studies on dust, which were quite developed in Anglo-Saxon countries in the 1980s; see the ongoing study at the musée national du Château de Versailles by Marie-José Solé and Dominique de Reyer, followed up by Maria-Anne Privat-Savigny.