Application Report:

EXCIMER LASER CLEANING FOR SENSITIVE SURFACES

This panel painting, from a small pilgrim chapel (Chapel of the Holy Mary of Genooy) in the south of the Netherlands was completely covered in soot. The soot was removed with the UV laser cleaning set-up of Art Innovation, without damaging the underlying varnish layer and revealing the illustration of the Entomb-ment of Christ". The laser cleaning was supervised by the SRAL (Stichting Restauratie Atelier Limburg).

ExciStar

Small Investment - Big Performance

Why Excimer Laser?

- Short wavelength fundamental (248 nm)
- No risk of damaging sensible surfaces (cold ablation process)
- Dry and contactless cleaning

Why Coherent's ExciStar?

- High and variable repetition rates
- Short pulse duration
- High pulse intensity
- Homogeneous beam profile
- Flexible and mobile laser
- Compact size
- User-friendly handling
- Repeatable results

Ongoing advances in excimer laser technology have borne a new generation of high repetition rate ultraviolet (UV) lasers that offer superior performance and lend themselves to a host of cleaning operations.

Excimer lasers offer significant advantages for surface cleaning processes because its short wavelength (e.g. 248 nm) can be focused to a smaller spot size than visible or infrared light. The UV light is very precise, with each pulse able to remove 0.25 microns of dirty material. In comparison: A human hair is about 50 - 100 microns thick.

Unlike some other laser types, excimer lasers do not create a great deal of heat, limiting the possibility of thermal damage to surrounding material. These attributes make excimer lasers well-suited for cleaning processes.

Why ExciStar? Features and Benefits

An important concern for real applications is the processing time or velocity. In general, the time need has to be reduced as much as possible.

Compared with a high power stand-alone this working velocity compensates the limitations by beam dimensions of only 3 times 6 mm^2 FWHM and likewise the pulse energy of maximum 15 mJ and makes a fast application possible.

Shipped in a compact casing it is suited espe-cially for realizing a mobile application system to clean objects just where they are located. This results in a user-friendly handling which enhances the acceptance for art restoration in principle.

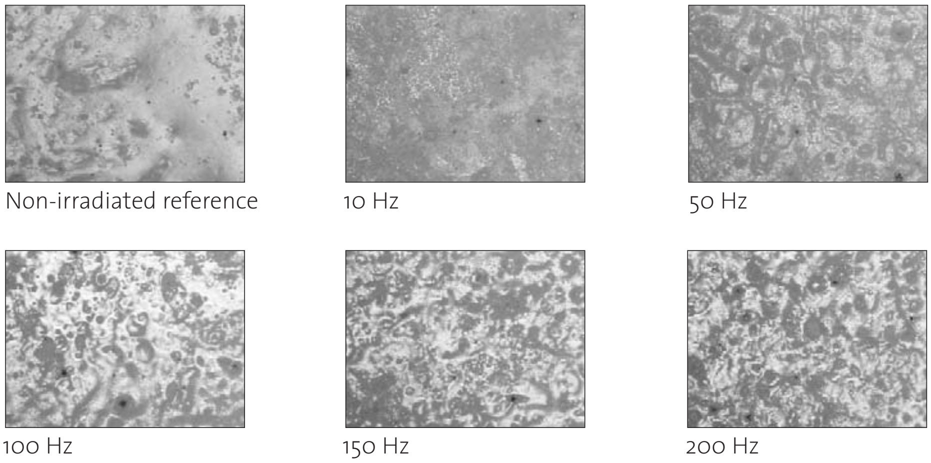
1. STUDIES OF THE F.O.R.T.H. TEAM

Excimer Laser Cleaning Byzantine Icon

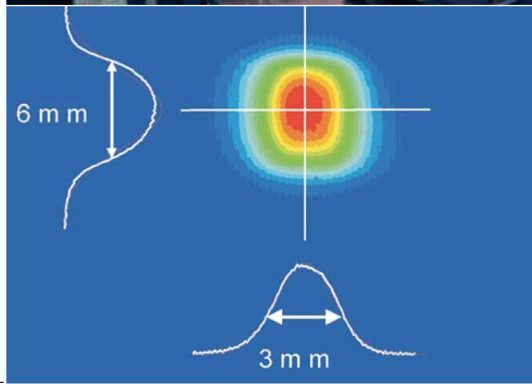
Background

Previous studies have shown that excimer lasers are an efficient and safe tool able to remove, in a controlled way, layers of a certain thickness from the surface of icons and paintings . Having this experience the I.E.S.L. – F.O.R.T.H. team in Heraklion, Crete, Greece has aimed to investigate the influence of combining high repetition rates with low laser fluences in optimizing of the cleaning process. Working close to the ablation threshold is expected to minimize any undesirable photochemical or photomechanical effects and mild thermal effects due to the high repetition rates may exhibit some advantages.

The Coherent ExciStar system offers a wide range of repetition rate settings and a reliable beam profile as well as a portable and practical size and therefore it is a versatile alternative to the systems used so far for this application.



50 Pulses @ F= 0.09 J/cm²
Spot Size= 0.14 * 1.2 mm², Overlapping in Y-Axis: 80%



Preliminary Studies

In order to determine the optimum cleaning result it was necessary to investigate the parameters on model samples. The studied samples, prepared by the National Gallery of Athens conservation team, simulate the typical stratigraphy of a Byzantine icon (wooden primer preparation, pigment layer and varnish).

They bare a quite homogeneous layer of varnish (20-30 μm in thickness). The samples have been aged into an artificial ageing chamber for 12 weeks. In this work it was chosen to study the varnishes Dammar and Mastich of Chios, which are commonly used on Byzantine icons.

Following preliminary ablation studies, a fluence (0.18 J/cm²) that lies below the cleaning threshold (0.20 J/cm²) was chosen to study the effect of variable repetition rates on the studied varnishes. A series of tests on a variable number of pulses (10, 20, 50, 75, 100, 200) and variable repetition rate settings (1, 10, 20, 50 100, 150, 200 Hz) were performed and the result was initially evaluated by means of optical microscopy.

It was shown that 50 pulses is a reliable number to proceed with the scanning of larger areas, which would give visual results of the actual cleaning process.

The images on the front were taken under the optical microscope and show the surface morphology of areas irradiated with 50 pulses of 0.09 J/cm2 (80% overlapping in the y-axis) in various repetition rates. A very interesting observation is that in high repetition rates (>100 Hz) no satisfactory cleaning could be obtained. Instead the morphology of the surface implies extensive "bubble" formation.

A longer period of investigation is proposed to ascertain the best possible parameter optimisation of the system (spot size vs energy density vs repetition rate) to achieve best cleaning speed.

2. STUDIES AT THE HELMUT-SCHMIDT-UNIVERSITY, HAMBURG

Excimer Laser Scanning Device for Sensitive Surface Cleaning

Background

Automated, non-polluting cleaning devices are of rapidly growing interest in science and industry. Particularly laser cleaning units avoiding wet chemical reactions and by this significantly reducing environmental contamination have proven successfully and found many new applications.

Most of these laser cleaning units are designed to completely remove the top layer of a surface or the surface itself, e.g. removing paint as a preparatory step for a new sealing of the surface (see aeroplane or car industry). In these cases it is important to make sure that no remaining lacquer is left. Likewise this applies to the cleaning of stone facades, antiques or other objects suffering from dust and environmental impacts.

Lasers, however, offer additional significant advantages compared to conventional cleaning mechanisms:

- So, soft and sensitive surfaces like paint or pla stics may be treated to ablate a few micrometers of the upper layer together withsome adherent impurities without destroying the protecting function of the layer or the underlying structure.

- In semiconductor epitaxy or optical coating fabrication substrates can be irradited to remove monolayers of water or oxygen from the surface even under ultrahigh vacuum conditions.

- Toxic chemicals or hazardous bacteria sticking at the surface can be cracked and vaporised to sterilise instruments or

- lasers can be used to decontaminate some equipment which was radioactively contaminted.

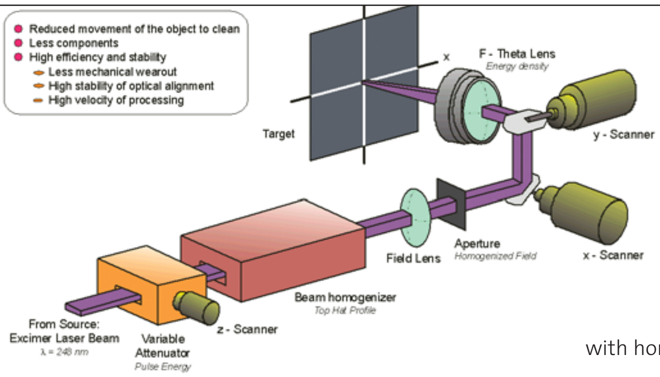


Fig. 1:
Galvanometric scanner
with homogenizer and attenuator

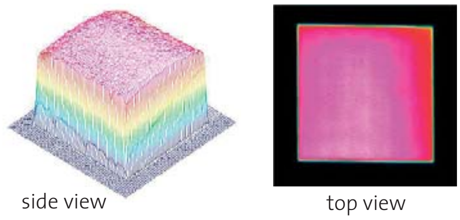


Fig 2:
Homogenized beam profile for cleaning

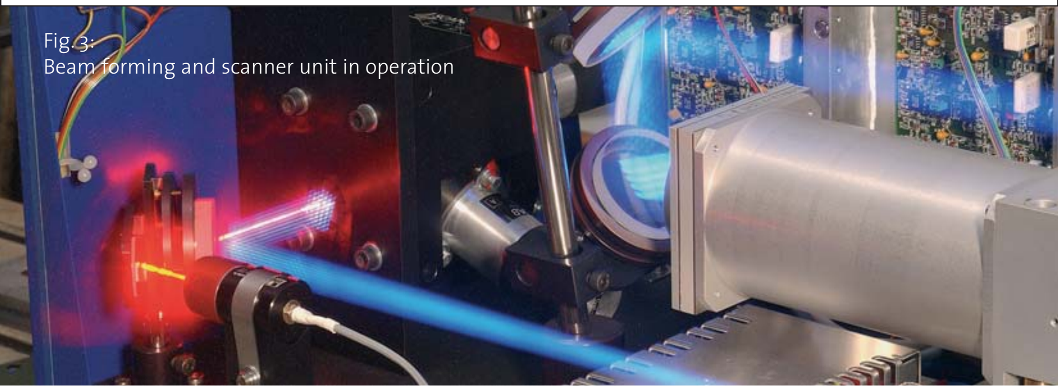
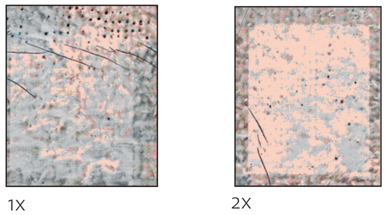


Fig. 3:
Beam forming and scanner unit in operation



(number of pulses @ position)

Fig. 4:
Extracts of laser cleaned oil painting.
The Fluence is F = 350 mJ/cm² and the spot size = 2 x 2 mm²

Actual Studies

Scientists at the Helmut-Schmidt-University (University of the Federal Armed Forces) in Hamburg developed a laser cleaning unit designed for an automated processing and cleaning of contaminated samples. Particularly dust, chemicals or radioactive isotopes sticking at varnish, lacquer or plastic sealing are cleared away together with a few ns thin film of the surface without destroying the sealing itself.

While for complete removal of a sealing it may be favorable when the laser radiation penetrates into deeper layers and causes some depth effect, ablation of only a thin film requires deposition of the laser energy in the top layer of the surface. This is best realized with lasers operating in the UV, where paint and plastics show significantly increasing absorption. Therefore the laser-group in Hamburg is working with a KrF-excimer laser.

The key element of the cleaning device is a beam forming and scanning unit (Fig. 1). To improve the laser beam quality for homogeneous irradiation of samples, a beam homogenizer was developed which forms a rectangular cross section with top-hat beam profile (see Fig. 2). The beam is focused down to 2x2 mm² and directed across the polluted surface by a beam scanner which uses two galvo mirrors. The scanning rate and by this the deflection of the beam is adapted to the pulse repetition rate and therefore allows an extremely fast automated processing.

An accurately controlled beam positioning together with the top-hat profile ensures a very homogeneous, uniform and reliable irradiation of each surface element with an almost identical laser fluence.

Preliminary investigations with this prototype show, that after optimising the relevant laser parameters like pulse energy, peak intensity, laser repetition rate, number of pulses and beam profile, an efficient cleaning without damage of the surface is obtained. A computer- controlled operation of the system guarantees the uniform and continuous cleaning as well as a comfortable handling. The unit is equipped with an adapted suction nozzle to dispose the detached particles from the surface.

To quantify the cleaning efficiency and to proof the applicability of laser cleaning even for radioactively contaminated samples the scientists prepared varnished plastic plates contaminated with ^{151}Eu at the surface. ^{151}Eu is favorably used as contaminating test material, since under normal conditions it is not radioactive but can be activated well-aimed by neutron radiation to a metastable configuration with a half-life of 9.5 h. Therefore, any handling of the plates during preparation and cleaning can be done without danger of radioactivity. The laser cleaning efficiency is determined by measuring the radioactivity of the plates before and after laser irradiation. The researchers find that with a fluence of 1 J/cm² only one or two pulses per position arenecessary to bring the initial contamination level down to less than 5%. The same set-up can also be used for cleaning of art paintings and restoration of antiques. The scanner unit, as seen in Fig. 3, directs the excimer laser radiation onto the painting and sweeps the beam across an area of 6 x 10 cm². For processing of larger areas the painting can be shifted automatically by stepper motor controlled displace units.

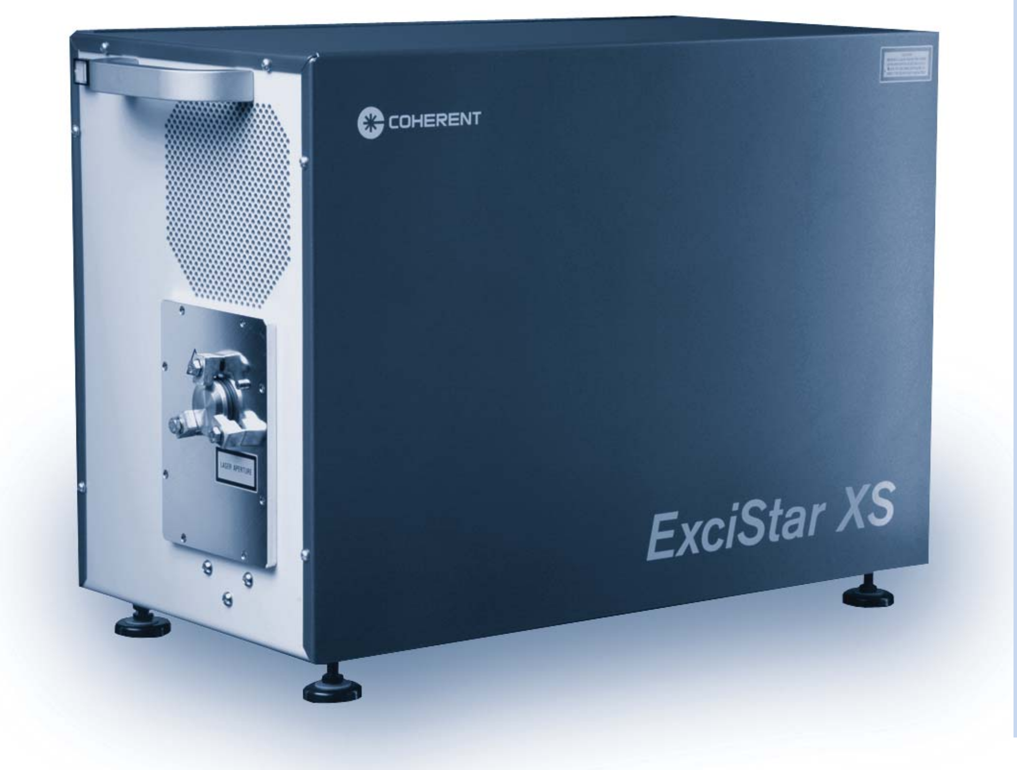
Fig. 4 shows a small section of an oil painting irradiated with different concentrations (pulses per position). This example demonstrates the well controllable, homogeneous treatment and the effiency of excimer laser cleaning of art objects. It results in an appealing and bright appearance of the processed area and shows the auspicious potential for future excimer laser cleaning applications.

COOPERATION

Art Innovation uses Coherent's ExciStar XS

Art Innovation provides innovative products and services for the international field of conservation of cultural heritage. The company operates as a trendsetter in the conservation industry by developing and producing valuable tools for conservators and restorers. The collaboration with leading conservators and research institutes ensures the development of customer-led solutions.

As a member of the Demcon Group, Art Innovation is supported by a large multidisciplinary team of engineers combining expertise and experience in the fields of mechatronics, mechanics, software, electronics, lasers & optics and industrial design. The availability of a micro-assembly workshop and sophisticated production facilities enables Art Innovation to cover all aspects of product development from design through production to servicing and maintenance."



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