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Lasers in the Conservation of Artworks

LACONA VI Proceedings,
Vienna, Austria, Sept. 21–25, 2005

With 419 Figures
Preface

Conservation and protection of works of art as well as of rare remnants of natural history has turned more and more into a race against time. Environments all over the world have become increasingly aggressive causing damage or at least deterioration to surfaces meant to be created for eternity. Conventional techniques do a lot against most of these dangers, but new approaches of high technology have to be explored to preserve the heritage of human civilization as well as the precious specimens of former life such as the feathers’ of birds which died out generations ago.

Mechanical and chemical methods are involved in traditional conservation treatments. Contactless cleaning by lasers, on the other hand, is a new and prospering field of laser materials processing. It allows avoiding mechanical disruption and the disadvantage of cleaning fluids – may they be toxic or just water – which could cause potentially long-term degradation of the substrate or health hazards. Moreover, laser cleaning may have the potential to accelerate conservatory work with high quality and moderate costs, and, thus, may help archives’, museums’ and collections’ strained budgets.

Laser cleaning in semiconductor, automotive and aerospace industries has already been motivated by cost-savings, yield enhancement, and environmental concerns so that substantial literature about laser processing and cleaning of technical surfaces has accumulated in scientific and technological journals in recent years. This wealth of knowledge and experience, however, is usually not accessible to the conservation, museum, and archiving community. Therefore, the series of the “International Conferences on Lasers in the Conservation of Artworks” – LACONA – was initiated by Costas Fotakis organizing LACONA I 1995 in Heraklion, Greece. This was followed by LACONA II 1997 in Liverpool, Great Britain, LACONA III 1999 in Florence, Italy, LACONA IV 2001 in Paris, France, and LACONA V 2003 in Osnabrück, Germany. The success of these unique conferences motivated the LACONA Permanent Scientific Committee to organize a LACONA VI – this time in the very heart of Europe, in Vienna, Austria.
The general development in laser conservation has led to the observation that scientific approaches and diagnostics have been introduced in an extent as never before in conservation. The key issues of the state of the art and future developments of laser cleaning of artefacts turned out to be as sketched in the following.

**Paradigm Change of Conservation.** Laser cleaning applies highly localized deposition of heat by a laser beam in contrast to traditional conservation involving both room-temperature mechanical and chemical methods.

**Advanced Chemical Analysis and Diagnostics.** In addition to the inspection by the conservator’s eye, micromorphological and spectroscopic methods are increasingly employed.

**Inhomogeneity and Precision.** The high-precision deliverance of laser radiation to morphologically and chemically inhomogeneous artefact surfaces allows an unprecedented treatment quality.

**Integration.** Merging laser cleaning with complementary conventional restoration steps may provide unrivalled solutions.

**Automation.** Laser precision processing can be highly automated allowing better precision, safety and cost-effectiveness in the future.

The 6th International Conference on Lasers in the Conservation of Artworks (LACONA VI) took place in Vienna, Austria, 21–25 September 2005. It represented the above listed new developments which entered the present proceedings volume.

Moreover, LACONA VI ran under the auspices of the United Nations endorsed “World Year of Physics 2005” initiative which started by the European Physical Society to demonstrate that natural sciences provide a significant basis for the development of understanding nature, and that scientific research and its applications are a major driving force to scientific and technological development, and remain a vital factor in addressing the challenges of the 21st century. The “World Year of Physics 2005” highlighted the vitality of natural science and its importance in the coming millennium, and will commemorate the pioneering contributions of Albert Einstein in 1905.

I want to thank Johann Nimmrichter, Chairman, and Manfred Schreiner, Co-Chairman of LACONA VI, for their unmatched enthusiasm and dedication to make LACONA VI a success. Further there has to be mentioned the invaluable support by the LACONA Permanent Scientific Committee, the LACONA Local Organizers (public institutions in Vienna), the LACONA Local Congress Committee, and last not least the LACONA Sponsors.

Finally, I would like to thank Robert Linke and Ed Teppo for their careful and generous support during the preparation of the proceedings of LACONA VI.

Vienna, May 2007

Wolfgang Kautek
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Summary. Laser divestment entered the field of art conservation through a nonlinear sequence of positive accidental events (serendipity) that involved the cinema industry, the invention of spread-spectrum and frequency-hopping communications, nuclear space propulsion, and oceanography. The unlikely chain of events began with the invention of a secure military communications system by a Viennese motion picture actress (1942). A first evaluation of the novel communications concept took place during a high-altitude nuclear test (TEAK) over the Pacific Ocean in 1958. The secure radio link proved to be a failure; however, analyses of the backscattered electromagnetic radiation contributed to the realization that nuclear-explosion plasmas need not be spherically symmetrical. Nobel Laureate Freeman Dyson exploited this nuclear option to guide in the design and prototype development of the ORION spaceship that was to rendezvous with the planet Saturn in 1970. For this space vehicle the high-specific-impulse nuclear propulsion was generated by means of superradiant X-ray-beam ablation of the spaceship’s rear surface by the remote detonation of a sequence of asymmetrical bombs projected rearward from the ORION. In the wake of the Nuclear Test Ban Treaty (1962) ORION was canceled. Through a Scripps Institution of Oceanography project in Venice (involving ORION scientists and holographic technology) the nondestructive radiation-ablation process found a resurrection in the field of stone conservation (1972). Ironically, the first major art-conservation project to employ laser ablation (Porta della Carta of the Palazzo Ducale) was paid for in part by Warner Brothers Motion Picture Studios (1980). Finally, the “Venice Laser Statue Cleaner” followed the Viennese actress (Hedy Lamarr/Hedwig Eva Maria Kiesler) to Hollywood where it was employed to treat the granite veneer of the Warner Center (1981).

1.1 Introduction

The fields of art conservation and laser science merged, formally and fittingly, in the land of Polyclitus and Democritus with a 1995 event now called LACONA I (held at FORTH). However, appropriate that symbolic recognition of the sources of Western cultural heritage may seem, LACONA VI has, in Vienna, returned to the direct technological genesis of lasers in the service
of art. The implausible trajectory of “unintended consequences” that led to the introduction of laser technology into art conservation was triggered in 1941–1942 when Viennese cinema actress Hedy Lamarr invented a novel (jamming proof) concept for the radio transmission of guidance information to naval torpedoes.

Subsequent decades witnessed initial evaluations of the Lamarr modulation schemes that helped uncover new avenues in nuclear weapons design as well as in the invention of the nuclear-propelled spaceship (ORION). Subsequently, the holographic plasma diagnostics developed for the engineering design of the spaceship were applied to the in situ archival recording of deteriorating Venetian statuary. This, in turn, led to the improbable realization that the radiation-propulsion mechanism of ORION could provide a means of self-limiting divestment (and conservation) of crumbling marble statues.

The series of “connections” and happy accidents that helped in bringing about LACONA VI are summarized in the paragraphs that follow.

1.2 Hedy Lamarr and Her Communications Patent

In 1942 Viennese motion picture actress Hedy Lamarr (Figs. 1.1 and 1.2) (Hedwig Eva Maria Kiesler) of MGM was granted US Patent #2,292,387 for a “Secret Communication System” based on her invention of spread-spectrum (Figs. 1.3 and 1.4) and frequency-hopping concepts. Evidently, the idea was a merging of art and science in that it sprang from her knowledge of the military business of her husband, Fritz Mandl, and her understanding of the player piano (gained from her friendship with artist George Antheil). As her discovery formed the basis of cell phone technology, Wi-Fi protocols, and the wireless Internet, she won a US$1/4M infringement claim against Corel Corporation and received the 1997 Electronic Frontier Award. (Upon receiving the award, 55 years after the fact, her response, “It’s about time,” received almost as much notice as her “au naturel” appearance in the 1933 Czech film, “Ecstasy.”)

Fig. 1.1. MGM motion picture star Hedy Lamarr
Fig. 1.2. The first page of Hedy Lamarr’s 1942 patent, “A Secret Communication System,” that introduced the frequency-hopping and spread-spectrum concepts to the communications field.

Fig. 1.3. Spread-spectrum communication link of Project ARGUS during the high-altitude nuclear detonation, TEAK (inset).

Fig. 1.4. The receiver site on the island of Niihau, Hawaii.

The first evaluation of Hedy Lamar’s approach to secure communications was carried out between Hawaiian Pacific Islands in 1958 during the Johnston Island high-altitude nuclear explosion TEAK (3.8 MT at 77 km altitude). Disappointingly, the experimental radio-wave transmission link was completely blacked out by the bomb’s gamma-ray-induced aurora. However, spectral
analyses of the backscattered electromagnetic signal revealed that the H-bomb had, through a performance asymmetry, ejected a plasma jet.

1.3 Orion: Nuclear Spaceship

The ARGUS backscatter data together with other theoretical and experimental results predicted that nuclear explosive devices possessed the potential for being redesigned into directed-energy radiation sources. Upon this realization, members of the TEAK team joined with theoretical physicist Freeman Dyson and virtuoso minibomb designer Theodore Taylor to exploit and optimize this phenomenon in order to develop a nuclear-propelled spaceship, ORION, for a mission to the planet Saturn (scheduled for 1970). Following a first ORION test flight (1962), the adoption of the Nuclear Test Ban Treaty led to the demise of the program. Figures 1.5–1.7 display a few of the test results of laboratory proof-of-principle ORION technology demonstrations that reveal the impulse delivered by laser ablation.

Fig. 1.5. Deformation of a restrained metallic coin through the impulse delivered by laser ablation pressure at a multigigawatt and kilojoule level

Fig. 1.6. A streak camera record of the laser propulsion of an unrestrained metallic disk to $V = 20 \text{ km s}^{-1}$
Fig. 1.7. Hypervelocity impact crater (and its cross section) produced by the energy released by a laser-propelled projectile

Fig. 1.8. A conceptual portrayal of a nuclear-driven ORION spaceship

Figure 1.8 presents a conceptual rendering of the ORION space vehicle near Mars.

1.4 Laser Divestment in Venice

The real-time holographic diagnostics developed for ORION were resurrected for art-conservation purposes in Venice in January 1972. This was a consequence of a collaboration of Scripps Institution of Oceanography geophysicists and ORION project alumni in research directed toward the alleviation of the “acqua alta” problem being experienced by the lagoon. By March 1972 the ruby holographic laser was being employed to clean marble sculpture by means of radiation-induced ablation in accordance with results from the radiation-hydrodynamic modeling of the earlier X-ray-beam nuclear-propulsion system (Fig. 1.9). This came about at the suggestion of Lorenzo Lazzarini and Giulia Musumeci of the Venetian Soprintendenza in response to the unacceptable cleaning results on friable stone with conventional air-abrasive and chemical approaches (Fig. 1.10).