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SHORT COMMUNICATION

LIMIT OF Nd:YAG LASER APPLICATION IN ARTWORK RESTAURATION

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Cleaning of artwork against biological agents by using modern technical tools, as e.g. laser removal of fungal colonies is not successful in all the cases. It is shown that the Nd:Yag laser irradiation at usual fluencies is not efficient in stopping the biological degradation by several agents as e.g. Penicillium sp., Cladosporium sp., Chaetomium sp., Alternaria sp., but contrarily, a stimulated growth of colonies of contaminants is produced.

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The cleaning of artworks by laser irradiation is a modern technique with many practical advantages (precision, rapidity, local action, etc...). The greatest part of the studies dedicated to laser cleaning is focused on the equipment development and cleaning procedures, including the researches on the quality of the remained particles and surfaces [1]. The main problems in the case of the biological degradation of the artwork is the complete elimination of the biological agents and the killing efficiency of the laser radiation.

In this short communication we try to demonstrate that Nd:YAG laser radiation with usual fluence does not kill and remove the fungal colonies but, contrarily, it can produce a stimulated growth of the *fungi*.

For cleaning tests the experimental set-up includes a pulsed Nd:YAG laser emitting on 1064 nm wavelength, operating on an optical microscope [2], and provided with a IBM PC compatible video capture system. The laser pulse length is 10 ns. Laser pulse is visualized and its fluence is automatically calculated by a SPIRICON Laser Beam Analyzer LBA 300. The equipment gives the possibility to select the working laser fluence regime. In our experiments a fluence regime of 0.8 J/cm^2 and a laser spot of 50 um diameter was used. The laser spot stability was better than 10 % (for 200 laser pulses). Some samples were irradiated in a softer regime: 0.2 J/cm^2 laser fluence and the spot diameter was 4 mm.

The following samples were used:

-disks of 4 mm in diameter with cultures of Penicillium sp., Cladosporium sp., Ulocladium sp., Chaetomium sp. and Alternaria sp. (Fig. 1). They were irradiated by various numbers of laser pulses: 10, 25, 50, 100, 200 500 and 1000.

-square marks (4 mm side) with cultures of the same fungi. They were irradiated by 10, 100, 500 and 1000 laser pulses.

-painting layer. This one was irradiated by 500 and 1000 laser pulses, respectively.

-painting layer on plaster. This sample was irradiated by 500 and 1000 laser pulses, respectively.

-square marks (4 diameter side) from mural painting. These marks were irradiated by 500 and 1000 laser pulses.

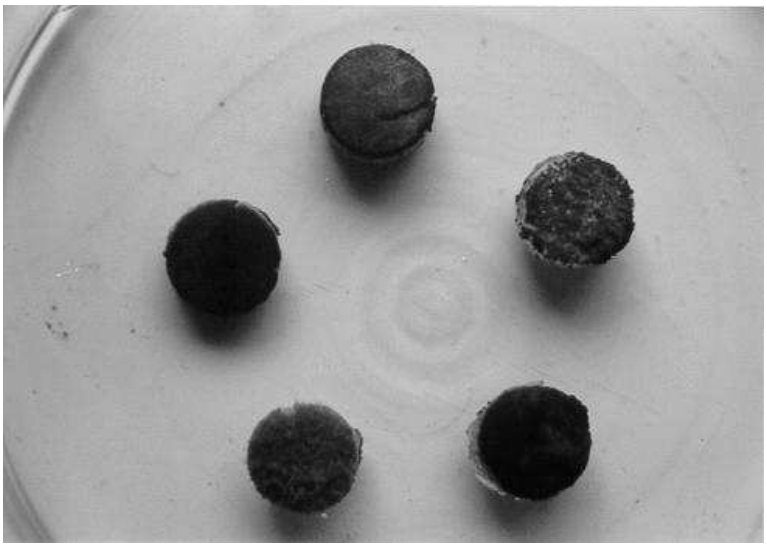

Fig. 1. Prepared samples for laser irradiation (e.g. *Penicillium sp.)*.

The samples of fungal cultures were extracted from the mural painting of "Casa cu Cerb" (Hose with Deer) from Sighisoara, one of the most important Romanian historical building included in the National Cultural Heritage.

The efficiency of the radiation procedure was appreciated in the mark method on nutritive medium, by growth of culture provided by viable spores. In the method of serial dilution of samples the efficiency of irradiation was appreciated by counting the units forming colonies on nutritive medium against control.

After irradiation, it was noticed a reduced lag phase and a high speed of germination process for all strains irradiated. In addition, after 48 hours, all cultures were sporulated, meaning a stimulation of growth as a result of irradiation (Fig. 2).

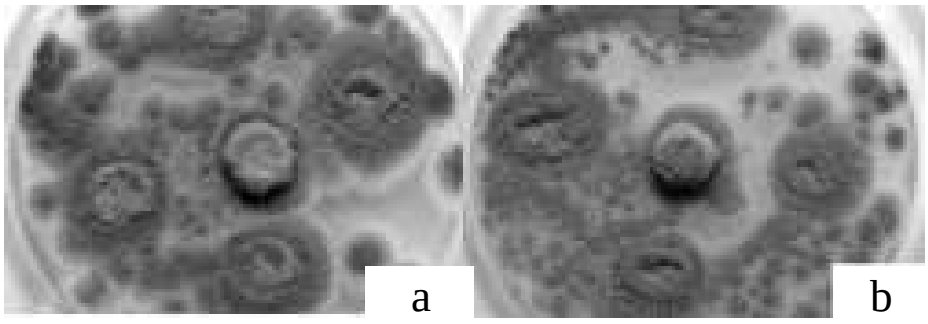

Fig. 2. Irradiated samples of *Penicillium sp. (a), Cladosporium sp. (b),* generated cultures with the same phenotype.

During irradiation the laser pulses spread spores on nearest surfaces and they could move from one place to another. As a proof, the Penicillium sp. developed colonies on medium inoculated with marks of Ulocladium sp. (Fig. 3).

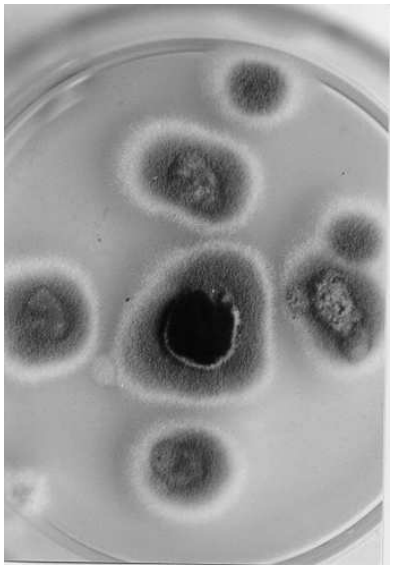

Fig. 3. *Penicillium sp.* and *Ulocladium sp*. developed colonies in the same medium.

In the case of adhesive band squares with the cultures of Alternaria sp., Ulocladium sp. and Chaetomium sp. the laser irradiation does not influence the viability of their spores. The units forming colonies shows the same values as the control sample (see Table 1).

Table 1. Fungal spore's viability after irradiation with various laser light fluencies.

Fungal strain	Number of laser pulses	Units forming colonies
Alternaria sp.	Control sample	12
	10	12
	100	9
	500	12
	1000	9
Ulocladium sp.	Control sample	65
	10	64
	100	65
	500	63
	1000	64
Chaetomium sp.	Control sample	29
	10	29
	100	28
	500	27
	1000	28

In the painting layer samples, the most frequently encountered biological agents were Chaetomium sp. and Penicillium sp. The irradiation by 500 and 1000 laser pulses did not changed the initial number of units forming colonies: 34. The same is true for the painting layers on plaster. After irradiation the number of units forming colonies remains unchanged: 40. The marks taken on adhesive band from painting layer exhibits a reduced number of units forming colonies: 11.

Cleaning tests using laser irradiation of adhesive band covered by spores of Chaetomium sp., Alternaria sp. and Cladosporium sp. have been performed with 2-10 laser pulses. Fungal spores are grouped in clusters. Depending of the size of the clusters an efficient cleaning is obtained with various number of laser pulses.

Our experiments have shown that Nd:YAG laser is efficient for cleaning the surfaces but not sure for killing the microbiological coverage. Thus, spores of Chaetomium sp. are removed with 2-4 laser pulses (Fig. 4).

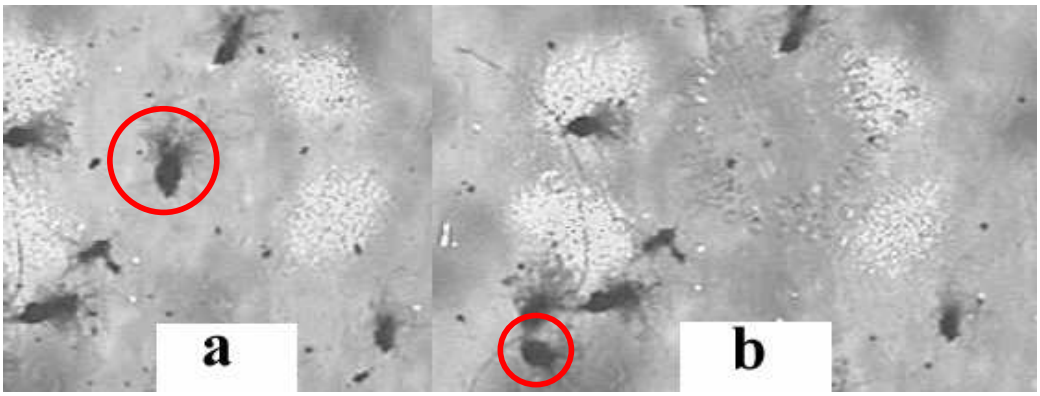

Fig. 4. Spores of *Chaetomium sp*.(a) have been slowly displaced by laser cleaning (b).

In the case of Alternaria sp. 5 –7 pulses are necessary. The spores of Cladosporium are very tiny and are arranged in big masses, and, as a consequence, a number of 10 pulses succeeds only to tear them into pieces.

The microbiological entities is generally considered as deleterious. In an adequate bioclimate (temperature, humidity, organic and inorganic compounds) they can develop rapidly and cover the mural paintings, plasters or cracks resulting in important damages of the artworks. In order to prevent the spore spreading the use of a vacuum pump is suggested.

To prevent spores spreading or hypha movement it is necessary to use a vacuum system during the laser cleaning treatment or an efficient biocide before this operation.

Irradiation by Nd:YAG laser pulses (with near infrared energy) of fungal cultures suposed to be the main biological agent for the attack of an artwork stmulates the growth of fungi and spread them out in the neighbouring surfaces. The number of colonies is not reduced. Nevertheless, it is possible to get a locally clean surface. In order to protect the cleaned surface against the spreading spores, an additional treatment with chemical substances, able to kill the spores, is suggested.

References

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