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DETECTION AND IMAGING OF SOME MEDICAL ULTRA-FAST PHENOMENA AKIN TO DIAGNOSTICS AND THERAPY
DETEKTIMI DHE IMAZHIMI I DISA FENOMENEVE ULTRA TË SHPEJTA MJEKËSORE QË MUNDE TË ZBATOHEN NË DIAGNOSTIKE DHE TERAPI

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PËRMBLEDHJE
Për të matur dhe kuptuar disa fenomene që manifestohen gjatë litotripsisë lazerike, ne propozojmë këtu një teknikë të rë interferimetrike duke zbatuar shedografinë si metodë komplementare. Interferometria dhe imazhimi ultra i shpejtë, në të cilin bazohet teknika që zbatuam, mundësoi vizualizimin dhe matjen e mëshikëzave brenda intervalit kohor prej disa nanosekondash. Kjo nuk ishte e mundur të bëhej me anë të teknikave ekzistuese. Teknika që propozojme bazohet në imazhimin ultra të shpejtë të mëshikëzave, në sipërfaqen e të cilave projektohen vija interferometrike. Interferogrami i fituar është procesuar dhe analizuar me anë të programit tonë kompjuterik. Rezulatet finale, të fituara pas sintetizimit interferometrik, nxorrën në pah fenomene të cilat shoqërojnë shkatërrimin e gurëzave gjatë veprimit të fuqisë lazerike.
Fjalët kyçe: dedektimi, imazhimi, interferogrami, interpretimi i vijave

SUMMARY
A new interferometric technique and shadography is applied for measurement and better understanding of high speed phenomena such as a bubble, generated during the laser lithotripsy. Inetrferometry and ultra fast imaging technique introduced here, made possible to visualize and measure some bubbles within the time span of several nano seconds which otherwise were invisible, and hard to be explained. This technique consists of ultra-fast imaging of bubbles with inteferometric fringes projected on their surfaces. The obtained interferograms are processed and interpreted with the new introduced software for fringe analysis. The final results obtained after the fringes are synthesized has reveled phenomena akin to the mechanism of the destruction of the stone during the action of the laser power.
Key words: detection, imaging, interferogram, fringe interpretation

INTRODUCTION

An ultra fast imaging and interferometric technique for visualization and deformation measurement is developed. Phenomena relevant to fragmentation of gallbladder stone during a pulsed laser action are studied. Actual condition in gallbladder has been simulated A stone is immersed in distilled water. Laser energy was delivered to the stone by an optical fiber. Two different cases are studied; namely, when the tip of the fiber is in contact with the stone and when it is at a distance from it. By using ultra-fast shadowgraph, interferometer with fringe analysis, photo microscopy, and electron microscopy, mechanism for destruction of a stone due to laser- based lithotripsy is studied. Laser methods are being used in medical therapy and diagnostics in the past [1-3]. This includes laser lithotripsy, photodynamic therapy, and laser destruction of bladder tumors etc. Recent improvements in laparoscopy, retroperinoescopy and endoscopy in general, make internal organs visually accessible [4-8]. All these areas become accessible via fiber-optic laser delivery. Here the laser energy for destruction of the stones formed in internal organs can be delivered via optical fibers. Therefore, laser lithotripsy of the gallbladder stones, or others formed elsewhere, has a potential to become a very attractive technique [9-13]: less invasive, less risky and low cost compared to conventional operation if the images of high speed phenomena are clearly presented. In this work, using optical techniques, we address the two factors that makes difficult to apply laser lithotripsy during the of electronic circuit, delay generator, firing of Ho:YAG laser, firing of N-Dye laser and the data gallbladder stone fragmentation. It is shown that visualization and image interpretation plays a key role.

RESULTS AND DISCUSSIONS

Visualization and deformation measurement is performed on the ultra-fast images akin to biomedical applications. Ultra-fast photography is performed to monitor the dynamics of laser lithotripsy of gallbladder stones. The gallbladder calculi were obtained from a stone analysis laboratory (Mubarak Hospital in Kuwait). We performed an experiment were Ho:YAG medical laser from (λ = 2.12 μm , 250μs). A 350 µm diameter low OH-fiber was used. Actual conditions inside a gallbladder are simulated, when the pulsed Ho:Yag laser is used to perform the stone fragmentation. A calculus was placed in water-filled glass cuvette at room temperature.

One end (the tip) of an optical fiber is placed on top of a stone under investigation. The placement is arranged with a homemade mechanical device, which is provided with a scale enabling a quantified change of the distance from the stone. Another end of the fiber is connected to a Ho:YAG laser delivering the pulsed power to the stone. The stone, laser pulse action and phenomena generated are illuminated with an N-Dye Laser (its pulse is 7ns).

The experiment is performed in a dark room where a camera placed at a distance from the civet with its “open mouth” will record all the phenomena. All these operations including the control acquisition to a computer is controlled by using National Instruments GPIB and data acquisition board along with a program written in Quick Basic.

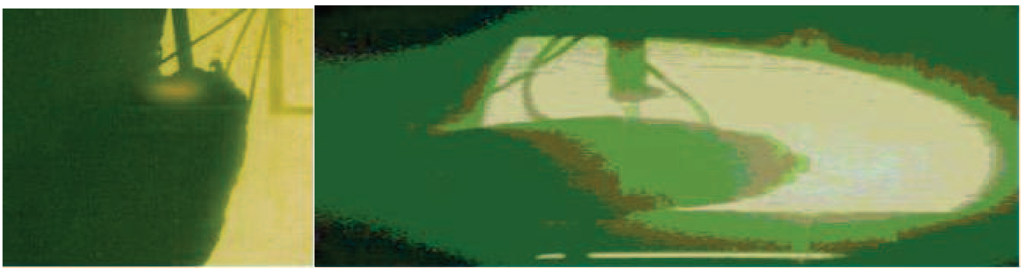
The main goal of the experiment is to monitor the dynamics of the phenomena during the Ho:YAG laser pulse (250 ns) action. Theoretically, this should be achieved by taking many photographs within the span 250 ns.

In the absence of the technology to perform this, an indirect approach is applied. Experimentally is confirmed that the Ho:Yag working regime and the single pulses fired at different points in time are the same. The electronic system described above is used to scan the N-Dye laser pulses at different points in time within the time of Ho:Yag laser pulse. Actually, this is performed by firing the first Ho:Yag laser pulse, and at initial instant of this pulse, in N-Dye laser pulse is fired as well. At the same instance the first photograph is taken. The next pose is taken when second firing moment of the N-Dye laser is shifted for 20 ns on the right to the initial point within the second pulse of Ho: Yag laser. This procedure continues until a complete scanning of Ho:YAG laser pulse by N-Dye laser pulses is performed.

The space above the top of the stone is illuminated with the beam, which is reflected by a mirror. The shadow gram obtained for this part is to be used for interferometry investigation. The length of Ho: YAG pulse is 250 ns, and the length of the pulse used as an illuminating source for ultra-fast photography is 7 ns. Therefore within the time of the Ho: YAG pulse many photographs can be obtained. Hence the dynamics of the phenomena occurring during the laser action can be monitored. The distances between two consecutive N-Dye laser pulses are selected to be 20 μm.

In Figure 1, the shadowgraphy results obtained by the described procedure are shown. Each image (shadowgraph) is obtained during the exposure time (7 ns) of illuminating N-Dye laser. As can be seen, here the tip of the fiber was touching the surface of the stone.

The upper surface of the stone is polished before the experiment is performed. In the first image 1.a, the swelled-convex meniscus of the surfaces during the laser action can be seen. In figure 1.b a clear thermal effect of the laser action can be seen shape of an ellipse is seen. These figures show the thermo-chemical effect as a relevant factor.



1.a 1.b

Fig.1.a. Shadograph before the optical processing of the image
Fig. 1. b .Shadowgraph shown after optical processing

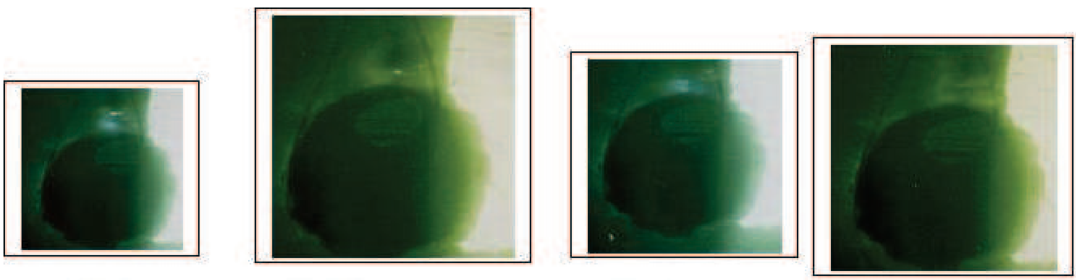


Fig.2.a Fig.2.b Fig. 2.c Fig. 2.d

Fig.2. Time resolved shadowgraphy: Each image is obtained within 9 ps.

In the Fig. 2 (a-d). the shadowgram obtained during the 9 pico-second exposure time. As can be seen, one can not tell which kind of phenomena is appearing between the tip of the fiber and the surface of the stone. In this case only interferometry visualization could visualize and reveal the phenomena occurred.

No information can be obtained from the images Fig. 2. a-d, shown here. This problem is solved using projection and interferometry technique [14-16]. Results are shown in Fig. 3. As shown here, a shadow of the stone with the shape of black ball with its clear contours is obtained. As mentioned above, the information about the bubble formed above the stone are blurred and are unreliable to make any conclusions. Nor is it possible to monitor change of its shape during the different points in time. Here another incident-coherent beam besides the main beam is introduced.

This beam, by passing through the bubble, will reach the black part where the shadowgraph is formed. Hence the black part of the shadow of the stone here is used as a screen for projection of the interferogram of the bubble. The formation of the interferogram is based on diffraction of the coherent laser beam on an optically transparent bubble. Namely, in the transmitted coherent beam through the body of the bubble a phase change is introduced. Or one could say the transmitted laser beam has collected information on the bubble. This phase change is due to the density distribution of the bubble. Hence an interferometric image is formed and projected on the black part of the image (dark shadow of the sally, the phase distribution of the coherent beam, the shape or information on hydrodynamic state of the bubble at this point is projected and encoded in the shape of an inerferometric pattern.

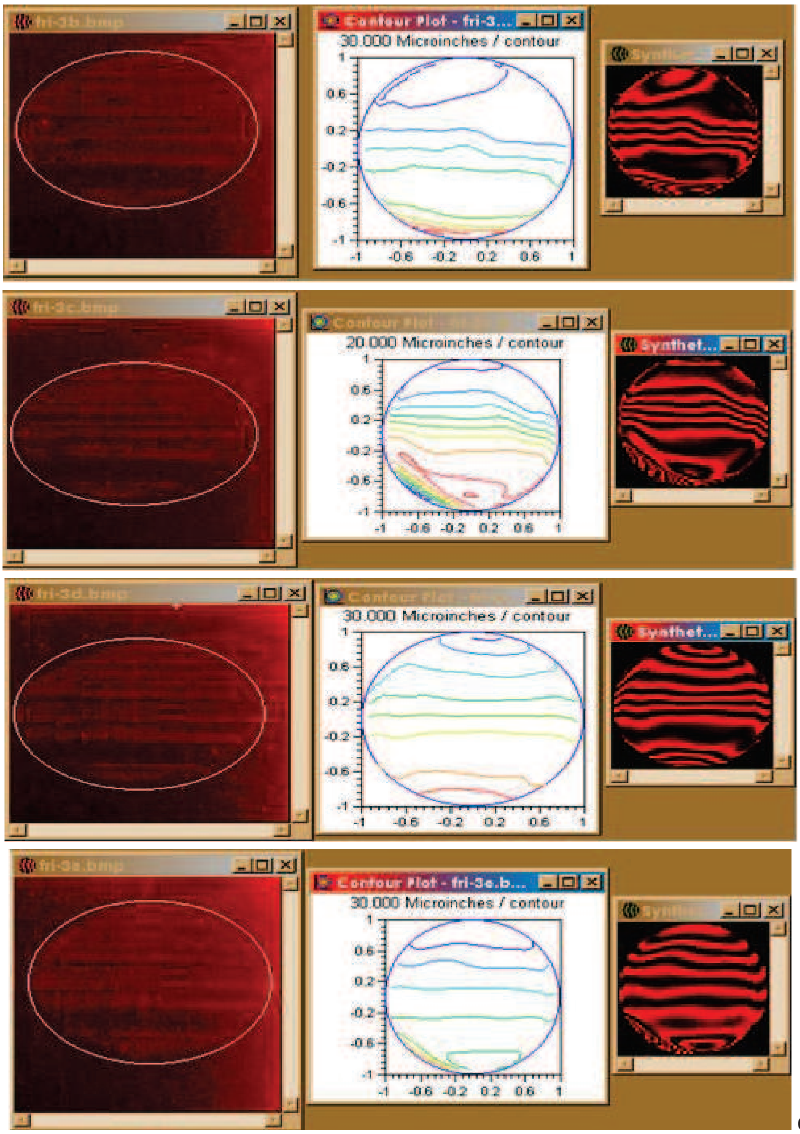


Fig.3. Interferometry results and fringe interpretation

The parts of the images where the fringe patterns are located are selected and cropped by using an image processing software. They are shown in the left column of the Fig. 3.a-d. The cropped images or interferograms from Fig. 2.a-d, are analyzed by using fringe analysis software, which was adapted for this particular case. The fringe patterns, as are shown in the Fig.3.a-d, are horizontal and parallel. These shapes have an appropriate fringe distribution for tracing of their centers and performing fringe analysis. In order to have a reliable comparison between the selected (cropped) fringe patterns and to quantify and monitor their change at different points in time, the size of the pattern to be analyzed is bordered with a circle (as is seen in Fig. 3.a-d, left column). In four different cases the radius of the circular border is the same. It means the selected sizes are the same.

The selected interferogram shown on the left column are processed using the fringe analysis software. The contour representation is shown in the middle column of the Fig. 3. a-d is very clear. The synthetic analysis is performed and results are shown in the right column of this figure. While from the actual interferometric patterns was very hard, or impossible to make the distinction between the patterns, and therefore here it impossible to monitor the changes or evolution of the bubbles at different point on time, after the fringe analysis is performed, clear outputs shown in the middle and right column of the figure 3. a-d , are obtained.

The obtained results of the fringe interpretation have revealed several features and therefore have demonstrated differences and evolution of the bubbles at different point of time. An important feature is synthetic fringes presentation, which is obtained for each case.

As is seen from the result, they represent the fluid distribution in the bubble (of which the lifetime is very short one). Finally, it should be pointed out that, the shapes of the bubble have been studied before. However, here by using fringe analysis technique, performed by program, we have generated for this purpose, the monitoring of the dynamics of the bubble and its morphology evolution within an ultra-short time (lifetime of Ho: Yag pulse) is reached. Quantified analysis can be performed as well, which remains as a task of our future work.

Another technique for visualization and quantization of the changes on the objects and phenomena is the image correlation [17-20]. This image processing technique enables one to recognize and select the phenomena and the objects under investigation.

CONCLUSION

Using an interferomeric technique and fringe analysis and interpretation, the formation of a bubble and evolution of its morphology during the laser pulse action was monitored. This was not possible otherwise. The study and results revealed that thermo chemical process is the main cause for laser lithotripsy. However, opto-mechanical effect should not be excluded for a certain position of the fiber and when the stone is immersed in a fluid. This cools down the space between the stone and tip of the fiber by absorbing the heat during the laser action. Therefore the main conclusion is that both the thermo chemical and opto-mechanical processes can take place during the laser pulse action and stone fragmentation.

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