LASER BEAM PRODUCTS

CO_2 Laser Reflective Mirrors:

Technical

Choosing Mirrors

A simple way of classifying the potential use of a mirror is to decide if the mirror is to be used for beam delivery (i.e. in the atmosphere) or in the laser cavity under vacuum.

Substrates

Copper – Has excellent heat conductivity, is readily available, and can be machined into various shapes. Generally used coated as oxidation occurs in the atmosphere. Use in the highest powered lasers both in beam delivery and for cavity optics.

Molybdenum - Hard, durable metal, but expensive and difficult to process. Always used uncoated. Natural reflectivity is poor (97%), limited to beam delivery use.

Silicon – Lightweight semiconductor that is cheap and easily polished. Never used uncoated. Difficult to machine and profile. Used in beam delivery and cavity applications. Limited to low and medium powered lasers.

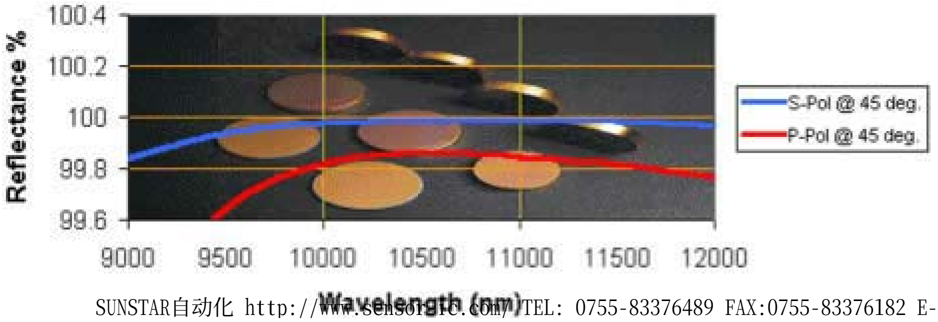
Aluminum- Lightweight metal, readily available, easily machined. Always used with coating such as gold. Often limited to scanning or where lightweight mirrors are needed. Can be used with low and medium powered lasers.

Beryllium – Lightweight stiff metal. Dust is severe health hazard and strictly controlled. Use limited to military and aerospace applications.

Coatings

Gold electroplate – Coating of choice for beam delivery, has zero phase shift to eliminate polarization effects. Will work at the very highest of powers and resists damage even when burnt or scratched. Not quite reflective enough for cavity use. Broadband reflectance is good for multi wavelength applications both pulsed and CW. Cannot be made on silicon.

Max R Dielectric – Favored for cavity use where the high reflectance of 99.9% is needed to give maximum power output. Can be used for beam delivery as well. Generally more fragile than gold coatings. UV resistance is an important feature for cavity optics. The reflectance is generally optimized for a specific wavelength and angle of incidence which must be known at time or ordering. Can be made on copper, or silicon.



Phase retarders – A vacuum deposited dielectric coating that introduces a ¼ wave phase shift. This circularly polarizes a linearly polarized beam. Very sensitive to incident angle (45 degrees) and wavelength (10.6 microns). Can be made on copper or silicon.

Laser Damage

Pulsed Laser Damage

The damage threshold of optics for use with true pulsed lasers such TEA CO_2 lasers is expressed in units of Joules/cm2, at a given pulse length.

It is difficult to scale this figure for damage threshold to account for different pulse lengths, but there is some correlation that the figure varies with the square of the pulse length. So for a pulse twice as long the damage threshold in units of J/cm2 is four times greater.

Gold coated copper has an enormous pulsed laser damage threshold of 46.7J/cm2 for a 80ns pulse length. The reason for this is the amorphous coating. Laser damage initiates at grain boundaries on the surface of a crystalline material. If the surface is amorphous (glass like, with no crystalline features) this disruption of the crystal boundaries (“slipbanding”) is eliminated and the damage threshold leaps to a higher value associated with melting of the metal.

Measurement of pulsed laser damage threshold is described well in a paper from NASA that can be found at
http://www.lbp.co.uk/Technical/PDF files/NASA-97-rp1395.pdf

CW Laser Damage

LBP in partnership with UK and European Universities has investigated the causes of Laser Damage and measured the Laser Induced Damage Threshold (LIDT) of many CO_2 laser optics.

This work has been published by SPIE:
Proc. SPIE Vol. 3244, p. 188-198, Laser-Induced Damage in Optical Materials: 1997, Gregory J. Exarhos; Arthur H. Guenther; Mark R. Kozlowski; M. J. Soileau; Eds.
Proc. SPIE Vol. 2714, p. 281-281, 27th Annual Boulder Damage Symposium: Laser-Induced Damage in Optical Materials: 1995, Harold E. Bennett; Arthur H. Guenther; Mark R. Kozlowski; Brian E. Newnam; M. J. Soileau; Eds.

The most important result is that Copper mirrors and ZnSe lenses in a typical industrial laser operate well within their Laser Damage Threshold. The reason(s) optics fail is entirely due to external factors from their operating environment. In particular, mechanical forces from mounting, clamping, etc significantly reduce the lifetimes of ZnSe lenses. Increased absorption from external contamination can quickly lead to laser damage. The difference between a good lens and a poor lens can be an increase in absorption of just 1 part per thousand.

Fortunately, the situation with copper mirrors is more forgiving as their ability to ”sink” heat is so much better. Gold coated copper mirrors are used on lasers of 40 KW power, and for 5 KW and above copper mirrors are the only realistic choice. Such a large power handling ability means that even when damaged or dirty, copper mirrors continue working with high power lasers.

For a laser with a 20mm beam diameter copper mirrors work at just a fraction of their potential:

Working power of copper mirrors				
Laser Power	2KW	4KW	5KW	20KW
Fraction of Laser Damage Threshold	2%	5%	6%	25%

Specifications

Metals are not an easy materials to polish or to obtain extreme optical specifications with.

By using advanced chemical polishing techniques, and the latest test equipment LBP has reached the physical limits possible with many metals such as copper, aluminum, and semiconductor materials such as silicon.

Specifications vary with the size of mirror, but can be confirmed at point of order. Many mirrors are made to customer drawings when the agreed specifications will be met.

By using typical specifications wherever possible parts will be the most cost effective.

Technical Specifications

Specification	Typical	Best	Comments
Diameter	+0/-0.12	+/-0.005mm	Imperial Tolerances also Accepted.
Thickness	+0/-0.12	+/-0.01mm	
Chamfers	0.4-0.6mm	n/a	n/a
Parallelism	3 arc mins	25 arc secs	n/a
Flatness(pwr)	1/2 wave vis	0.1 wave vis	Interferometer certificated
Flatness(irreg)	1/4 wave vis	0.1 wave vis	
Clear Apeture	90% of Diameter	100%	n/a
Polish Quality	20-10 Scratch/dig	Better than 10/5	Subjective test
Surface Roughness	5nm Ra	1nm Ra	Zygo measured
Reflectivity Gold	98.8%	99.1%	@10.6 Microns
Reflectivity Max R	98.85%	99.94%	
Phase Shift Gold	0.5 degree	n/a	
Phase Retarder	90+/- 3 deg	90+/- 1 deg	
CW Damage	4000W/mm	n/a	see website
Pulsed Damage	46.7 J/cm2	n/a	80ns pulse
Max Power(gold)	40KW+	n/a	Limit not known
Largest Diameter	150mm	n/a	n/a
Smallest Diameter	5mm	n/a	n/a

Cleaning Mirrors

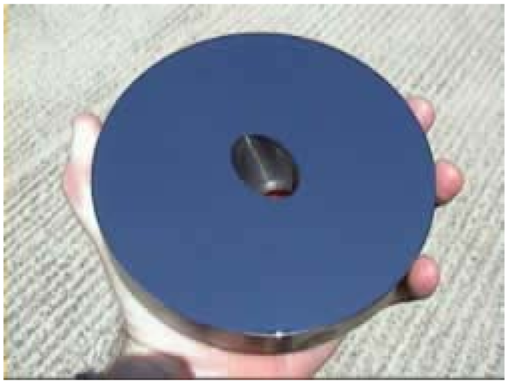
For high power optics (particularly ZnSe lenses) an increase in absorption of just 1 part per thousand can be the difference between success and failure.

There are many sources and types of contamination that can absorb the beam, leading to increased heating, optical distortion, and ultimately catastrophic failure of the optic.

To see a technical article on the nature of contamination and how it can affect an optic download this pdf file: contamination.PDF

Cleaning optics is a scientific task; done correctly the working life of optics can be extended greatly. Download this technical article to see how: cleanoptic.PDF

Heating of optics from absorption will lead to optical distortion. To find out how much and what affect this has in real applications download this technical article: thermalbehaviour.PDF



Surface Quality

Diamond Machined or Polished?

Even the latest diamond machining centers will produce optics with flycutting arcs, target patterns, and other artifacts in the optical surface. These cause laser light to diffract and scatter, and for visible light the losses can be so great that the beam is completely lost after several reflections.

Often diamond machined optics are “post polished” to remove the waviness and ripple in the machined surface. Even a casual observer can see these surface problems. Click here for a picture of a typical diamond machined surface. Sometime the cutting lines are seen as a “rainbow blaze” on a reflective surface.

Poor alignment of the cutting tool can leave a central spike in the mirror click here.

LBP have developed chemical polishing techniques used in the production of high quality UV optics, for producing infra red optics. Electroless nickel is an amorphous metal that can be polished to extreme smoothness, just a few angstroms of surface roughness.

The combination of chemical polishing and amorphous coatings mean LBP optics have the smoothest flaw free surfaces available.