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Cleaning of CO₂ laser optics

CLEANING OF LENSES AND MIRRORS

The principles of cleaning optical elements outlined here, apply broadly to all optics, regardless of the conditions they operate under. That the examples are mainly related to infra red lasers, is more to do with the authors experience, than any other limitation.

With an imaging system, increasing detector amplification can offset absorption of light by optical elements. With high power systems however, that absorbed light will lead to heating of the elements and a level of distortion is inevitable, as the optic changes shape, or refractive index, with temperature.

Sadly in laser processing this can have a positive feedback effect, as optical elements distort, the focussed spot or beam alignment drifts away from the predetermined conditions, process back spatter can increase, causing even more contamination and debris.

All optics from the moment of use, and occasionally in storage, will acquire a level of contamination. A cutting lens close to plastic being cut, will be contaminated with condensates and smoke that are essentially organic in nature, whereas a dental laser system will see contamination that is essentially aqueous, or "watery" in it's nature.

That a single prescriptive cleaning technique could deal with such diversity is not realistic.

Few optics can be mechanically abraded or soak cleaned, so everyday cleaning is limited to wiping with a solvent and a swab. There are several aims in doing this,

- 1) The optic is not mechanically damaged by scratching
- 2) The optic is not chemically damaged, by etching or other chemical attack
- 3) That absorption is lowered (transmission increased) to a suitable level for a lens or window
- 4) That absorption is lowered (reflectance increased) to a suitable level for a mirror.

Given that physical removal of the debris or contamination by rubbing is not feasible, cleaning is reliant on the solvent dissolving the contamination, allowing the resulting solution to be soaked up and removed by the swab.

The essential point here is that the solvent **dissolves** the contamination, resulting in a solution of dissolved dirt that can be taken away from the optics surface.

Consider an every day example, washing car bodywork. Rock salt is obviously easily dissolved into water, but no matter how many gallons of water were used, no one would expect it to dissolve even a fleck of tar. However a drop of paraffin results in complete removal of tar. This shows how successful the approach is of knowing the properties of the contamination, and then choosing the appropriate solvent.

The only restrictions in choosing a solvent are, avoiding chemical damage to the optic and it's coating, and Health and Safety guidelines: even the most exotic solvent will cost just a few pence per optic cleaned.

Choosing a solvent

A good rule of thumb is "like dissolves like", although how a solid can be "like" a liquid is not immediately obvious. The answer is to do with electrical field distribution at a molecular level; this is termed "Polarity". A better adage would be "Highly polar liquids dissolve highly polar solids, non polar liquids dissolve non polar solids".

In our car-washing example, salt is highly polar solid, water a highly polar liquid. Tar is non-polar, as is paraffin, thus ideal for it's removal.

It is sufficient merely to have an "instinct" for the polarity of the contamination to choose a solvent, as there is a fairly broad overlap.

The following table gives a feel for polarities of everyday solids and liquids.

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Matching contamination to solvent for cleaning optics

SOLID	POLARITY	LIQUID
Salts/Water Residue	HIGH	Water/Vinegar
		Alcohol
Light Oil		Acetone
		Methyl Ethyl Ketone (MEK)
Heavy Oil		Ethyl Acetate
	MEDIUM	Trichloromethane (Chloroform)
		Dichloromethane
Light Grease		Trichloroethane "TRIKE"
		Xylene
Heavy Grease		Toluene
		Hexane
Tar, Fat, Plastic Residue	LOW	Octane

All of these solvents should be readily available, but the user should check with the optics supplier for compatibility, and be aware of Health and Safety issues.

Even if one is lucky in choosing just the right solvent, it is likely to only dissolve just a fraction of its weight in solids, so several repeated applications will be needed to effect removal of a high proportion of the contamination. At no time is mechanical pressure needed, the solvent does the work, frantic rubbing will not increase its dissolving power in the slightest.

The cleaning process

1) The author prefers a swab such as cotton wool, which will hold a large volume of solvent. Use natural cotton wool, rather than man made mixtures, which will cause scratches. The swab needs to be free from all particles, and kept in a sealed bag. Check for seeds and knots before use. The swab should be well wetted, but capable of absorbing a little more liquid. Use a piece at least as large as the optics diameter so only a single wipe is needed for the entire surface.

2) Firstly blow particulate matter off the optic with "canned" air, all shop airlines contain oil vapour, no matter how well filtered. Don't forget to check the sides/chamfers and back of the optic where debris can be attached.

This can be caught up into the swab and then dragged unobserved across the surface.

3) The solvent soaked swab is dragged, under its own weight ONLY, slowly across the optic. The solvent at the leading edge will dissolve the dirt; the trailing part of the swab will absorb the resulting solution back off the optic. This should be repeated several times. It is important that the solvent is absorbed back onto the swab and not allowed to dry into a tide mark of concentrated dirt. Change the swab every time, as fresh solvent will dissolve the contamination better. Also particles picked up in the swab cannot be repeatedly dragged back across the optic.

4) Check the optic is clear and free from stains and tide marks. Again don't forget the back and sides of the optic or locating holes. These can retain liquid that can later leak out unobserved during mounting or installation

5) If this approach is not familiar, then try a few tests on some "dead" optics first to get a feel for the technique.

Just how much care in cleaning is needed ?

Two questions should be asked,

1) Have I scratched the optic unduly?

2) Has the absorption of the optic returned to a low enough level to allow it to function well?

Any short answer to these questions will be incomplete, and probably provocative, but some guidance is essential.

Considering scratching: Optics for high power lasers will be of good quality despite a small number of scratches that appear to be no more, than say, 2- 4 microns wide.

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With perfect eyesight, and good natural lighting, unskilled examination will fairly easily detect scratches of this level. The absence of scratches when viewed in this way indicates a good quality surface.

If after cleaning the optic passes this test, then well done. There is in general no need for artificial lighting, or viewing aids in the majority of situations.

Considering absorption:

For high power infra red laser lenses, such as those of ZnSe, a lens absorbing 0.2% of the beam will generally prove serviceable. Note this is a very small figure, just 2 parts in a thousand. Beyond this thermal effects are likely with very high power systems. A 100 watt system will be one tenth as sensitive as a 1000 watt system, so owners of high power cutting systems need to especially careful.

Metal mirrors are less sensitive, Molybdenum and Copper mirrors for example can often absorb 2.0% of the beam quite happily, ten times that of a lens.

Output windows are particularly important, as the laser cavity is sensitive to misalignment and shifting waist locations that occur as the window distorts.

Of the two factors here I hope the reader sees that low absorption is the more difficult to assess, and achieve. Unfortunately lowering absorption is often the factor that determines the success of cleaning.

As an optical manufacturer Laser Beam Products can justify the use of sensitive PC based temperature logging; this can measure precisely the amount of a probe laser beam an optic absorbs.

