Lasers in Art Conservation. State of the Art on the Fundamental Research and the Applications carried out at FORTH-IESL

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1. ABSTRACT

There is a number of laser material processing, spectroscopic and interferometric techniques, which have been adapted to the requirements in a variety of demanding conservation applications. Nowadays, a significant number of successful examples of laser cleaning and diagnostic applications of artworks and antiquities rely on the use of different types of lasers. Laser based diagnostic techniques are largely non-intrusive and appropriate for the in-situ analysis of composition and structural diagnosis of objects. In contrast, the intrusive character of laser cleaning is raising several challenging questions for its safe applications. Laser spectroscopic techniques, for the on line monitoring of the laser cleaning process together with fundamental studies for parameter optimization are critical in this respect. Selected examples will be given and the prospects and limitations of laser technology in art conservation will be discussed.

2. INTRODUCTION

There are several laser material processing, spectroscopic and holographic techniques, which have been used for the conservation, restoration and/or evaluation of painted artworks and sculpture [1-5]. These include cleaning and non-destructive analytical, diagnostic and authentication applications, which are now reaching an era of maturity. This applies particularly for diagnostic applications, which are non-destructive, they do not require sample preparation, and they can be used in situ and on-line. For laser cleaning, although there are several successful examples, further research aiming to define the limitations and prospects of relevant laser techniques is required. Of central importance in this respect, is the study of the short and long term effects, which laser irradiation may induce on the artworks. To this effect, fundamental studies in realistic or model systems, aiming to a better understanding of the thermal photochemical and photomechanical interactions involved and the optimization of laser parameters employed is important. It appears that a balanced interplay among the laser pulse duration, wavelength and fluence is critical, especially for demanding applications. The optimal choice of these parameters and the implementation of on line monitoring techniques is also crucial in laser cleaning applications. There is a range of effective control techniques, which rely on combinations of laser spectroscopy with imaging methods. These techniques are capable of monitoring the progress of the cleaning process, thus safeguarding from potential damages. In this work, selected examples of laser applications in art conservation will be presented and the prospects of these techniques will be overviewed.

3. Diagnostics of Artworks

3.1 Spectroscopic Techniques

Laser Induced Fluorescence (LIF), Laser Induced Breakdown Spectroscopy (LIBS) and Laser Raman Spectroscopy have been extensively used not only for the analysis of pigments and

binding media of artworks but also for determining the degree of ageing and oxidation or polymerization processes, which take place [6- 10]. Nowadays there are available portable workstations incorporating these techniques, which are capable for in situ analysis, without the need of separate sampling. In particular, LIBS presents several interesting possibilities for elemental and in-depth analysis. As it has been demonstrated, LIBS may be combined with cleaning applications, using lasers or other conventional means, for monitoring and controlling the cleaning process [11- 12]. Multispectral imaging techniques are also interesting along these lines since depending on the wavelength region used, information may be obtained about the surface texture and interventions (reflectography in the ultraviolet), pigment composition (fluorescence in the visible and near infrared) and the content of underlying layers (reflectography in the infrared) [13- 16].

3.2 Interferometric Techniques

Different schemes of interferometric techniques, including double exposure holographic interferometry have been applied for the determination of a full topographic map of hidden defects on the surface or bulk of artworks [5, 17- 19]. These techniques offer high sensitivity in both out-of-plane and in-plane surface displacements with a resolution of about a micrometer. Such studies are important for the assessment of existing defects by more than 10 mm under the surface layer. Also these techniques are useful for the assessment of potential damages induced in the bulk of artworks due to the environment they are stored or the conditions prevailing during their transport.

4. Laser Cleaning

Laser cleaning is an intrusive technique, which must be combined with on line control techniques (imaging or spectroscopic) for ensuring the absence of any damages. A balanced interplay of the laser and material parameters involved is critical for the success of the laser cleaning. Nowadays, there are available several types of commercial laser cleaning workstations [20]. There are also many successful demonstrations of laser cleaning of different types of stone [21, 22] and painted artworks [23, 24]. In the former case the simultaneous use of infrared and ultraviolet wavelengths, has been proven optimal in several applications [25- 28]. The cleaning of painted artworks is a more delicate application, requiring a detailed study of the thermal, photochemical and photomechanical effects induced [29-34]. Detailed studies in model systems representing sensitive conservation cases have been carried out for estimating the relative importance of these processes and optimizing the laser parameters to be employed [35, 36]. As a general conclusion, it could be stated that the success of any laser cleaning application relies on the degree of confinement of the thermal, mechanical and chemical effects, which operate for the removal of the undesired layers.

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