Antimatter, clockwork orange, laser divestment

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ABSTRACT

In 1972 Ente Nazionale Idrocarburi sponsored a program to holographically record the images of Venetian sculptural treasures for archival purposes. At Laboratorio San Gregorio, where the initial holography took place, G. Musumeci and K. Hempel suggested an experiment to determine whether the concentrated beam from the ruby holographic laser could ablate black-patina crusts from decaying marble. Initial success of a laser-divestment test on a Palazzo Ducale capital launched a search for funding to enable a full-scale laser-conservation demonstration. Later, at a Caltech reunion one of the author's physics professors (Carl Anderson, the discoverer of mu mesons and the positron), noting the prominence of the Venice Film Festival suggested our approaching the motion picture industry. Many years earlier Anderson's Caltech classmate, Frank Capra, had supported the research that led to the discovery of cosmic-ray-generated antimatter on Pikes Peak. (After Caltech, Capra had become a director at Columbia Studios.) Anderson's chance comment led to an introduction to producer Jack Warner at a festival screening of his "A Clockwork Orange" in Asolo. He and his friends contributed US$5000 toward the laser conservation of a marble relief of "The Last Supper" in the Porta della Carta of Venice. This work was conducted in 1980 under the direction of Arch. G. Calcagno. In 1981 it was found that the granite veneer or the newly completed Warner Center Tower had been stained during transit from the quarry. The Venice laser successfully restored the veneer, thereby returning the Warner Brothers' favor.

KEYWORDS: Art conservation, holography, laser cleaning, Venice, stone restoration, building conservation, granite

1. INTRODUCTION (HUMAN SPACEFLIGHT)

When technical preparations for human space flight were initiated almost 50 years ago, it was recognized that meteor impact on space vehicles could pose a safety hazard. Consequently, a spacecraft test facility that included a laser system for the production of terrestrial micrometeorites was established at the General Atomic (GA) Laboratory in La Jolla, California.

The laboratory meteorites received their acceleration through plasma-reaction pressure applied during rear-surface laser ablation. The beam from a three-stage Nd:glass oscillator/amplifier laser (100J/100ns) was focussed onto 100um beryllium disks. The magnitude of the impulse delivered by the laser is suggested by the deformation imposed upon a restrained coin (Figure 1). Figure 2 presents a sweep camera record of a 100um projectile being accelerated to a meteoric velocity (20km/s) [1]. In the GA meteorite facility the projectiles flew through vacuum for 10cm and then impinged upon spacecraft materials in order to characterize the meteorite impact damage hazard. A typical hypervelocity impact crater in aluminum is reproduced in Figure 3.

The laser-radiation optimization required to yield solid (rather than vaporized) projectiles relied upon extensive diagnostics of the radiation-hydrodynamics at the plasma/projectile interface. Puled ruby-laser holography proved to be the most valuable and helpful of the plasma diagnostic tools employed in the program. Figure 4 shows the reconstruction of a pulsed ruby-laser hologram (and a schlieren picture for comparison) of an electromagnetically accelerated plasma jet that shows the detail that is revealed with this technique.

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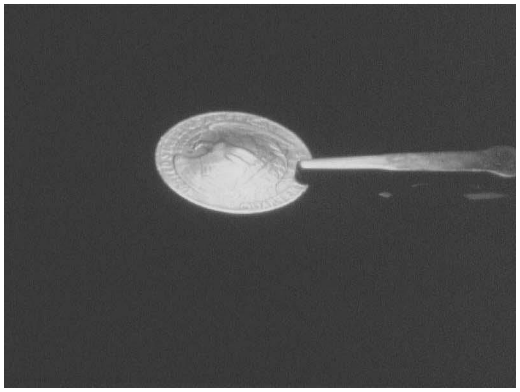

Fig. 1. Laser impulse applied to 25-cent coin.

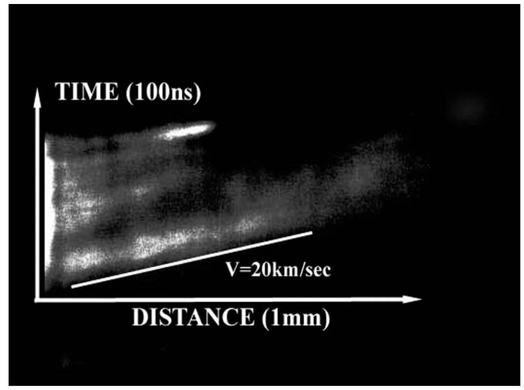

Fig. 2. Streak camera record of laser-propelled micrometeorite.

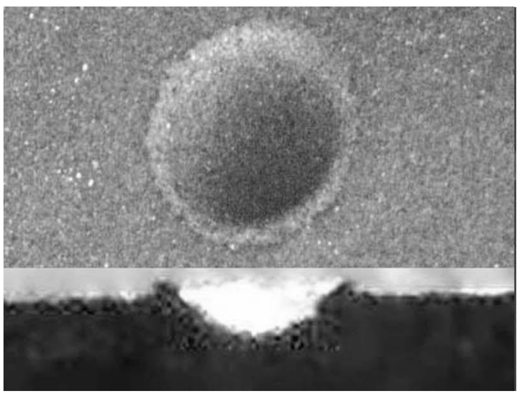

Fig. 3. Crater and crater section from laser micrometeorite.

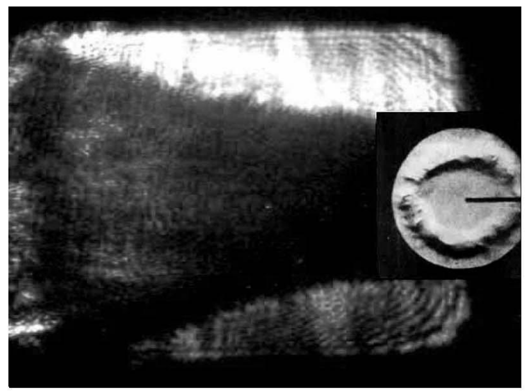

Fig. 4. Hologram and schlieren image of plasma jet.

The real time in-situ pulsed ruby laser holography was described at a UCSD symposium. Several geophysicists from the attached Scripps Institution of Oceanography attended the gathering. One of these was W. Munk (Director of the Institute of Geophysics and Planetary Physics). He had just returned from several weeks of consulting on an exchange program pertaining to the subsidence and flooding problems confronting Venice. He reasoned that it was now technically feasible to record three-dimensional diffraction-limited images of the deteriorating and crumbling marble sculpture of Venice for posterity. A few months later he returned to Venice armed with a proposal to perform a study to assess the feasibility of performing in-situ holography and holographic interferometry of large artworks.

2. HOLOGRAPHIC RECORDING OF VENETIAN SCULPTURE

In September 1971 a program was instituted to produce archival holograms of Venetian sculpture with funding support from Ente Nazionale Idrocarburi and the cooperation of Istituto Centrale del Retauro, the University of Rome, and CNR laboratories. Subjects included works by Donatello and Nino Pisano. Figure 5 shows the work in progress in San Gregorio with a ruby laser oscillator/amplifier and the holographic optical apparatus (January 1972). Holograms and holographic interferograms (to identify and map defects) were produced on 10cm and 20cm glass-substrate plates[2].

In March 1972 a Venetian restorer (G. Musumeci) suggested experimenting with the ruby oscillator-amplifier holographic laser as a possible tool for the cleaning of marble. She introduced her concern by demonstrating some of the problems associated with conventional chemical and air-abrasive stone cleaning (Figure 6). She also pointed out that several conservation teams had recently demonstrated state-of–the-art stone conservation technologies at one corner of Piazza San Marco (Figure 7). The work was evaluated by a team of UNESCO experts and it was determined that all of the methods were unsatisfactory for the conditions found at San Marco. Ms. Musumeci pointed out that, as a consequence, nothing was being done to either conserve or restore the stonework. Thus, in the absence of a new cleaning technique the stone deterioration would continue, unabated. In addition, the test-cleaned areas had been "repatinated" with black stucco.

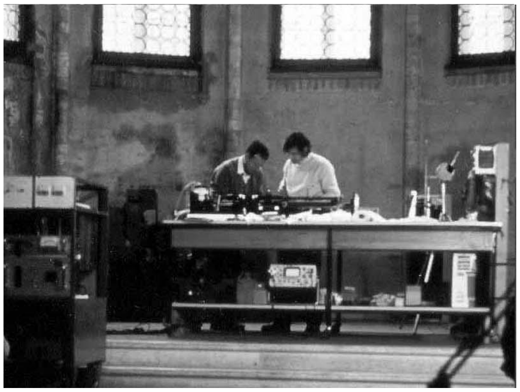

Fig.5. Ruby-laser holography in San Gregorio (Venice).

Fig.6. G. Musumeci demonstrating chemical cleaning of stone.

The micrometeorite program had demonstrated the feasibility controlled laser ablation and the conditions under which substrate damage could be avoided. After performing a few calculations, the beam of the 1J/pulse (Q-sw) ruby laser was directed to a 1cm spot on a marble test specimen. Then the passive Q-sw was removed and 1ms pulses were applied to a 3mm spot. Both experiments led to self-limiting cleaning of the marble[3] with no visible evidence of damage to the stone. During the next three years a variety of laser types were evaluated for the cleaning of a wide variety of stones and other materials employed in art and architecture. Extensive diagnostics were employed to evaluate the results. Eventually, one of the ruby laser heads was mounted on a tripod and a 10x20cm rectangle on a Palazzo Ducale capital was laser cleaned (Figure 8)[4].

Fig.7. Chemical and abrasive cleaned areas at Piazza San Marco.

Fig.8. G. Calcagno laser-cleaning a Palazzo Ducale capital.

3. FRANK CAPRA AND THE DISCOVERY OF ANTIMATTER

Interest turned to organizing a full-scale monument conservation project in Venice to demonstrate and validate the efficacy of laser divestment. However, the required funding seemed out of reach.

At a Caltech reunion celebration in Pasadena, California the author encountered his physics teacher, C. Anderson, the discoverer of antimatter. Upon hearing of the laser work in Venice, Prof. Anderson mentioned that he had faced funding problems as well. He had been unable to afford all of the materials required to construct his cloud chamber (Figure 9). (His first antimatter cloud-chamber tracks are reproduced in Figure 10.) Further, he had no way of transporting his equipment to the top of Pikes Peak (Figure 11) to capture the cosmic rays, had no power source, and could not afford to have it shipped by rail (Figure 12). Anderson then realized that a classmate in electrical engineering, F. Capra, had become a successful motion picture director at Columbia Studios. Anderson called upon his friend and Columbia supplied a large truck and electrical generator as well as tons of electrical equipment. The results from Pikes Peak earned Prof. Anderson a Nobel Prize[5].

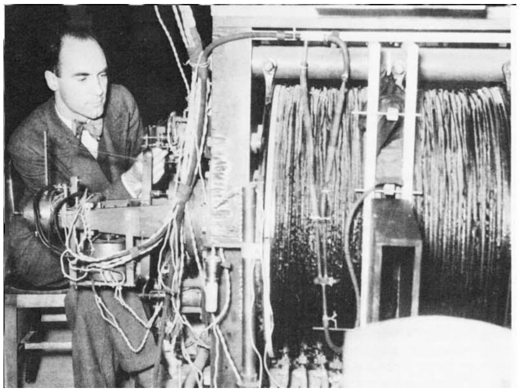

Fig.9. C. Anderson with his positron-detecting cloud chamber.

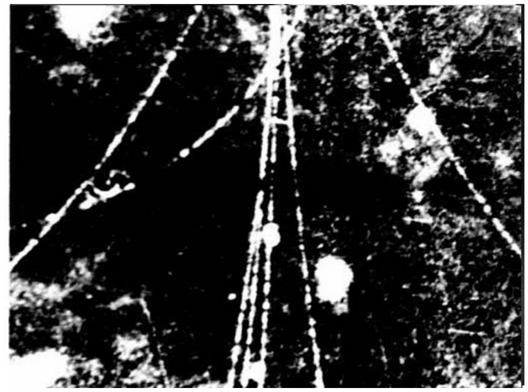

Fig.10. First cloud-chamber positron track.

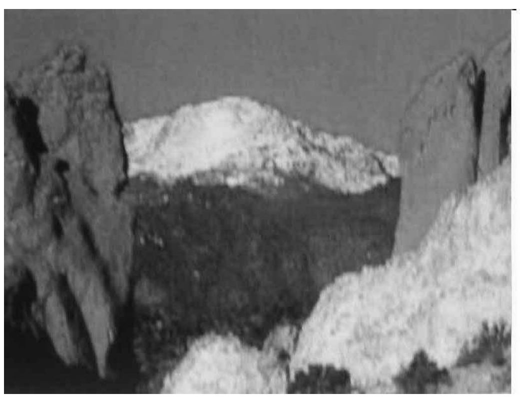

Fig.11. Pikes Peak (mu-meson discovery site).

Fig.12. C. Anderson and R. Millikan at Pikes Peak.

Prof. Anderson noted that Venice was the venue for a famous film festival. He was entirely serious when he suggested that the film industry be approached to contribute financially toward a laser art conservation project for Venice.

4. CLOCKWORK ORANGE AND LASER DIVESTMENT OF ARTWORK

The UCSD personnel in Venice generally stayed at the Pensione alla Salute da Ci Ci that is a few meters from San Gregorio. The poet E. Pound lived around the corner from the Ci Ci and dined there weekly. He provided an introduction to another poet (Dame F. Stark, Figure 14) who had organized a Festival showing in Asolo (Figure 15) of Warner Brothers' "A Clockwork Orange" (Figure 16). With the manifest financial success of the film it was an easy matter to entice J. Warner to contribute US$5000 toward the laser restoration project.

With the pledge from J. Warner in hand other doors were opened for additional support. A group of Texans had established a nonprofit foundation known as "The Friends of Venice". They organized a Villa Tour and a Grand Ball as fundraisers and contributed additional support toward the laser project. Finally, Smithsonian Magazine decided to write a feature article on the laser in art conservation and arranged for the transportation of UCSD staff and equipment back to Venice for the conservation work that would be described in the magazine. The only remaining item to be worked out was the selection of a specific monument for conservation and the approval of Venetian and UNESCO authorities.

At that precise time word was received from Arch, G. Calcagno that he was initiating work on the conservation of the Porta della Carta of the Palazzo Ducale in Venice. Further, he had determined that laser divestment was the optimum approach considering the condition of several of the marble elements. Finally, he reported that he had received the approval of the authorities for the laser approach.

Fig.13. E. Pound at Piazza San Marco.

Fig.14. F. Stark dining in Iraq.

Fig.15. Cinema festival party in Asolo.

Fig.16. The Warner Brothers' hit.

5. RESTORATION OF THE PORTA DELLA CARTA

By 1980 when the laser statue cleaner was returned to Venice two significant changes had been instituted. First, as Nd:YAG laser rods had become widely available at a reasonable price, the laser was converted from ruby to YAG. (At UCSD there had been an intermediate evolutionary step that incorporated Nd:glass.) Second, an optical articulated-arm beam director had been built and attached to the laser so that it was no longer necessary to swivel the entire laser on a tripod.

After a few days of use it was noticed that the 45^o reflective coatings of the turning mirrors in the articulated arm were deteriorating. As these were the best available in 1980 (Laser Power Optics, Inc.), there was no option other than returning to the original method of scanning the laser across the surface by rotating the entire laser head. (Turning prisms had also been investigated while the system was back at UCSD, and they, too, had suffered optically induced damage.) A damaged prism and coating are shown, respectively, in Figures 17 and 18.

The artwork to be laser cleaned in the Porta della Carta was a marble relief depicting "The Last Supper". It was approximately 60cm high and 180cm wide. As the relief had been laid horizontally on its back for treatment, the laser was mounted on a beam above the artwork. The laser beam was directed vertically downward to impinge on the marble surface. The laser head was attached to the supporting beam with a swivel joint so that the beam could be manually scanned across the surface. The laser functioned in the normal mode (400us) at 1J/pulse. In most areas a spot size of 3mm was employed. Figure 19 shows the Porta della Carta and the laser pointing downward onto the relief. The initial, centrally cleaned, area is shown in Figure 20.

Fig.17. Laser beam-director mirror in holder.

Fig.18. Coating damage on laser turning mirror.

Fig.19. Porta della Carta (left), cleaning marble (right).

Fig.20. Central laser-cleaned portion of marble relief.

6. LASER RESTORATION OF THE WARNER CENTER GRANITE

A new Warner Brothers corporate office complex was constructed in the Los Angeles area while the laser work proceeded in Venice. The following year (1981), with the completion of the central corporate tower of the Warner Center, the general contractor found that rubber cushioning used during shipping had discolored the tower's South African granite veneer. Chemical treatments that removed the stains also etched the stone and left it with a frosted appearance. As a last resort, the Venetian laser was sent to the Warner Tower for a cleaning trial. At low fluxes and high fluences the laser induced optical damage in the mineral grains, not unlike that experienced with beam-turning prisms in Venice. The resulting cleavages within the mineral grains resembled the normal heterogeneity of granite, yet masked the chemical blemish. This approach was selected as the most suitable treatment, thereby repaying the Warner Brothers' investment in the laser.

Figure 21 shows the central tower of the Warner Center complex. The dark vertical stripe, as well as the horizontal bands at the top and bottom, are the South African granite veneers. Figure 22 is a close-up of the stone illustrating the original appearance. The dark band at the top is the area discolored by cushioning material during the protracted ocean voyage from Africa to California.

During the laser irradiation process, the unstained granite was masked from laser illumination by means of stainless steel adhesive tape. This is depicted in Figure 23. The post-treatment area is at the top, and the stainless steel masking tape is at the bottom. The final result of the laser stain removal is depicted in Figure 24. The light scattering from the laser-generated cleavages (top portion of the figure) has masked the aesthetic effect of the stain. The stone surface in its original (unstained) condition appears at the lower half of the figure.

Fig.21. Warner Center Tower (Los Angeles).

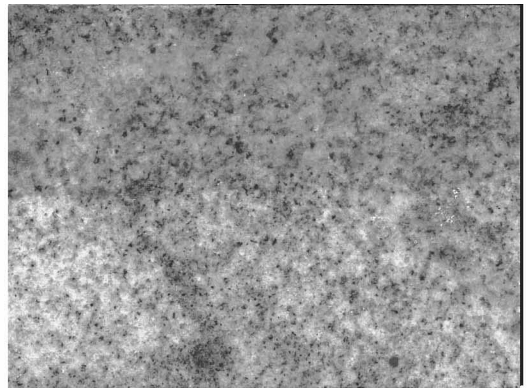

Fig.22. Discolored granite (top), normal granite (bottom).

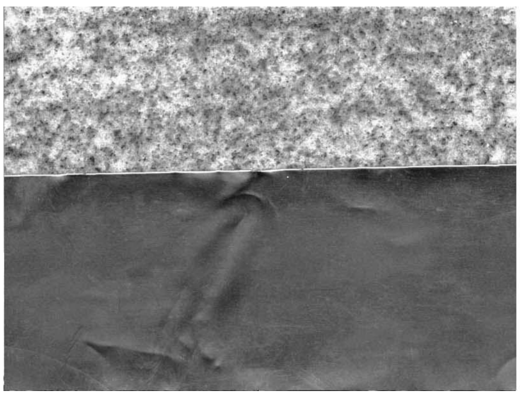

Fig.23. Cleaned granite (top), stainless steel tape (bottom).

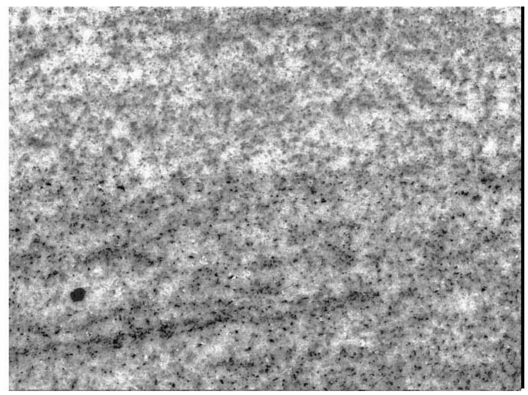

Fig.24. Cleaned granite (top), original granite (bottom).

7. CONCLUSION

The sequence of events related in this paper reveal the curious twists and turns that often pervade the evolution of a technology. The roles of coincidence, chance, and serendipity fall quite clearly into the pattern illustrated most comprehensively by Burke in his popular book "Circles"[6].

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