Multi-layer dielectric (MLD) gratings for pulse compression

The rapid development of ultrafast lasers has prompted the need for new ultra-high performance, high damage threshold, diffraction gratings for pulse compression. HORIBA Jobin Yvon has been a leading supplier of gold coated pulse compression gratings since the development of the technique. Today HJY is developing unique MLD gratings[1] with higher damage threshold for very high power laser chirped pulse compression.

Traditional diffraction gratings for pulse compression applications are holographically recorded and coated with a gold metallic film. Metalized gratings have many useful features including diffraction efficiencies that can exceed 94% over a broad range of wavelengths. The groove profile as well as the optical properties of the metal coating determines the properties of the grating.

As far as laser induced damage threshold is concerned, gold coated gratings typically present the following values:

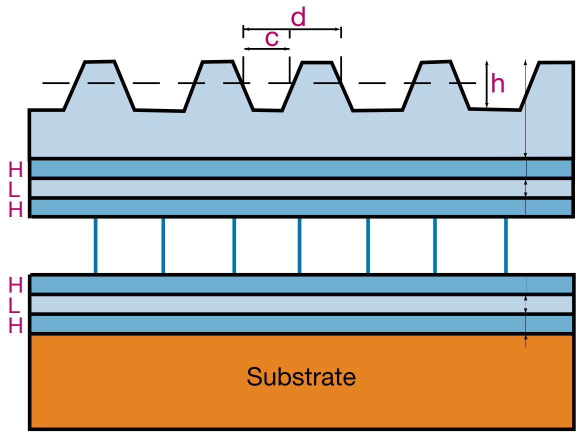
- 400 mJ/cm^2 on the grating surface for nanosecond pulses
- 250 mJ/cm^2 on the grating surface for picosecond pulses and lower fluences for shorter pulses or shorter wavelengths.

Relevant features

- High efficiency: typically from 92% to 95% absolute efficiency on TE polarization,
- Spectral domain: centred at 1053 nm with ~30 nm bandpass,
- Ideal for high energy lasers: Nd:glass (1053-1057 nm),
- Groove density: 1740 gr/mm,
- Wavefront quality: < λ/3 PV at 1053 nm.

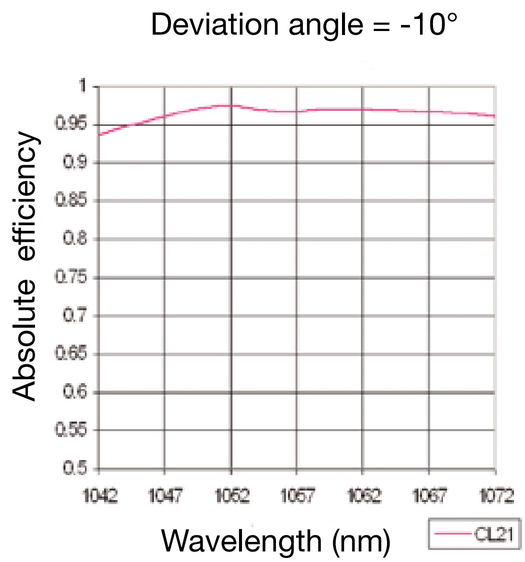
For many years Multi-Layer Dielectric (MLD) structures composed of alternating high and low index layers have been well known to be highly reflecting. At each interface between a low and high index pair about 4% of the light is reflected. Summing all of the light from the many layers gives an optic that can approach close to complete reflection. Since MLD structures are insulators they lack the conduction electrons that make metals good reflectors and thus can have intrinsically higher damage thresholds.
The manufacture of MLD gratings requires control of the stack of dielectric films, each of a predefined thickness, uniform coating of photoresist and very precise generation of the holographic pattern that defines the groove shape and distribution. The latent image in the photoresist is transferred permanently into the dielectric stack by ion etching.

A 210 x 420 mm size Multi Layer Dielectric grating

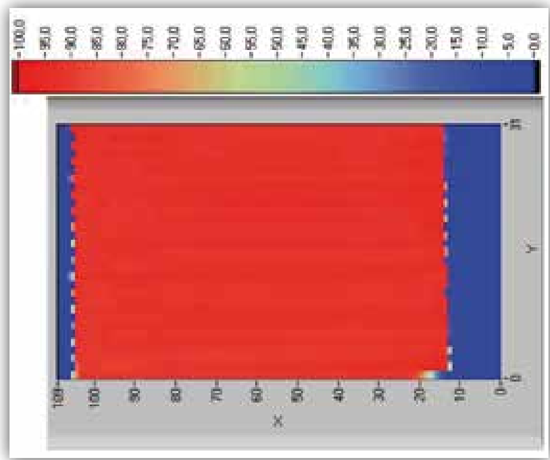


Multi layer dielectric grating, grooves engraved into the low index MLD upper layer

[1] *Sold in the US under license of Patent # 5,907,436*

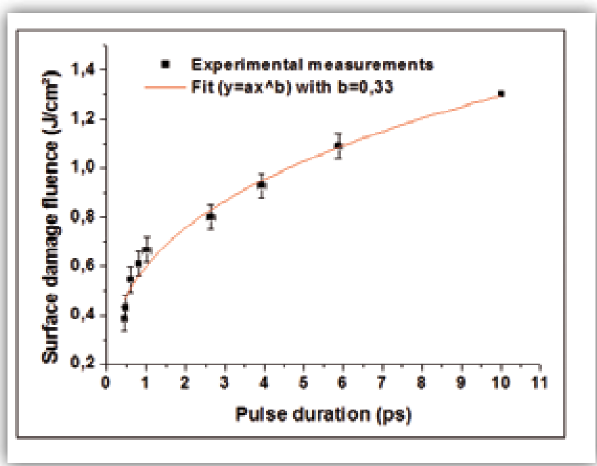


1740 l/mm, optimized 1053 nm, MLD grating bandpass



Efficiency map of 300x450mm, 1740 gr/mm optimized at 1053nm for Nd:glass Petawatt laser (average efficiency is measured at 94% with a high uniformity

This curve is for reference only and is not meant to be a specification.



Laser Damage Threshold (LDT) measurements of a MultiLayer Dielectric (MLD) grating vs pulse duration from 500fs to 10ps

Our damage threshold conversions

Influence of the incident beam angle: if 1.7 J/cm^2 fluence on the grating surface has been measured for 10 picosecond pulses, it may correspond to different beam fluences.
For example:
for 61° incidence, 1.7 J/cm^2 fluence on the grating surface, will be equal to 3.5 J/cm^2 beam fluence
(cos61° = 0.48);
and for 72° incidence, 1.7 J/cm^2 fluence on the grating surface will be equal to 5.5 J/cm^2 beam fluence (cos 72°=0.31).
Consequently, designs with higher incidence angle on the grating at the output of the compressor are expected to be favorable for damage threshold.

MLD gratings laser damage threshold (LDT) depends strongly on the pulse duration. In the femtosecond regime, the damage threshold of MLD gratings is around 3 times lower than at 10 picosecond and close to gold gratings damage threshold.

Blank size (nm)	Groove density (l/mm)	Central wavelength (nm)	Reference
165 x 220 x 30	1740	1053	524 40 223
210 x 420 x 50	1740	1053	524 40 525
335 x 485 x 50	1740	1053	524 40 820
420 x 450 x 43	1740	1053	524 40 920