Study on Contamination Control of Optical Thin Films with First Contact^{TM}

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Abstract: In high power laser system, it is very lethal of contamination on the surface of optical thin films. The contamination can be heated and burn rapidly under high power laser irradiation, which would result in damage to the optical thin films or even the whole optical component. Therefore, it is the key to control the contamination on the surface of optical thin films. First Contact^{TM} can be used to clean the surface of optical thin films, remove fingerprints, dust and other contamination attached to the surface of optical thin films. It has been applied in many important projects such as aLIGO. In this paper, the First Contact^{TM} was used to clean the optical thin films for chemical lasers. A microscope was used to test the appearance of the optical thin films before and after cleaning, which showed that, the First Contact^{TM} is able to remove contamination, such as fingerprints and dust, attached to the surface of optical thin films for chemical lasers. The absorption coefficients of the optical thin films before and after cleaning were measured by an intra-cavity device, which is 286.5ppm and 216.9ppm respectively. The absorption coefficient was decreased by 24.3% after cleaning. The above results show that, the First Contact^{TM} can effectively clean the optical thin films for chemical lasers, and there is no First Contact^{TM} remain on the surface of optical thin films. It is found that the shortcoming of the First Contact^{TM} is that, it cannot repair the defects in the substrates or optical thin films of the optical components, and cannot clean the optical thin films online. Finally, the use of First Contact^{TM} was optimized, and the optimized method is conducive to the long-term preservation of optical components.

1 INTRODUCTION

The control of contamination on the surface of optical thin films has always been the concern of the researchers in the field of high power laser (Raman R N, et al., 2016; Xiaofeng Cheng, et al., 2014; Kai Han, et al., 2016).. In the process of high power laser system, the power density on the optical thin films is very high. Then, the presence of contamination is fatal. Irradiated by the high power laser, contamination will be heated, even burning, and causing a damage of optical thin film. This is a serious threat to the stability and security of the system.

First Contact^{TM} is a kind of cleanser for optical surface, which is produced by a company called Photonic Cleaning Technology. It is a mixture of solvent and polymer in liquid form. When it is painted or sprayed on the optical surface, a soft layer of film is formed, and there is not any damage to the optical surface. When it is dry, it can be torn down easily. At the same time, the contamination on the optical surface is taken away, such as dust and handprint, then a clean optical surface is left. First Contact^{TM} is used for removing contamination on the surface of optical thin films in many projects, such as aLIGO, which is short for advanced Laser Interferometer Gravitational-Wave Observatory (Margot H. Phelps, et al., 2013; Photonic Cleaning Technologies, LLC, 2018). But there are no applications in chemical lasers. In this paper, the cleaning method of optical thin films used for chemical lasers was studied experimentally, and the cleaning effect is tested by means of microscope and an intra-cavity device (Xiaoting Fang, et al., 2015; Yan Baozhu, et al., 2015).

2 CLEANING METHOD

As shown in Fig.1, the steps of cleaning the surface of the optical thin films with First Contact^{TM} are:

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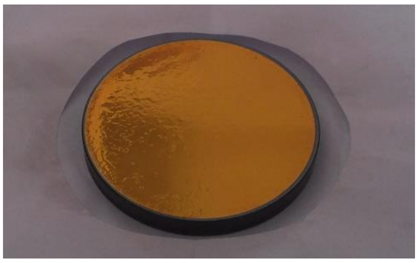
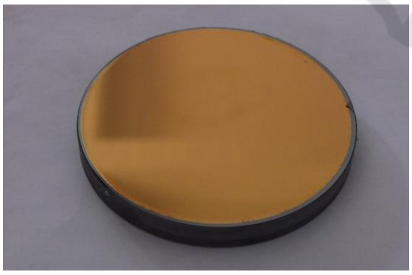
a) Firstly, one layer of First Contact™ is sprayed on the surface of the optical thin films, as Fig.1a;
b) 15 minutes later, a sticker is pasted on the layer of First Contact™, then another layer of First Contact™ is sprayed on them, as Fig.1b;
c) Another 15 minutes later, by tearing the sticker, double layers are torn off simultaneously. The surface of optical thin film is very clean as Fig.1c, and the tearing film of First Contact™ is shown as Fig.1d.

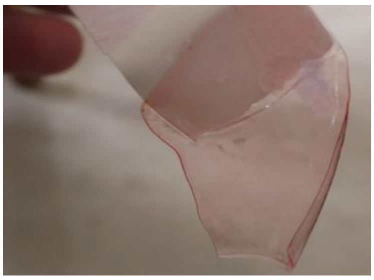


a)

b)



c)



d)

Figure 1: The cleaning process.

The tearing film of First Contact™ is about 0.2 millimeter in thickness. This thickness is more suitable. If too thin, the First Contact™ film is not strong enough; if too thick, the First Contact™ film will not be dry inside. In these two cases, the film will be easy to break and can not be tearing clean.

3 CLEANING EFFECT

Two methods are used to test the cleaning effect. The first way is to compare the state of optical film surface before and after cleaning by microscope. As shown in Fig.2a and Fig.2c, there are handprints and a lot of micron scale white spots on the surface of optincal thin film before cleaning. After cleaning, the handprints are removed completely (as Fig.2b), and the number of white spots is reduced significantly (as Fig.2d).

It is found that some of the white spots are contamination, and the others are defects in the substrate or optical thin film. Contamination, such as dust, can be removed by the First Contact™, and this is the reason for the decrease of white spots. But defects in the substrate or optical thin film can not be repaired, so there are still some white spots after cleaning.

Another way is to measure the absorption coefficient of optical thin film before and after cleaning by an intra-cavity device (Xiaoting Fang, et al., 2015; Yan Baozhu, et al., 2015). As is shown in Fig.3, an intra-cavity device is established based on a discharge-drived CW DF chemical laser of hundred watt level. The center wavelength is about 3.8 μm. Utilizing an output mirror M2 with a low output coupling ratio (τ=0.03), the intra-cavity device could produce a laser beam of about 2.5-6.5kW/cm^2 and 1 cm^2 in the resonant cavity. When placed in the resonant cavity, the testing mirrors S1~S4 are irradiated by the laser beam of high power density.

In the test, the irradiation is lasting 100 seconds continuously, and the equilibrium temperature rise of the substrate after the irradiation can be measured by temperature sensors, which are pasted at rear surface of testing mirrors S1~S4. The output power is measured by power sensor. Then, the absorption coefficient of optical thin film can be calculated by calorimetry.

Five times of measurements are carried out by use of the intra-cavity device in this paper, and the absorption coefficients of optical thin film are listed in Tab.1. The Pd, E, $\triangle$T and α represent power density of laser beam in the resonant cavity, energy

a) Handprints on the surface before cleaning.

b) The position of handprints after cleaning.

c) White spots on random area outside of the handprints before cleaning.

d) Random area outside of the handprints after cleaning.

Figure 2: The cleaning effect of First Contact™.

radiated on the optical thin film, equilibrium temperature rise of the substrate after the irradiation, and absorption coefficient respectively.

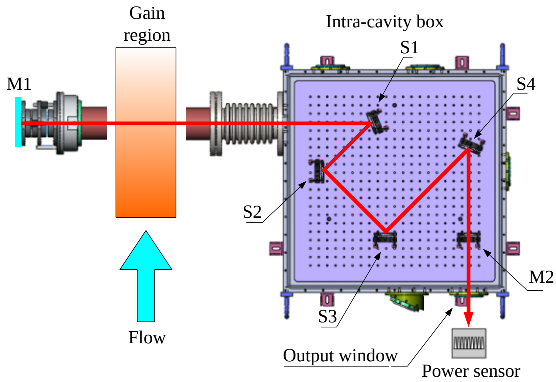


Figure 3: Layout of intra-cavity device.

The first three times of measurements are carried out before cleaning, and the average value of absorption coefficients is 286.5ppm. After cleaning by First Contact™, other two measurements are made. The average absorption coefficient is 216.9ppm, which is 24.3% less than the value before cleaning. The reason for the decline is the removal of dust and other contamination on the surface of optical thin film. On the other hand, the results reveal that the layer of First Contact™ is torn off completely, and there are no residue on the surface of optical thin film. There is no new pollution to the optical film, which is of great practical significance.

Table 1: The absorption coefficients measured by the intra-cavity device.

Num	Pd / (kw/cm^2)	E / kJ	ΔT / ℃	α / ppm	Status
1	3.45	328.0	5.71	295.8	Before cleaning
2	2.88	368.1	6.47	298.7	
3	2.92	472.8	7.37	264.9	
4	3.80	547.2	6.95	215.8	After cleaning
5	4.02	579.1	7.43	218.0	

4 PROTECTION OF OPTICAL COMPONENTS

One layer film is formed when First Contact™ is sprayed on the surface of the optical thin film. The layer of First Contact™ can isolate optical thin films from water vapor and prevent it from being damaged by other things. So First Contact™ can be used for protecting optical components during preservation and transportation.

In order to explore the method of using First Contact™ to protect optical thin films, two layers of

First Contact™ are sprayed on the surface as step a and b in the part 2. One week later, double layers can still be torn off completely, but a imprint like watermark appeared on the surface of optical film, as shown in Fig.4, and there is a clear boundary around the sticker. The imprint can be removed by using First Contact™ again, but the boundary can't.

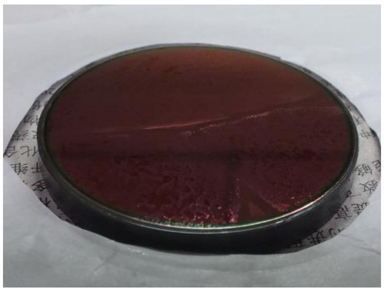


Figure 4: The optical film tearing down the First Contact™ film after a week.

Thus, the spraying method need to be optimized. After spraying the first layer of First Contact™ on the surface of the optical thin films, the sticker is not pasted immediately. When the optical component need to be used, maybe a few days later, paste a sticker, tear off the sticker and the layer of First Contact™. Tests verify that, using the optimized method, the layer of First Contact™ can be torn off completely even 3 months after spraying and there is no boundary around the sticker. If there is a watermark-like imprint on the surface of optical film, it can be cleaned by use of the method in part 2 again.

5 CONCLUSIONS

In this paper, the cleaning method of First Contact™ to the surface of optical thin films is studied experimentally. The test results of the microscope and the intra-cavity device reveal that, the cleaning effect of First Contact™ is perfect, and there are no negative effects, such as pollution and damage. But the defects of substrates or optical films can not be repaired by First Contact™. The layer of First Contact™ can be torn off completely even 3 months after spraying, so it may be used for protecting optical components when preservation and transportation.

REFERENCES

Raman R N, Demos S G, Shen N, et al., 2016. Damage on fused silica optics caused by laser ablation of surface-bound microparticles, Opt. Express, 24(3), 2634.

Xiaofeng Cheng, Xinxiang Miao, Hongbin Wang, et al., 2014. Surface contaminant control technologies to improve laser damage resistance of optics, Adv. Condens, Matter Phys, 210.

Kai Han, Baozhu Yan, Xiaojun Xu, et al., 2016. Thermal damage mechanism of the optical element used in mid-infrared high power laser system, J. Infrared Millim, Waves, 35(6), 741.

Margot H. Phelps, Kaitlin E. Gushwa, Calum I. Torrie, 2013. Optical contamination control in the Advanced LIGO ultra-high vacuum system, Proc. of SPIE Vol. 8885, 88852E-1.

Photonic Cleaning Technologies, LLC, 2018, http://www.photoniccleaning.com/.

Xiaoting Fang, Shengfu Yuan, Wenguang Liu, et al., 2015. Absorption measurement of optical thin films under high power density with a Closed Cavity, Chinese Optics Letters, 13(3), 033101.

Yan Baozhu, Liu Wenguang, Zhou Qiong, et al., 2015. An intra-cavity device with a discharge-drived CW DF chemical laser, Proc. of SPIE Vol. 9513, 95131A-1.