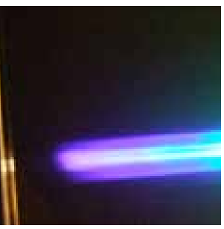
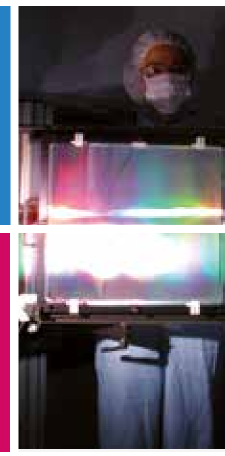
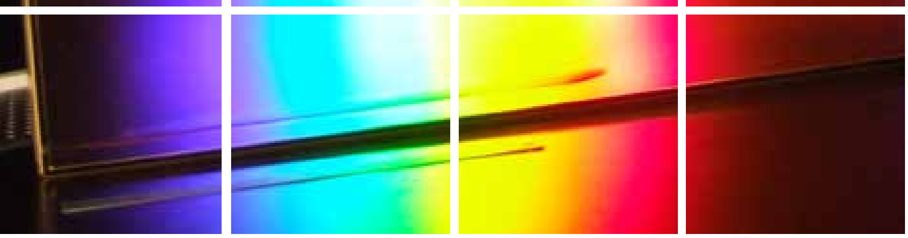
HORIBA
Scientific



Scientific Gratings & Custom Gratings





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JOBIN YVON
Technology

Commitment to quality

HORIBA Jobin Yvon offers complete customer service, including expert technical advice for optimizing system configurations to meet customers' needs.

HORIBA Jobin Yvon is ISO 9001:2000 certified, and our well-staffed departments are committed to customer satisfaction and product quality.

Contents

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Introduction

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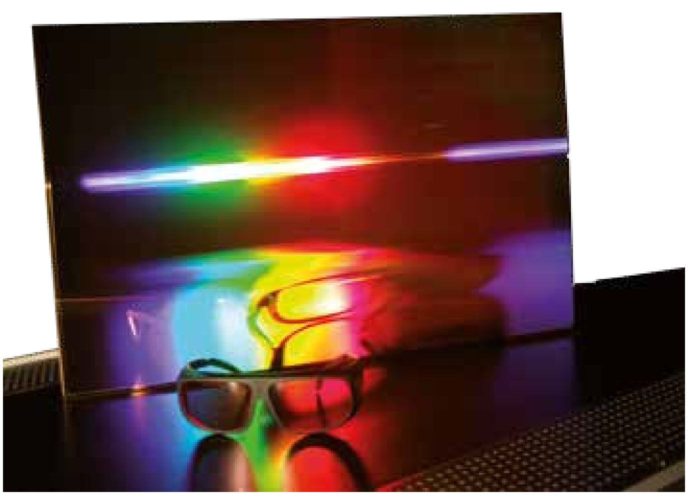


As a pioneer and world leader in the field of diffraction gratings, HORIBA Jobin Yvon continues to develop advanced manufacturing processes for scientific/custom diffraction gratings and optics.

Founded in 1819, HORIBA Jobin Yvon (HJY) has defined the leading edge of optics for spectroscopy for over 190 years. Our leadership in optics has been demonstrated by the continuing development of both ruled and holographic grating technology, including the invention of aberration-corrected holographic gratings and ion-etched blazed holographic gratings.

HORIBA Jobin Yvon's scientific/custom diffraction gratings are found in cutting-edge scientific applications including ultrafast and high-energy lasers, space flight instruments, astronomy, and synchrotron spectrometers. In addition, our high-volume replicated gratings are used in OEM instruments including spectrophotometers, bioanalyzers, and colorimeters. HJY's gratings for high volume OEM instruments can be found in our OEM Gratings catalog, while this catalog focuses on diffraction gratings for scientific and research applications.

HORIBA Jobin Yvon's scientific gratings are either masters or replicas, depending on the application. HORIBA Jobin Yvon also produces custom diffraction gratings, which can be specified according to our customers' unique technical requirements.

Contact your HJY representative for assistance with choosing the right grating for your application

our website: www.horiba.com/scientific/grating

our email: gratings.sci@horiba.com

Advanced technologies for grating production

A diffraction grating is produced by first ruling or holographic recording a master grating. We can then replicate this master into a large number of exact copies, called replicas, for cost savings and product consistency.

Master gratings are manufactured using the following technologies:

- Holographic recording
- Ion-etching of holographic master
- Mechanical ruling

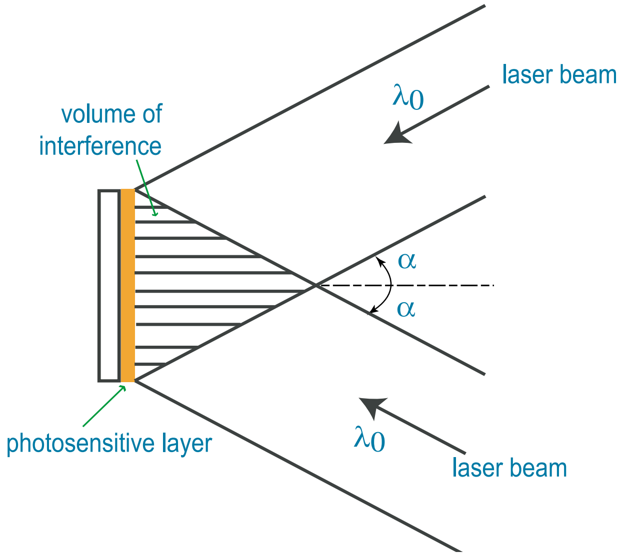
Holographically recorded gratings

The era of modern holography began in the 1960s with the use of lasers as coherent light sources. In 1967 the HORIBA Jobin Yvon engineering team, led by J. Flamand and A. Labeyrie, produced the first holographically-recorded diffraction gratings. Intensive R&D efforts led to HJY's production of holographically-produced aberration-corrected gratings, for which the company was awarded numerous international patents.

Holographic recording setup

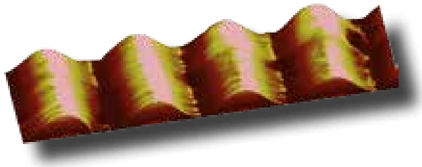
To manufacture holographic gratings, highly-polished and precisely-figured blanks (exceeding λ/10 for many applications) are coated with a layer of photosensitive material, which are then exposed to fringes created by the interference of two coherent laser beams. Chemical treatment of the photosensitive layer selectively dissolves the exposed areas of the photoresist layer, forming grooves in relief.

Through careful design and configuration of the holographic recording apparatus, we can obtain plane and concave "Type I" gratings (parallel grooves, uniformly spaced), or "Type IV" gratings with variable-spaced grooves for full aberration correction. Optimization of the holographic recording geometry requires optomechanical stability far greater than most optical applications.



Recording a plane holographic grating with straight and equidistant grooves: type 1

The shape of the grooves produced by holographic recording is typically sinusoidal or pseudo sinusoidal (sinusoidal profile, AFM image below).



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Signal-to-noise ratio of holographic gratings

In many applications, the most important system parameter is the signal-to-noise ratio. The signal level is proportional to light collection properties and efficiency of the grating. For a classically ruled grating, the noise arises from ghosts (associated with periodic errors in the lead or pitch of the high precision screw), and from stray light due to random, non-periodic surface defects and the roughness of the reflecting surfaces.

Holographic recording produces grooves that are perfectly equi-spaced, completely eliminating all ghosts due to periodic errors. The overall quality of the grating surface is such that imperfections and roughness are considerably less than those found in classically ruled gratings, thus reducing stray light. In addition, the holographic technique is well-suited for producing large numerical aperture concave gratings (F/2 or even more).

As a result, holographic gratings generally present a much higher signal-to-noise ratio compared to classically ruled gratings.

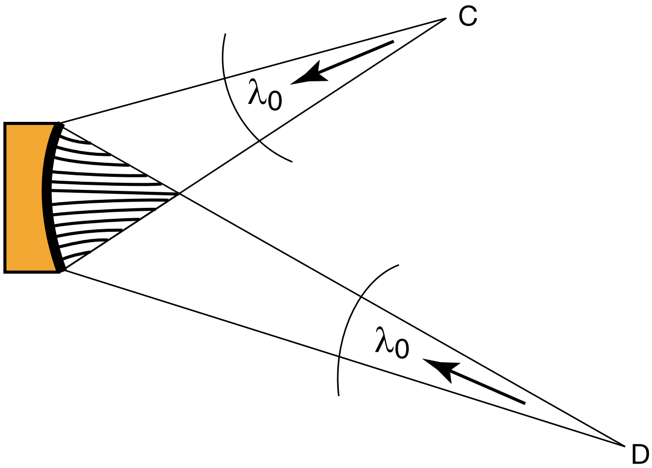
Type I, plane and concave gratings

For the production of plano and concave Type I holographic gratings, the two recording beams are collimated and oriented symmetrically with respect to the grating normal. Gratings produced in this manner have grooves which are parallel with a constant pitch.

We produce Type I grating masters for many applications, including high-energy ultrafast lasers, spaceflight and astronomy, and vacuum ultraviolet systems, and we produce Type I replicas for general spectroscopic applications. Large-aperture holographic gratings are routinely produced in our laboratories, up to 600 mm in dimension.

Type IV, aberration corrected gratings

Type IV aberration-corrected gratings are typically recorded using two point sources. As a consequence, the grating grooves are no longer straight and parallel, but instead correspond to confocal hyperboloids or ellipsoids. Optimizing the position, angles and arm lengths of the two sources provides the optical designer with the degrees of freedom necessary to minimize aberrations, typically astigmatism and coma. Auxiliary optics such as gratings provide the optical designer with additional flexibility for recording more specific goove patterns and distributions (see US patent 4842353 “Diffraction apparatus with correcting grating and method of making,” A.Thevenon et al., for a description of our methods).

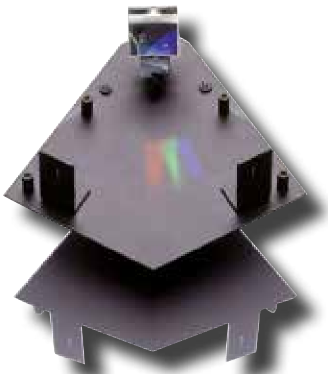


Recording a concave holographic grating type IV: aberration corrected

Type IV aberration-corrected gratings have become the dispersive element of choice in many spectroscopic systems, as they require no other optics in the instrument for imaging or focusing. These gratings are used in various configurations, including monochromator, spectrograph and monograph (scanning spectrograph) systems.

Using this technology, HJY has designed several new grating types for specific applications: **Type IV, Aberration Corrected, Flat Field and Imaging Gratings:** These concave gratings disperse, collimate and refocus light from the entrance slit onto a plane surface; these gratings are well-suited to take advantage of solid-state detectors with either a linear or 2D array of independent photosensitive elements.

Type IV, Aberration Corrected, Monochromator Gratings: these concave gratings are specifically designed for use with an entrance slit and an exit slit. Wavelength scanning is performed by a simple rotation of the grating.



H1061 monochromator

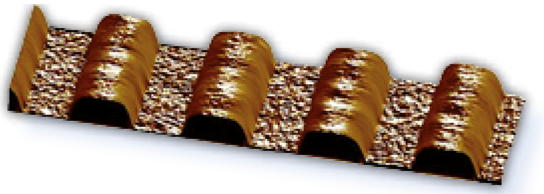
Variable Line Spacing Gratings (VLS gratings) for Vacuum UV applications: Gratings and mirrors used in the far vacuum UV and soft X-ray regimes must be operated in grazing incidence, to enhance the reflectivity of the coatings. The considerable astigmatism of traditional Type I concave gratings at grazing incidence results in low signal throughput at the instrument exit slit. To correct astigmatism and coma in this difficult case, HJY has developed specific aberration corrected plano and concave holographic gratings, which present a variation of the groove density according to a specified polynomial law (VLS gratings).

HJY optical engineers will recommend a standard Type IV aberration-corrected grating or will custom-design a specific aberration-corrected grating to maximize performance for a given application.

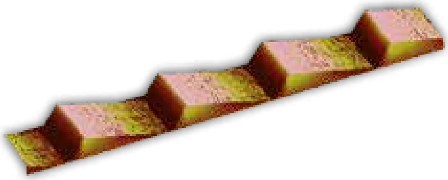
Ion etching

Ion etching allows the shape of the grooves on a holographic master grating to be "sculpted" as needed for an application. It is possible to produce blazed holographic gratings with different groove shapes, including triangular and laminar profiles.

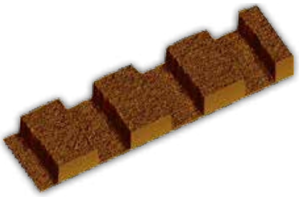
The technique uses an ion etching system to mill surface atoms through a holographic mask. This holographic mask is formed by the illumination, and subsequent chemical processing, of a laser generated interferogram in photoresist. The process is compatible with plano, spherical, and aspheric substrates.



Initial pseudo sinusoïdal, holographically recorded groove profile



Triangular holographically recorded and ion etched groove profile



Laminar holographically recorded and ion etched groove profile

Ion-etched 'sawtooth' profiles enhance efficiency at the blaze wavelength in the first order, as well as in the higher diffraction orders. Laminar groove profiles can be designed to minimize or nearly eliminate undesirable second-order efficiency.

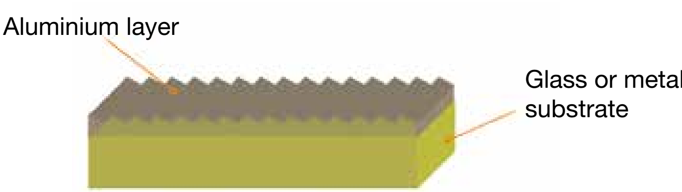
Ion-etched gratings can be replicated for quantity production, but they are often used directly as master gratings. In this case the grating grooves are ion-etched directly in the blank itself, resulting in a grating which is very robust, even under the extreme illuminations of the most intense synchrotron light sources.

Mechanical ruling

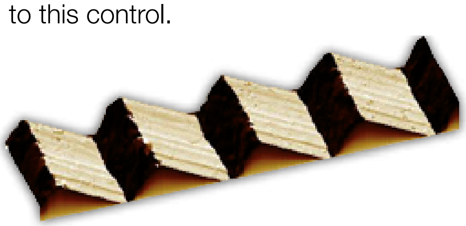
Classically-ruled master gratings are produced by first evaporating a coating of gold or aluminum onto a highly-polished substrate, and then mechanically burnishing triangular grooves using a precision diamond tool.

The incredible specifications required for the ruling of gratings demand such a high degree of technology, that few facilities in the world are able to produce them. The ruling engine at HJY is one of the rare operating machine which made gratings for space experiments.

The most important requirement of the ruling engine is that the diamond carriage follows an exact path on each stroke. Any lateral displacement will introduce an error in the groove spacing of the finished grating. The carriage rides on perfectly-smooth tracks, under the very precise control of a heterodyne laser interferometer which controls the carriage displacement in order to maintain absolute parallelism and displacement accuracy.



Finally, the exact profile of the groove must be faithfully maintained across the entire surface of the grating. Any wear of the ruling tool during the course of operation must be compensated; an Atomic Force Microscope (AFM) is devoted to this control.



Diamond ruled sawtooth profile

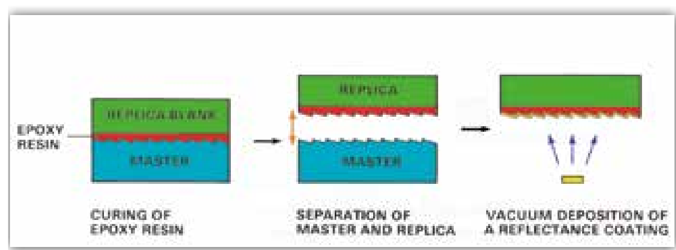
Given the difficulties (and associated high costs) of ruling a grating, most of the gratings used in instruments are more-affordable replicas of the directly ruled master grating.

HORIBA Jobin Yvon has one of the widest inventories of ruled masters from which we produce high precision replicas.

High precision replication

Once a master grating has been manufactured according to the techniques previously described, it can be replicated to produce exact copies of the original. A replica blank of high optical quality is coated with a layer of epoxy and "sandwiched" together with the master. When the epoxy is cured, the master and replica are separated and the epoxy layer remains attached to the replica substrate. The epoxy layer is now an exact copy of the grooves of the master, and this replica can now be coated with a reflective layer using vacuum deposition. It is possible to replicate gratings with many different shapes, including spherical and mildly aspheric surfaces.

The replication process is highly accurate. Replica gratings retain the diffracted wavefront, efficiency, and stray light characteristics of the master to a very high degree.



The reproducibility of replica gratings makes them ideal for high-volume production, and for scientific experiments in which a smaller quantity of absolutely identical gratings are required.

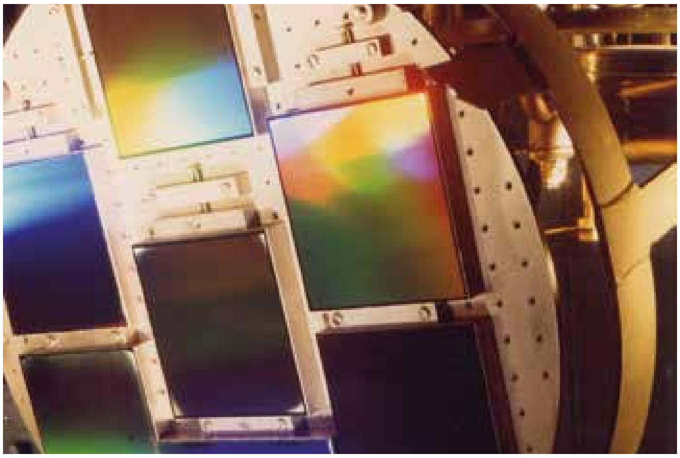
Production facility

HORIBA Jobin Yvon has two grating manufacturing facilities, in Longjumeau, France (near Paris) and in Edison, New Jersey (USA). Between these facilities HORIBA Jobin Yvon possesses a wide array of technological resources for grating manufacturing and metrology:

- Holographic recording (to half-meter dimension)
- Ion etching for small and large size gratings
- Ruling engines
- Large vacuum coating (equipment)
- Optical polishing, with highest specifications in slope error and microroughness
- Grating metrology tools, including atomic force microscopes, interferometers, efficiency measurement systems, and microroughness measurement systems
- Two operational replication facilities

Quality control: efficiency measurement

Grating facilities are installed in high class cleanrooms



Quality control: microroughness measurement

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Custom gratings

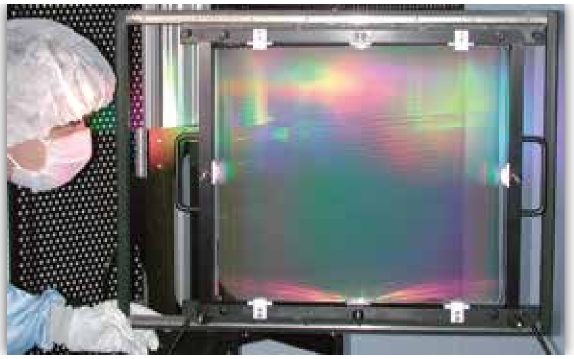
The Custom Gratings activity at HORIBA Jobin Yvon addresses the needs of the scientific community for very specific, high-performance diffraction gratings. This group excels in designing and manufacturing challenging diffraction gratings for applications including space flight, astronomy, laser pulse compression, high energy lasers, synchrotron and XUV sources.

For over 40 years, HORIBA Jobin Yvon has played a leading role in the design, development and manufacture of master and replica custom diffraction gratings for laboratories throughout the world.

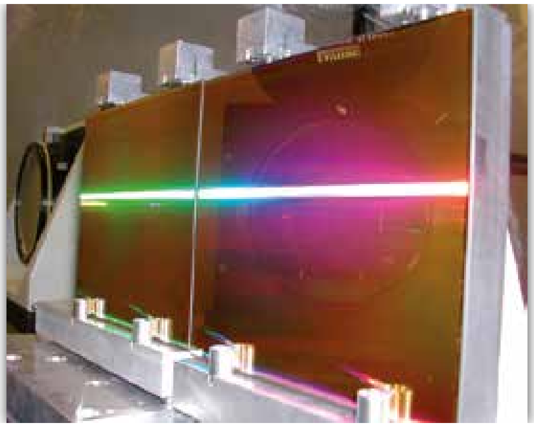
Our recent groundbreaking work such in the development of large, high-efficiency, high-energy transmission gratings for the French MegaJoule Laser (LMJ) program is one well-publicized example of HJY's long tradition of innovation in the field of diffraction grating technology.

In the field of Space Science, HJY is regularly selected by NASA and ESA to provide gratings for the most demanding missions.

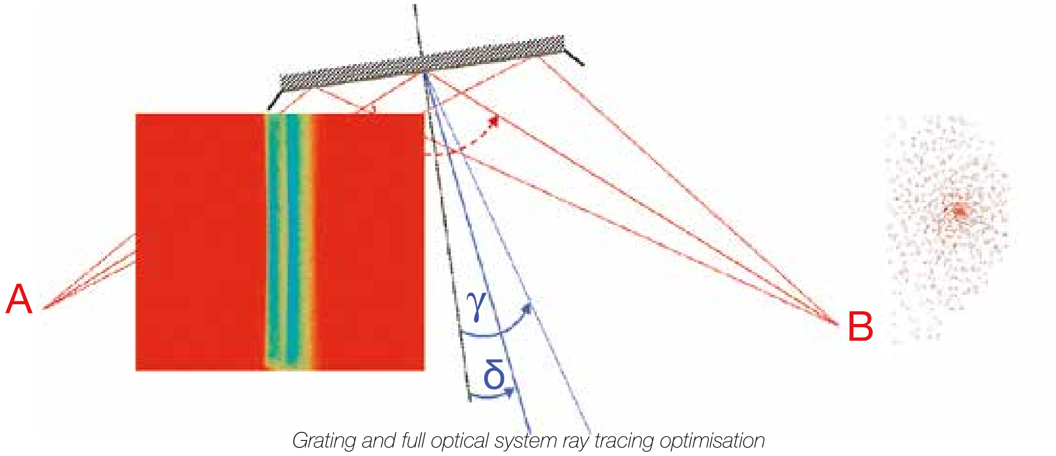
A full team of HORIBA Jobin Yvon optical engineers is dedicated to supporting our customers' design efforts, and to help optimize custom gratings for specific applications. Our extensive experience, combined with our strong optical modeling capabilities, allows us to partner with our customers and provide the best solution for performance and cost.



90% high efficiency transmission grating, 420x470 mm size for high energy lasers (LMJ)



Laser pulse compression gratings optimized for tiling



Grating and full optical system ray tracing optimisation

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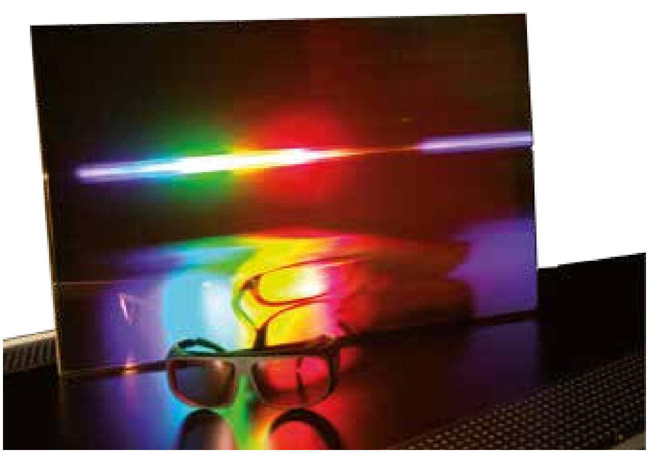
Gratings for laser pulse compression

Gold coated master pulse compression gratings

HORIBA Jobin Yvon has produced the first holographic gratings for the demonstration of the Chirped Pulse Amplification (CPA) technique in 1985 [1]. Diffraction gratings are widely used now for pulse compression in CPA laser systems. High diffraction efficiency, high wavefront quality and high damage threshold are essential characteristics for these gratings.

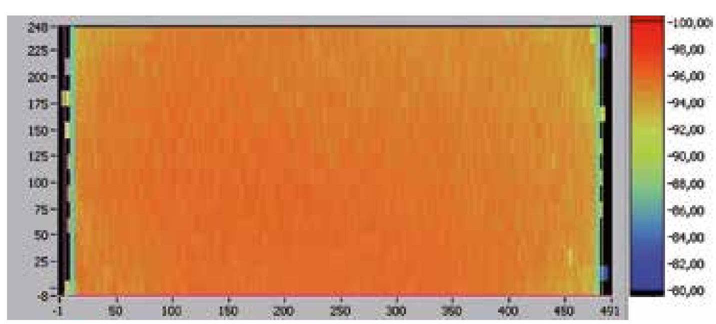
HORIBA Jobin Yvon has pioneered the design and development of pulse compression gratings using holographic techniques. By carefully designing the grating groove parameters, gold-coated pulse compression gratings **can achieve typically diffraction average efficiencies as high as 94% at 800 nm (TiSa), 910 nm (OPCPA), 1030 nm (Ytterbium), 1 053 nm (Nd glass) or 1.55 µm.** In addition, the holographic manufacturing technique can produce very large gratings that demonstrate an excellent uniformity and quality of the diffracted wavefront.



Relevant features

- High efficiency: typically from 90% to 94% absolute efficiency on TM polarization,
- Operation in large spectral domain: from 600 nm to 1600 nm,
- Ideal for ultrafast lasers: TiSa (800 nm), OPCPA (900 nm), Ytterbium (1030 nm), Nd:glass (1053 nm), ...
- Groove densities: in standard 1200, 1480 and 1740gr/mm,
- Dimensions: Up to H360xL565xT40 mm,
- Large range of standard and custom sizes for all groove densities,
- High wavefront quality: up to λ/20 RMS of holographic error,
- Custom gratings design to match with your pulse compressor.

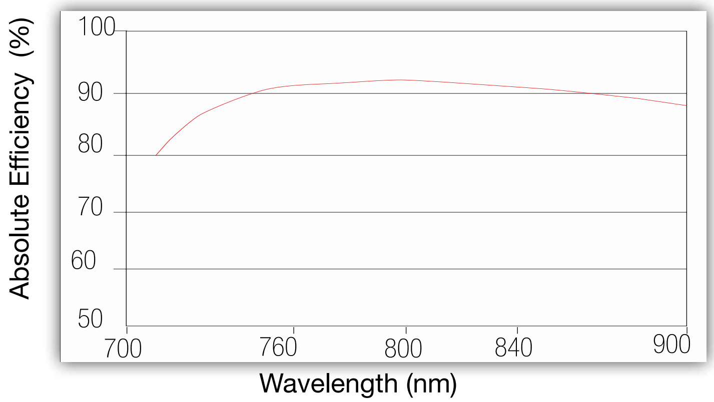
In CPA lasers where the highest optical performance and damage thresholds are required, a master gold-coated holographic grating ensures best performances. Master gratings are the technology of choice for large-area gratings, and HJY currently supplies a large range of several standard sizes up to **360 x 565 mm**. Standard groove densities include **1200, 1480 and 1740 lines/mm**, for operation in the spectral range from 600 nm to 1600 nm. Custom sizes can be considered up to 500x500 mm, and alternate groove densities, non-standard wavelength optimization, and/or larger grating sizes will be reviewed upon request.



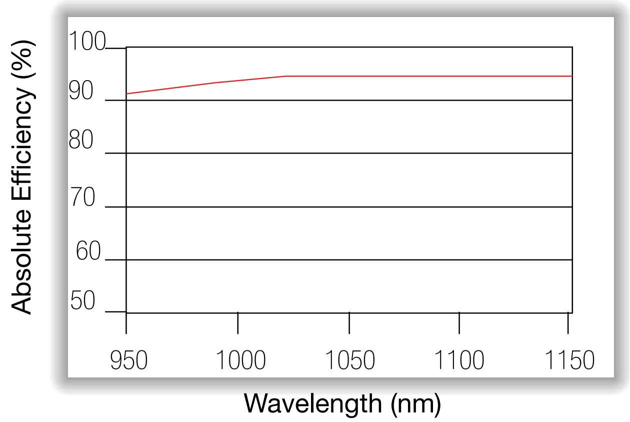
Efficiency map of 300x485mm, 1480gr/mm optimized at 800nm for Ti:Sa Petawatt laser (average efficiency is measured at 94% with a high uniformity)

[1] D. Strickland and G. Mourou, «Compression of amplified chirped optical pulses», Opt. Comm. 56 (1985)

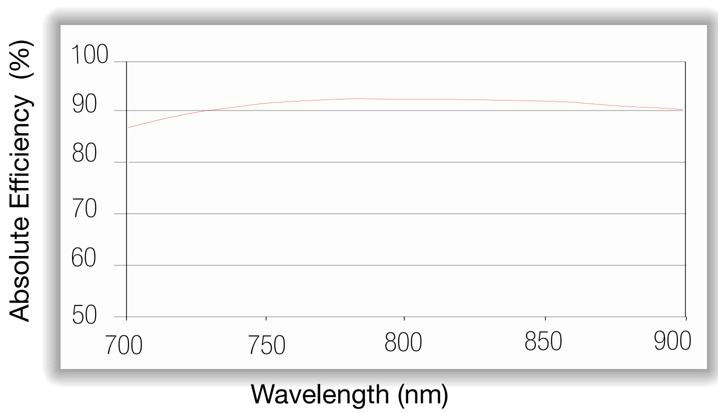
Typical theoretical diffraction efficiencies for pulse compression gratings



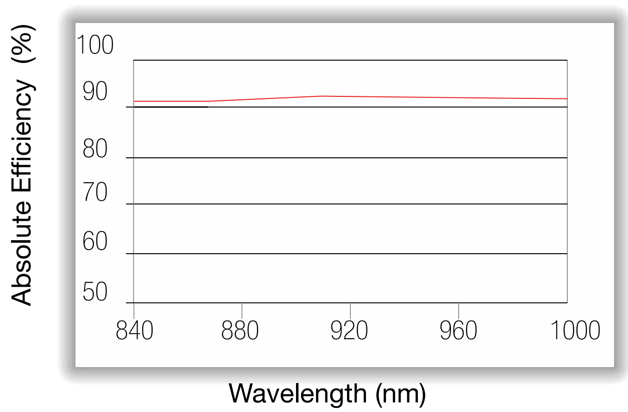
1200 g/mm, 800 nm (TiSa), TM, deviation=10°, Au coating



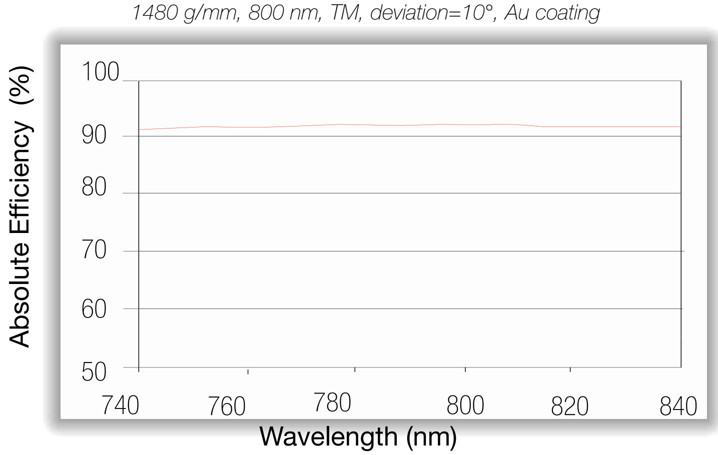
1200 g/mm, 1053 nm, (Nd: glass), TM, deviation=10°, Au coating



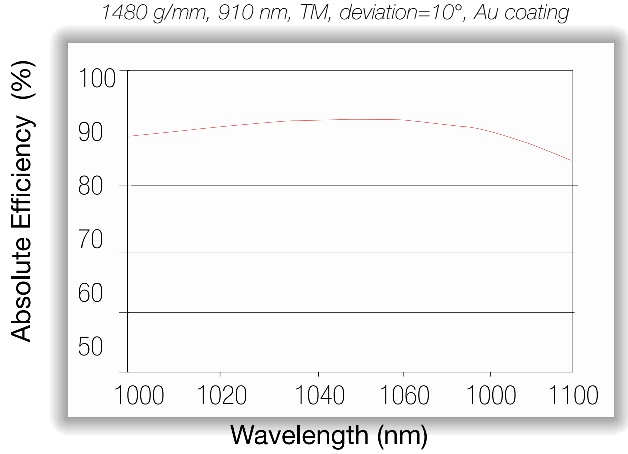
1480 g/mm, 800 nm, TM, deviation=10°, Au coating



1480 g/mm, 910 nm, TM, deviation=10°, Au coating



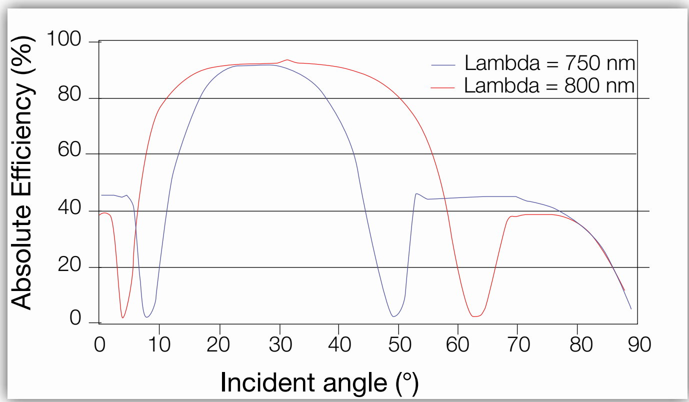
1740 g/mm, 800 nm, TM, deviation=10°, Au coating



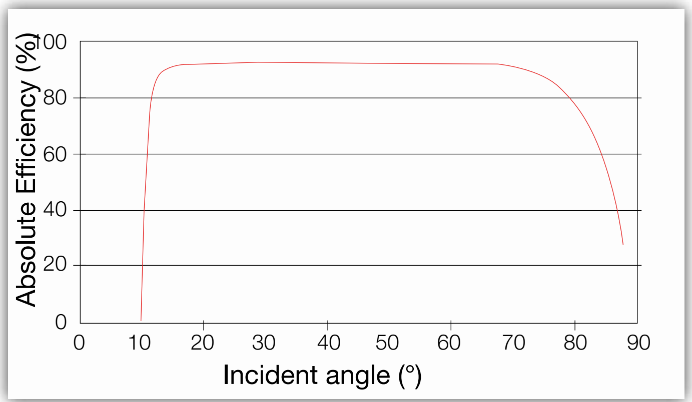
1740 g/mm, 1053 nm, (Nd glass), deviation=10°, Au coating

These efficiency curves are absolute theoretical efficiencies, calculated using rigorous electromagnetic theory, taking into account the true groove profiles of manufactured gratings measured with an atomic force microscope (AFM). These curves are for reference only and do not indicate grating specifications.
These efficiency curves are calculated with constant deviation angle of 10°.

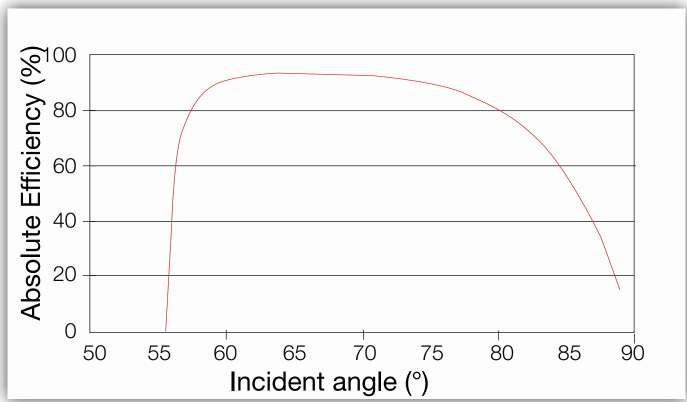
Diffraction efficiency according to incident angle



1200 gr/mm, 750nm and 800 nm, variable incidence, TM, Au coating, Littrow angle = 28.7° at 800 nm



Typical absolute efficiency vs Incidence Angle 1480 gr/mm, coating Au, wavelength = 800 nm, TM



Typical absolute efficiency vs Incidence Angle 1740 gr/mm, coating Au, wavelength = 1053 nm, TM

The efficiency can vary significantly depending upon the user geometry.

Efficiency values depend primarily on deviation angle (angle between incident beam and diffracted beam). In general, if deviation angle does not exceed 15°, the efficiency and bandpass remain stable, if deviation angle exceeds 15°, a careful evaluation is necessary (see 1200 gr/mm grating variable incidence efficiency curve example).
For the same deviation angle, bandpass depends on the incidence angle being smaller or larger than the Littrow angle (less or more grazing incidence angle). In general more grazing incidence angle is more favorable for the bandpass.

Guaranteed specifications

- Efficiency at optimised wavelength (800 nm, 1053 nm, ...)

> 90% average absolute efficiency on TM polarisation, in near-Littrow configuration (10° deviation angle between the incident and diffracted beams)

- Wavefront quality

Typically better than $\lambda/4$ at optimized wavelength (800 nm, 1053 nm,...) in the -1 diffracted order

- Ruled area

Please find the warrantied ruled areas according the substrate size:

Size code	Blank size	Warrantied ruled area
090	40 x 60 x 10	36 x 56
160	80 x 110 x 16	76 x 106
180	110 x 110 x 16	106 x 106
200	120 x 140 x 20	115 x 135
208	135 x 175 x 30	125 x 165
223	165 x 220 x 30	155 x 210
504	190 x 350 x 40	180 x 340
524	210 x 420 x 40	200 x 410
X51	300 x 485 x 40	290 x 475
930	360 x 565 x 40	340 x 545

Substrate material

Standard substrate material can be fine annealed Pyrex®, fused silica or low thermal expansion material depending on application, size and availability.
It may be of interest for high repetition rate laser in order to avoid any temperature effect on laser stability.

Delivered documentation with master pulse compression gratings

For large gratings (165x220 mm and larger):
- Absolute efficiency, measured in nine spots distributed over the clear aperture of the grating
- Interferograms of -1 order and 0 order wavefronts
- A certificate of conformity

For small gratings:
- Absolute efficiency, measured in the center of the grating
- Quality of the -1 order diffracted wavefront
- A certificate of conformity

		80x110x16	110x110x16	120x140x20	135x175x30	165x220x30	190x350x40	210x420x40	300x485x40	360x565x40
1200 l/mm	750-850 nm	524 26 160	524 26 180	524 26 200	524 26 208	524 26 223	524 26 504	524 26 524	524 26 X51	
	1.06 µm	524 27 160	524 27 180	524 27 200	524 27 208	524 27 223	524 27 504	524 27 524	524 27 X51	
	1.55 µm	524 33 160	524 33 180	524 33 200	524 33 208	524 33 223	524 33 504	524 33 524	524 33 X51	
1480 l/mm	750-850 nm	524 28 160	524 28 180	524 28 200	524 28 208	524 28 223	524 28 504	524 28 524	524 28 X51	524 28 930
	1.06 µm	524 29 160	524 29 180	524 29 200	524 29 208	524 29 223	524 29 504	524 29 524	524 29 X51	524 29 930
1740 l/mm	750-850 nm	524 20 160	524 20 180	524 20 200	524 20 208	524 20 223	524 20 504	524 20 524	524 20 X51	524 20 930
	1.06 µm	524 21 160	524 21 180	524 21 200	524 21 208	524 21 223	524 21 504	524 21 524	524 21 X51	524 21 930

Replica gratings for pulse stretcher and compressor

HORIBA Jobin Yvon has traditionally provided master gratings for pulse compression applications, to ensure the highest optical performance and damage threshold. Master gratings are manufactured by HJY in both small and large dimensions.

We have also developed a very accurate replication process for producing high-quality and lower cost replica gratings. These replica gratings are the perfect solution for grating pulse stretching. This specific replication process is available for small size gratings up to 110 x 110 mm in dimension.

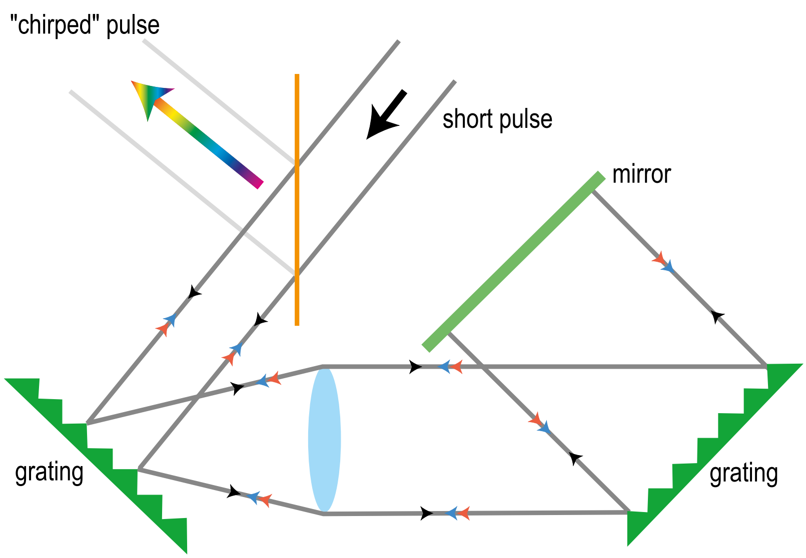
All replica gratings for pulse stretcher or compressor are gold coated.

Relevant features

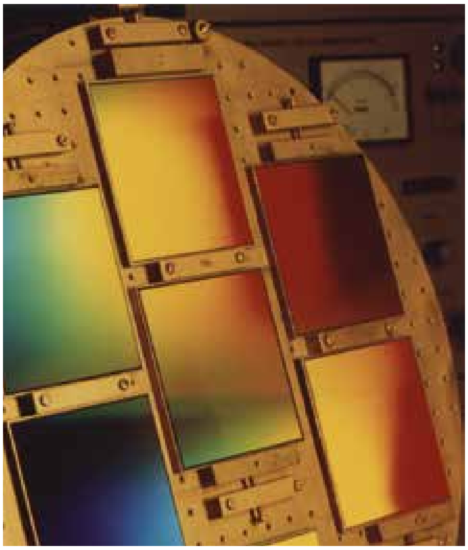
- Absolute efficiency on TM polarization: > 86%,
- Surface Flatness: < lambda/3 PV at 800nm or 1053nm,
- Coating: gold,
- Several groove densities and dimensions are available,
- Cost effective solutions for pulsed strecher and compressor

Delivered documentation with replica pulse compression gratings

o Absolute efficiency, measured in the grating center location
o Quality of the -1 order diffracted wavefront
o A certificate of conformity



Grating replication



	1200 l/mm		1480 l/mm	1740 l/mm
blank size (mm)	750 to 850 nm	1.55 µm	750 to 850 nm	1.06 µm
40x60x10	C524 26 090/T3	C524 33 090/T3	C524 28 090/T3	C524 21 090/T3
80x110x16	C524 26 160/T3	C524 33 160/T3	C524 28 160/T3	C524 21 160/T3
110x110x16	C524 26 180/T3	C524 33 180/T3	C524 28 180/T3	C524 21 180/T3

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:

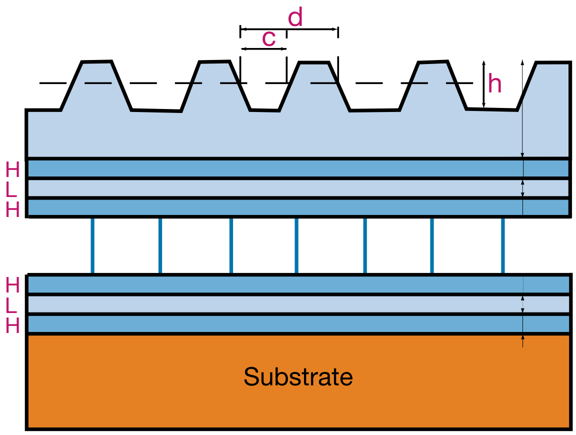
- 400 mJ/cm^2 on the grating surface for nanosecond pulses
- 250 mJ/cm^2 on the grating surface for picosecond pulses and lower fluences for shorter pulses or shorter wavelengths.

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.

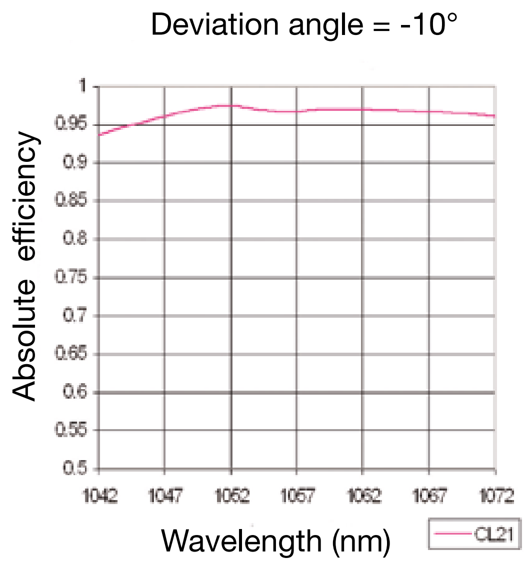
For many years Multi-Layer Dielectric (MLD) structures composed of alternating high and low index layers have been well known to be highly reflecting. At each interface between a low and high index pair about 4% of the light is reflected. Summing all of the light from the many layers gives an optic that 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

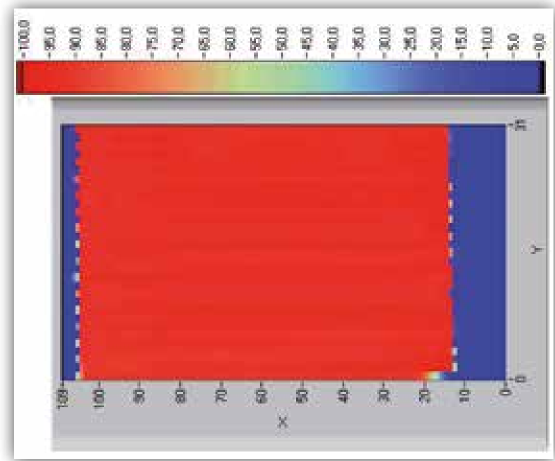


Multi layer dielectric grating, grooves engraved into the low index MLD upper layer

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

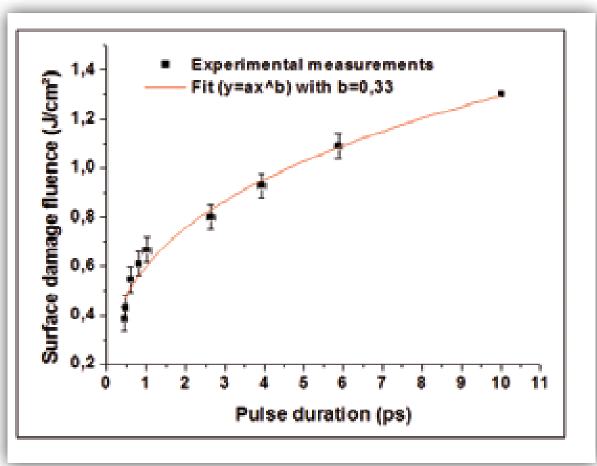


1740 l/mm, optimized 1053 nm,
MLD grating bandpass



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

Transmission gratings for high energy lasers

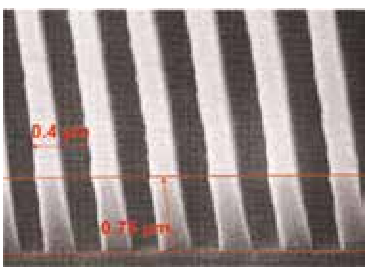
The Laser Megajoule (LMJ) gratings

The Laser Megajoule (LMJ) is a high energy laser facility under construction in Bordeaux for the French nuclear research agency (Commissariat à l'Energie Atomique, CEA). At completion, 208 pulsed laser beams will be focused on a 2 mm target, delivering 2 MJ and producing the high density, pressure and temperature conditions where nuclear fusion triggers.

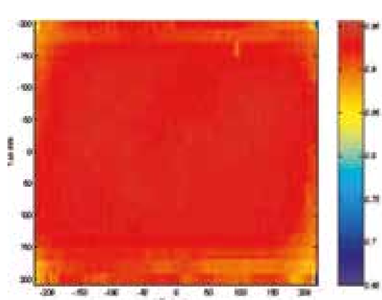
An original feature of the LMJ is the use of large diffractive optic components, where the only compar-able system in the world (the American National Ignition Facility at Lawrence Livermore Laboratories in California) uses classical dioptric components.

Thanks to a close cooperation between CEA and HJY scientists, the feasibility of these unique components (400×400 mm focusing gratings) was confirmed and production started in 2000 for the demonstration prototype which confirmed the high performance of the design.

The profile figure presents the SEM profile of the gratings produced at HJY: the groove depth is 2 times the period which was a real challenge. The uniformity over the 420x470 mm surface is also a technological achievement.



SEM groove profile of 2500 l/mm transmission grating



The efficiency map of a 1w LMJ transmission grating demonstrates the large scale ion-etching uniformity

Relevant features

- Transmission gratings for nanosecond high-energy lasers,
- 1ω grating optimized at 1053 nm,
- 3ω grating optimized at 351 nm,
- Large dimensions: 420x450mm,
- High efficiency: > 90% absolute efficiency on TM polarization,
- High damage threshold.

Specifications of the transmission gratings for high energy lasers

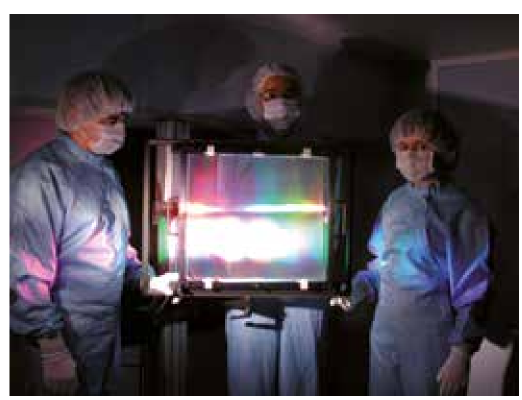
To produce the LMJ-type transmission gratings, we produce first a holographic mask, then we transfer the mask modulation directly into the fused silica substrate. So the grating is made only of fused silica (without any photoresist on epoxy layer). As a result the laser-induced damage threshold is as high as a fused silica plate.

We are producing two types of transmission gratings for high energy lasers:

- gratings 1w: gratings with straight and equidistant lines, 800 l/mm, optimized for 1.053 µm, 92 to 94% average efficiency on TM polarization.

- gratings 3w: focusing grating with curved and non-equidistant lines, 2400 l/mm optimized for 351 nm, 90 to 92% average efficiency on TM polarization.

This focusing grating acts as a stigmatic focusing lens.



Gratings for astronomy and space experiments

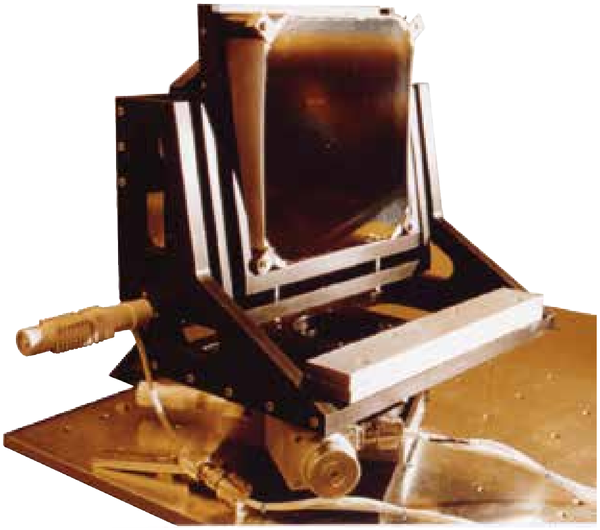
Holographic master and replica gratings: HJY expertise in gratings for space experiments

HJY has been producing gratings for space experiments since 1968. The first ruled gratings were produced for the French space experiment D2A in 1970.

HJY has produced some of the most technically-challenging space-flight gratings ever designed, applications ranging from off-plane X-ray gratings to toroidal VLS gratings for the VUV and transmission deep groove gratings for the IR range.

For example, HJY produced the four gratings for NASA/JHU FUSE spectrograph.
The gratings are 5800 gr/mm, aberration corrected, holographically ruled on 300x300 mm, aspherical light weight ceramic.

A prototype FUSE spectrograph grating being removed from a vacuum tank in a clean room at HORIBA Jobin Yvon. The FUSE gratings are approximately a foot square with 5300-5800 lines per millimeter etched onto the surface (the exact number changes as a function of position across each grating, and they are slightly curved). These etchings are what disperse far-UV light into a spectrum for analysis, and provide the high spectral resolution of the spectrograph.



Relevant features

- Long experience and expertise on gratings for astronomy, space flights
- Custom design,
- High efficiency and low stray light,
- Large range of groove densities available,
- Large spectral range : from VUV to IR.

FUSE spectrograph with four aberration corrected holographic gratings, 5800 l/mm, 300x300 mm

HJY has also often been selected by NASA and ESA for their most demanding missions. A very reduced list includes:

SOHO SUMER	France + Germany
SOHO UVCS	USA
STIS (Hubble telescope)	USA
GALEX	USA + France
ROSETTA Alice	USA + France
COS (Hubble telescope)	USA
SOFIS	Japan
SPICAM/ MARS Express	France
OMI - EOS	Netherlands
LYMAN FUSE	USA + France
ROALEX	USA
GOMOS (Hubble telescope)	France + Belgium
MERIS/ENVISAT	France
UVS MARS	Japan
GOME	Italy
WEASAT	China

Recently we produced gratings for missions such as EVE (NASA/LASP) and SSULI (NRL).

gratings.sci@horiba.com
www.horiba.com/scientific/grating

HJY receives NASA award

HJY received the NASA award "Commitment to Excellence in Technology Achievement" for its grating technology contribution for its specific support on the COS project.

"In recognition of your holographic gratings for the COS instrument that will enable a new generation of scientific exploration for the Hubble Space Telescope […] and every person who looks to the sky in wonder […] **the gratings were delivered above the specification, on time and within cost**," said Prof. Jim Green.

Production and test facilities

HORIBA Jobin Yvon's underground grating labs provide the necessary environmental stability required to mechanically rule and holographically record the highest-specification diffraction gratings.

Our ruling engines, lasers, collimators, optical components, and chemical processing equipment are housed in clean rooms throughout the facility.

Coating and chemical operations are performed in our own processing laboratory. The lab is geared to accommodate all the company's replication and deposition requirements with equipment including fully-automatic high-vacuum evaporation systems.

All equipment involved in handling and processing of master gratings are operated in different cleanrooms down to class 100.

Space qualification

Space qualification was achieved for HJY's ruled and holographic gratings (masters and replicas) by the French CNES as early as 1971 and 1972, when we produced gratings for the D2B satellite.

Wolter mirror (manufactured by replication)

LDEF (Long Duration Exposure Facility)
NASA experiment

HORIBA Jobin Yvon ruled and holographic gratings were aboard the LDEF satellite, which stayed in space for 69 months before retrieval by the Space Shuttle. Extended space vacuum experiments (34000 orbits, with thermal cycling each orbit) demonstrated that HJY's ruled and holographic gratings (masters and replicas) maintained wavefront quality, stray light levels, and absolute efficiency under harsh space conditions.

Bulk transmission gratings for astronomy : Holographic ion-etched ruled transmission gratings

High-efficiency IR transmission gratings (grisms) engraved into fused silica substrates

In many astronomy applications, grisms (transmission gratings patterned on a prism) are widely used for in-line dispersion of an infrared spectrum.
In the infrared, classical replicated grisms present many limitations. The epoxy layer, necessary for replication, absorbs infrared light. In addition, this epoxy layer compromises the integrity of the grism when used at low temperatures.

High-efficiency UV transmission gratings (grisms) engraved into CaF_2 substrates

Through our expertise in ion etching, HJY has developed a process which allows us to produce optimized groove patterns in CaF_2. A master grating is ruled in a gold layer deposited on top of the grating substrate, and then the groove profile is transferred by ion etching directly into the substrate itself. The result is a monolithic sawtooth-profile grating which can withstand extreme temperatures and environmental conditions.
A saw-tooth profile transmission grating, ion-etched directly into a CaF_2 substrate for use at 140 nm in second order, has been successfully produced for the GALEX experiments.

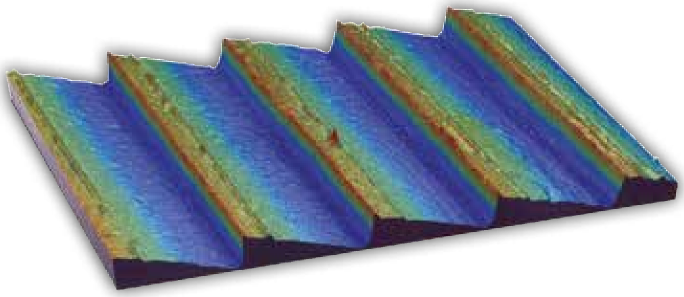
Rosetta mission: fly by of Mars

To address these issues HJY has designed and manufactured transmission gratings which are holographically patterned and etched directly into IR fused silica substrates.

Three grating types were developed, for wavelengths ranging from 1 micron to 2.4 microns. The diffraction efficiency reaches 60% to 70% in natural light.

Engraved directly into fused silica, these gratings can survive very low temperature conditions and vacuum environments.

Example of a high efficiency IR transmission grating (GRISM) directly etched into an IR grade fused silica substrate



Example of an ion-etched ruled grating profile (into CaF_2 material) made for the GALEX experiment

Ion-etched gratings for vacuum UV and soft X-ray applications

Holographic ion-etched lamellar master gratings for synchrotron and soft X-ray applications.

HORIBA Jobin Yvon's holographic ion-etched lamellar gratings exhibit ultra-low stray light levels, making them ideal for synchrotron and soft X-ray applications. These gratings are fully compatible with the latest synchrotron systems, as they are fully engraved in the substrate material and can therefore withstand high thermal loads.

The holographic ion etching manufacturing process is compatible with most high-grade polished substrate materials, including:

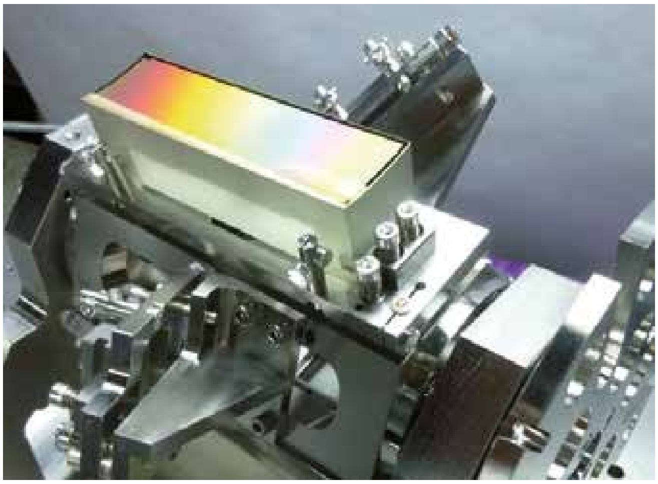
- Silicon,
- Fused Silica

HORIBA Jobin Yvon produces holographic ion-etched gratings on plano, spherical, and toroidal substrates. We can tailor the groove distribution (i.e. constant spacing, aberration correction, or VLS) to optimize gratings for the most demanding applications.

VUV gratings types

1. Constant groove density: type I

The groove density of the grating is defined by the interference of two plane wavefronts, resulting in a uniform and constant groove spacing along the grating length.



Ion-etched Variable Line Spacing (VLS) grating mounted in a synchrotron beamline

Relevant features

- Leading experience and expertise on VUV gratings,
- Holographic ion-etched lamellar master grating,
- Material: Silicon, Fused Silica, Pyrex,
- Shape: plane, spherical, cylindrical, toroidal,
- Low stray light and harmonics minimisation,
- Type I or VLS custom design for synchrotron beamlines,
- Coatings: Au, Ni, Pt.

2. Aberration-corrected groove density: Type IV

The groove spacing along the grating length is non-uniform, resulting from the interference of two spherical wavefronts. The non-constant groove density enables the correction of certain aberrations in the optical system.

3. VLS groove density

The Variable Line Spacing grating displays a groove-density variation that is defined by a polynomial law. This type of grating is commonly used in synchrotron beamline designs to correct for the defocusing of a grating monochromator. HORIBA Jobin Yvon and the synchrotron community together have developed software tools to define holographic recording geometries for VLS gratings, which allows us to produce gratings according to an arbitrary polynomial VLS law.

▶ **Please contact us for a custom VLS grating design.**

Examples of holographic ion-etched lamellar master gratings

Spherical constant groove density grating

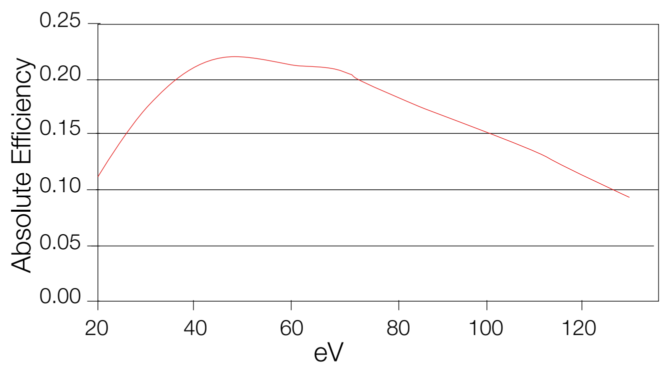
- Radius of curvature: 17 800 mm
- Radius of curvature tolerance: ±1 000 mm

Reference	Blank dimension	Useful area	Groove density	Blank	Spectral range
549 00 133S	30 x 100x 20	20 x 90	1200	Si	300-950eV / 1.3 - 4.5nm
549 00 134S	30 x 100 x 20	20 x 90	600	SI	170-600 eV / 2-7 nm
549 00 135S	30 x 100 x 20	20 x 90	300	Si	100-300 eV 4-12 nm

Plane variable line spaced (VLS) grating Well adapted for synchrotron beamlines

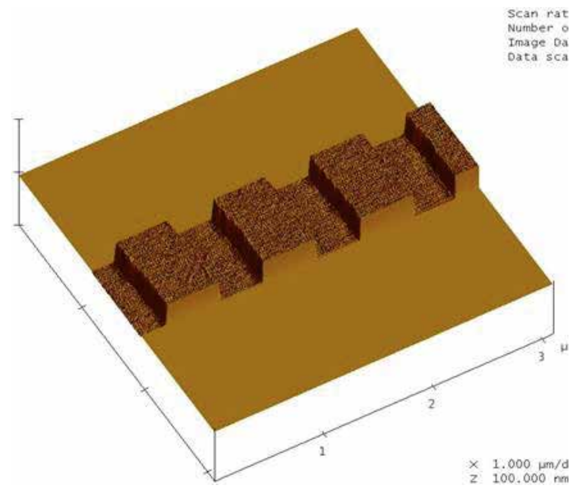
- VLS law: $N(x) = N_0 \times (1 + 2b_2 x + 3b_3 x^2 + ...)$

Custom design on demand



Typical theoretical absolute efficiency of a custom 400gr/mm VLS grating, unpolarized light for a Synchrotron beamline

▶ **If you are interested by a specific grating for your application, please contact your HORIBA Jobin Yvon representative. He will be glad to review your specific requirements.**



Typical 3D AFM grating profile

Toroidal ion-etched holographic master gratings for VUV applications

Relevant features

- Ion-etched holographic master gratings,
- Single focusing/dispersing optic,
- Compact design in a HORIBA grating spectrograph/monochromator,
- High throughput,
- Large spectral range: from soft X-Ray to UV,
- Large choice of groove densities.

Single focusing/dispersing optic for cost-effective VUV optical systems

The holographic recording process – a non-contact manufacturing technique – allows for the patterning of gratings on aspheric surfaces. HORIBA Jobin Yvon has developed manufacturing methods to define, produce, and test diffraction gratings on toroidal substrates. Toroidal gratings combine the off-axis focusing properties of a toroidal reflector and the dispersive properties of a grating into a single optic, allowing for simplified, high-throughput monochromator and spectrograph designs.

Toroidal diffraction gratings are recorded with a varying groove density along the grating length, which is defined and optimized for correcting aberrations in a particular instrument. This non-uniform groove density is holographically generated by interfering two spherical wavefronts on a photoresist layer deposited on the toroidal surface.

The grating pattern is then transferred directly into the substrate bulk using an ion etching process; this technique (used in the semiconductor industry) creates a lamellar groove structure that minimizes unwanted harmonic contamination.

Our toroidal substrates are polished and tested in our own optics fabrication laboratory, allowing us to maintain strict quality control.

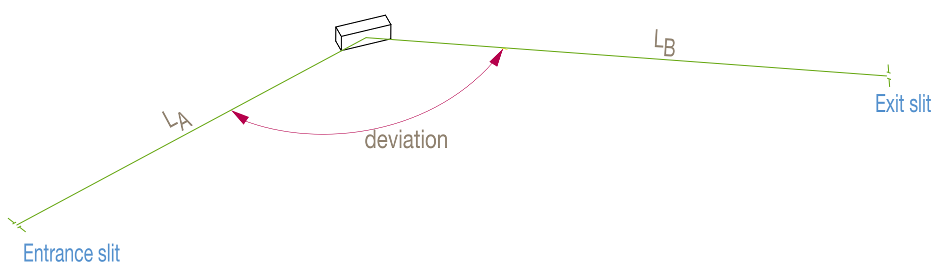
HORIBA Jobin Yvon toroidal diffraction gratings are a cost-effective solution for de-signing high throughput vacuum UV instruments.

Toroidal Grating Spectrograph - TGS300

Toroidal grating monochromator

Ion Etched Gratings

Deviation (deg)	Spectral range nm	eV	Groove Density (l/mm)	Blank dim (mm)	Useful area (mm)	l_A (mm)	l_B (mm)	Reference
150	8-32	30-155	1800	45 x 90 x 16	40 x 85	1146	1927	540 00 600
150	32-128	10-39	450	45 x 90 x 16	40 x 85	1146	1927	540 00 610
146	12.5-52.5	23-100	950	30 x 110 x 30	25 x 105	1000	1168	540 00 800
146	50-200	6-25	250	30 x 110 x 30	25 x 105	1000	1168	540 00 810
142	10-50	25-124	550	31 x 31 x 15	27 x 27	319.9	319.5	540 00 900
142	15-150	8-82	550	31 x 31 x 15	27 x 27	319.9	319.5	540 00 910
142	50-300	4-25	275	31 x 31 x 15	27 x 27	319.9	319.5	540 00 920

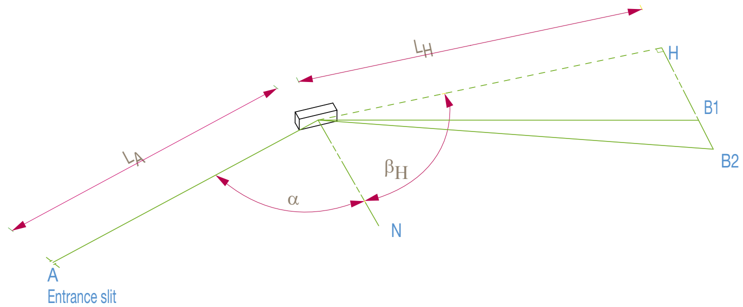


Toroidal grating monochromator optical layout

Toroidal grating spectrograph

Ion Etched Gratings

Deviation (deg)	Spectral range nm	eV	Groove density (l/mm)	Blank dim (mm)	Useful area (mm)	l_A	α deg	l_H (mm)	$β_H$ (deg)	Reference
140	9.5 - 32	39 - 130	2105	12x34x10	8x22	292.1	-71.78	306.0	86.54	541 00 220
140	10 - 110	11 - 124	450	12x34x10	8x22	292.1	-70.56	306.0	87.85	541 00 200
140	15.5 - 170	7 - 80	290	12x34x10	8x22	292.1	-70.56	306.0	87.85	541 00 210



Toroidal grating spectrograph optical layout

gratings.sci@horiba.com
www.horiba.com/scientific/grating

Variable Groove Depth (VGD) master gratings for XUV applications

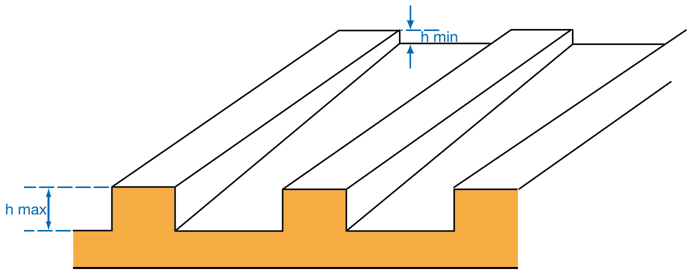
One VGD grating gives you the efficiency of several classical gratings

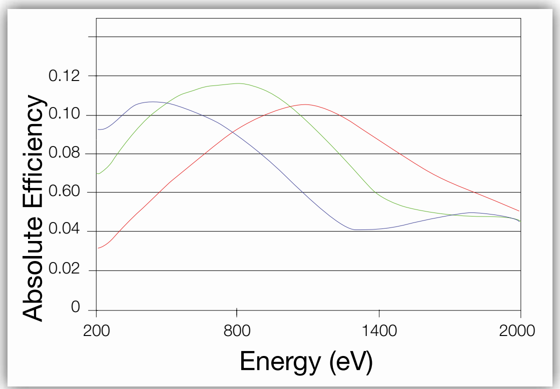
Variable Groove Depth (VGD) gratings from HORIBA Jobin Yvon exhibit a continuously-varying groove depth across the grating width, allowing for continuous adjustment of the grating blaze wavelength with a simple lateral translation. When such blaze adjustments are combined with rotational scanning and a narrow beam, our VGD gratings provide a unique opportunity to perform continuous on-blaze scans and to minimize harmonic contamination over a wide spectral range.

Our VGD grating technology is compatible with the most-recent synchrotron beamline designs that provide a mm size synchrotron beam onto the grating. Replacing a classical or multi-track gratings with a HORIBA Jobin Yvon VGD will open new experimental opportunities, with optimized flux performance over the entire beamline spectral range.

Relevant features

- Grating blaze wavelength tuning,
- Synchrotron compatible,
- Holographic recording processes,
- Low stray light and minimized harmonic contamination,
- Material: Silicon, Fused Silica,
- TGroove depth: typically from hmin to hmax=4hmin,
- Land to groove ratio: ~0.55 ± 15%,
- Coatings: Au, Ni, Pt.





VGD efficiency

Example of VGD gratings. Contact us for custom design.

Blank size (mm)	Useful area (mm)	Groove density (l/mm)	Nominal depth variation over 25 mm		
			h min (nm)	h centre (nm)	h max (nm)
40 x 100 x 30	35 x 90	1800	4.5	10	15.5
40 x 100 x 30	35 x 90	600	18	35	52
40 x 100 x 30	35 x 90	300	42.5	80	117.5

Holographic plane gratings

Relevant features

- Replica gratings from master holographic gratings,
- Perfect periodicity and excellent microroughness,
- Elimination of ghosts and low stray light,
- Substrate materials: Fused silica, Zerodur, Pyrex…
- Large range of groove densities: from 150 to 5670gr/mm,
- Multiple spectral range: from UV to NIR,
- Available dimensions: many references up to 120x140x20mm,
- Coating: Al.

HORIBA Jobin Yvon has produced a wide range of holographic master gratings from which we manufacture high precision replicas.

Our replica gratings retain the advantages of our master holographic gratings:

- Perfect periodicity, plus excellent micro-roughness of the surface eliminates ghosts and enhan-ces stray light rejection,
- Minimal groove errors provide very high resolution,
- Availability of very high groove densities: up to 5670 lines/mm.

Dimensions of our high-precision replica gratings typically range from 25x25 mm up to 120x140 mm.
For customers in need of larger dimensions, HJY can record a custom-made holographic grating master specifically for replication.

Typical efficiency performances of holographic plane gratings

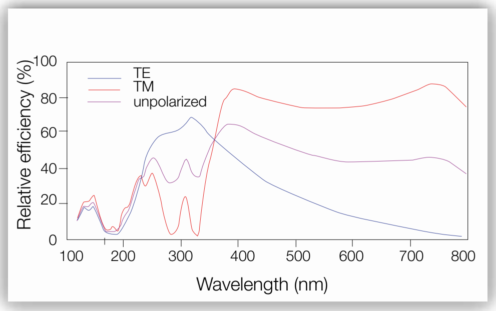
The efficiency of a sinusoidal holographic grating is determined by the ratio of the wavelength and groove spacing λ/σ. In general:

- if $\lambda/\sigma \geq 0.8$, efficiency will approach 85% in TM polarized light, and 60% in unpolarized light
- when $0.2 \leq \lambda/\sigma \geq 0.8$, efficiency for unpolarized light is between 35% and 50%.
- when $\lambda/\sigma < 0.2$ maximum efficiency in unpolarized light will be approximately 35% for the UV, visible, and near IR region of the spectrum.

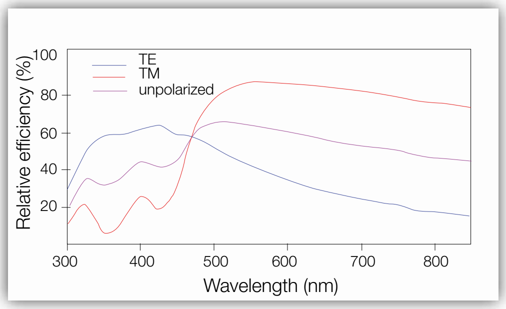
Holographic gratings usually exhibit a very broad spectral bandwidth.

Typical holographic plane grating efficiencies

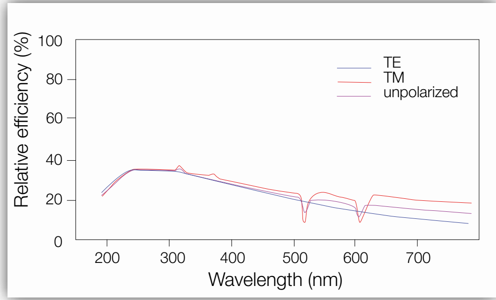
Example of theoretical curves



520 13, 2400 l/mm, 170-500 nm



520 19, 1800 l/mm, 450-850 nm



520 25, 1200 l/mm, 190-700 nm

Nota: These efficiency curves are absolute theoretical efficiencies, calculated using rigorous electromagnetic theory, taking into account the true groove profiles of manufactured gratings measured with an atomic force microscope (AFM). These curves are for reference only and do not indicate grating specifications.

List of standard holographic plane gratings

l/mm	Spectral range (nm)	Available max replica dimension (mm)	Reference
5670	100-300	76 x 76 x 16	520 01
4960	100-300	76 x 76 x 16	520 02
4320	170-400	110 x 110 x 16	520 04
[redacted]	[redacted]	[redacted]	[redacted]
3600	150-450	110 x 110 x 16	520 07
3000	250-550	110 x 110 x 16	520 09
2400	300-650	120 x 140 x 20	520 12
2400	170-500	110 x 110 x 16	520 13
2400	100-300	110 x 110 x 16	520 14
2000	450-750	120 x 140 x 20	520 15
2000	190-700	120 x 140 x 20	520 16
2000	150-450	110 x 110 x 16	520 17
2000	100-300	110 x 110 x 16	520 18
1800	450-850	120 x 140 x 20	520 19
1800	190-700	120 x 140 x 20	520 20
1800	150-450	110 x 110 x 16	520 21
1800	100-300	110 x 110 x 16	520 22
1200	400-1300	120 x 140 x 20	520 24
1200	190-700	120 x 140 x 20	520 25
1200	150-450	120 x 140 x 20	520 26
1200	100-300	110 x 110 x 16	520 27
900	1250-1750	44 x 44 x 10	520 95
600	400-1300	120 x 140 x 20	520 29
600	150-450	110 x 110 x 16	520 30
150	250-800	110 x 110 x 16	520 32
150	400-1200	110 x 110 x 16	520 33

Ruled area: extends to within a 2-4 mm border around the grating edge.

Standard substrate material is Pyrex; on request, substrates including fused silica, Zerodur, ULE, metals, or other materials can be considered.

Standard coating is aluminium. On request, $AlMgF_2$, gold or platinum are also available for an additional cost.

Size code	Blank size
020	25 x 25 x 8
050	34 x 34 x 10
070	30 x 40 x 10
080	44 x 44 x 10
090	40 x 60 x 10
330	50 x 50 x 6
110	58 x 58 x 10
120	68 x 68 x 9
140	76 x 76 x 16
150	90 x 90 x 16
160	80 x 110 x 16
180	110 x 110 x 16
190	110 x 135 x 25
200	120 x 140 x 20

To place an order

Please use the grating reference number and add the size code.

Example:
For 2000 lines/mm and the spectral range 150-450 nm, use the grating reference 520 17.

For the size 58x58x10 mm, use the size code 110.
Therefore, the full part number of this grating is
520 17 110.

Blazed holographic plane gratings

Relevant features

- Replica gratings from blazed master holographic gratings,
- Perfect periodicity and excellent microroughness,
- Elimination of ghosts and low stray light,
- Substrate materials: Fused silica, Zerodur, Pyrex …
- Large range of groove densities : from 600 to 2400gr/mm,
- Multiple spectral range : from UV to NIR,
- Available dimensions: many references up to 120x140x20mm,
- Coating: Al.

HORIBA Jobin Yvon has produced a wide range of blazed holographic master gratings from which we manufacture high precision replicas.

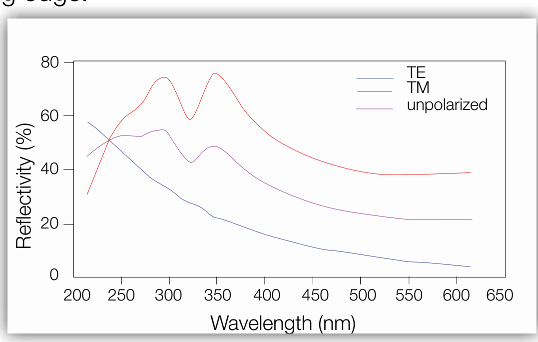
Our replica gratings retain the advantages of our master holographic gratings:

- Perfect periodicity, plus excellent micro-roughness of the surface eliminates ghosts and enhances stray light rejection
- Minimal groove errors provide very high resolution

In addition, owing to their ion-etched, sawtooth groove profiles, these gratings offer higher peak efficiency than standard holographic gratings.

List of blazed holographic plane gratings

Ruled area: extends to within a 2-4 mm border around the grating edge.



530 13, 2400 l/mm, 190-700 nm

Standard substrate material is Pyrex; on request, substrates including fused silica, Zerodur, ULE, metals, or other materials can be considered.
Standard coating is aluminium. On request, $AlMgF_2$, gold or platinum are also available for an additional cost.

Typical blazed holographic plane grating efficiencies

These curves are for reference only and do not indicate grating specifications.

Groove density (l/mn)	Spectral range (mnm)	Blaze (nm)	Max replica dimension (mm)	Reference
2400	190-700	250	120 x 140 x 20	530 13
2400	240-750	330	120 x 140 x 20	530 11
2400	300-800	400	110 x 135 x 25	530 15
1800	190-700	250	110 x 110 x 16	530 20
1800	250-900	400	110 x 110 x 16	530 18
1800	450-900	500	110 x 110 x 16	530 19
1200	190-1200	250	110 x 110 x 16	530 25
1200	240-1200	330	110 x 110 x 16	530 22
1200	360-1250	500	110 x 110 x 16	530 24
1200	400-1300	630	110 x 110 x 16	530 27
1200	500-1500	750	110 x 110 x 16	530 28
1200	600-1600	900	90 x 90 x 16	530 50
950	700-1700	900	110 x 110 x 16	530 60
900	700-1700	850	110 x 110 x 16	530 66
600	360-1250	500	90 x 90 x 16	530 29
600	700-1750	1000	110 x 110 x 16	530 34

Size code	Blank size
020	25 x 25 x 8
050	34 x 34 x 10
070	30 x 40 x 10
080	44 x 44 x 10
090	40 x 60 x 10
330	50 x 50 x 6
110	58 x 58 x 10
120	68 x 68 x 9
140	76 x 76 x 16
150	90 x 90 x 16
160	80 x 110 x 16
180	110 x 110 x 16
190	110 x 135 x 25
200	120 x 140 x 20

These efficiency curves are absolute theoretical efficiencies, calculated using rigorous electromagnetic theory, taking into account the true groove profiles of manufactured gratings measured with an atomic force microscope (AFM).

Holographic concave gratings-Type I

Type I Holographic Concave Gratings are recorded on spherical substrates, with equidistant and parallel grooves. Their geometric optical properties are the same as classically ruled gratings and are interchangeable with them.
When used in a spectrograph, Type I Holographic Concave Gratings are traditionally disposed on the Rowland circle (i.e., the circle defined by the grating center and the tangential radius of curvature of the grating). The point-source entrance slit is also located on this circle, and the grating forms a spectrum on this same circle, virtually free of defocus and primary coma. Spherical aberration is generally reasonable, yet astigmatism is very significant. As a result of this astigmatism, many Rowland spectrographs offer high resolution but are limited in their light-collection efficiency.

Relevant features

- Replica gratings from master holographic gratings recorded in concave substrates
- Perfect periodicity of grooves
- Very low stray light compared to concave ruled grating
- Grating preferably used in mountings based on Rowland circle
  - o slit is located in a circle equal to the radius of curvature of the grating
  - o allow to obtain high resolution spectrograph
- Substrate materials: Pyrex, Zerodur

List of Type I holographic concave gratings (1/2)

Groove density (l/mm)	Spectral range (nm)	Concave-radius (mm)	Blank dimensions (mm)	Reference
1200	200-800	112.14	32 x 32	521 12 350
100	450-600	112.14	32 x 32	531 26 350
150	500-700	139.19	Ø 70	521 30 390
150	500-700	139.19	Ø 90	521 30 430
83	400-800	173.9	Ø 53	521 25 380
1200	200-600	201.4	58 x 58	521 12 060
1200	340-800	201.4	30 x 30	521 12 040
600	400-700	201.4	30 x 30	521 15 040
600	400-700	201.4	58 x 58	521 15 060
2700	120-400	498.1	Ø 50.8	521 22 360
3600	100-300	499.7	58 x 58	521 02 100
3600	150-450	499.7	Ø 63.5	521 03 101
2400	100-300	499.7	30 x 30	521 05 100
2400	200-400	499.7	30 x 30	521 06 100
4800	118-166	499.8	58 x 58	521 24 370
2700	120-165	600	Ø 50	531 27 400
2400	165-590	600	Ø 50	531 28 400
1200	60-150	995.4	Ø 114.3	521 10 130
3000	130-520	995.5	Ø 63.5	521 23 160

List of Type I holographic concave gratings (2/2)

Groove density (l/mm)	Spectral range (nm)	Concave-radius (mm)	Blank dimensions (mm)	Reference
3000	130-520	995.5	Ø 63.5	521 23 160
2550	120-415	998.8	Ø 63.5	521 17 160
2400	100-300	998.8	Ø 63.5	521 05 160
2160	70-200	998.8	Ø 63.5	521 20 160
2160	170-450	998.8	Ø 63.5	521 19 160
1080	337-815	998.8	Ø 50.8	531 21 420
3600	160-450	1500	Ø 63.5	521 03 180
2400	160-450	1500	Ø 63.5	521 05 180
2400	200-650	1500	Ø 63.5	521 06 180

Ruled area: extends to within a 2-4 mm border around the grating edge.

Standard substrate material is Pyrex; on request, substrates including fused silica, Zerodur, ULE, metals, or other materials can be considered.

Standard coating is aluminum.
On request, $AlMgF_2$, gold or platinum are also available for an additional cost.

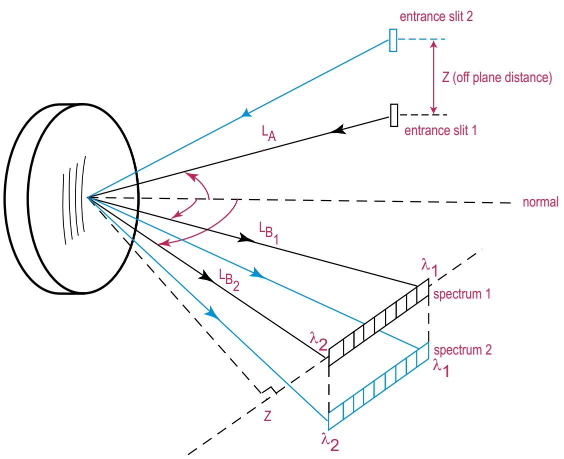
gratings.sci@horiba.com
www.horiba.com/scientific/grating

Flat field and imaging gratings - Type IV

Type IV aberration corrected flat field & imaging gratings are designed to focus a spectrum onto a plane surface, making them ideal for use with linear or 2-D array detectors.

These gratings are produced with grooves that are neither equispaced nor parallel, and are computer optimized to form near-perfect images of the entrance slit on the detector plane.

Owing to their large optical numerical aperture and correction from aberrations, these Type IV aberration corrected flat field & imaging gratings provide much better light collection efficiency and signal to noise ratio than traditional Type I Rowland circle concave gratings.



The illustration shows a "super corrected grating" imaging two independent sources onto two independent linear arrays. Spectrum 1 is a "sample spectrum" from slit 1and spectrum 2 a reference spectrum from slit 2. These "slits" could be fiber optic inputs.

Relevant features

- Replica gratings from holographic aberration corrected master gratings,
- Holographic Master can be blazed by Ion-beam etching method for higher efficiency,
- Ideal for robust, compact and low stray light spectrometers,
- Several references available (not all are listed in the catalogue),
- Large range of dispersion available (from few nm/mm to above 100nm/mm),
- Multiple spectral range from UV to IR,
- Coating: Al or gold.

When an area detector such as a CCD is utilized, it is often possible to focus multiple sources onto the entrance slit and independently evaluate the spectrum from each source. These "Imaging Gratings" are nearly free from astigmatism, and therefore only one fixed optical element is required to construct an imaging spectrograph.

List of Type IV flat field & imaging gratings

Reference	Dispersion (nm/mm)	Wavelength range (nm)	Spectrum length (nm)	LA (mm)	Blank dim. (mm)	F / #	Groove density (l/mm)	Note
523 00 080	4	300-400	25	210	Ø70	3.2	1200	a_1
523 00 010	8	200-400	25	210	Ø70	3.2	600	a_1
523 00 020	16	400-800	25	210	Ø70	3.2	300	a_1,b
523 00 030	24	200-800	25	210	Ø70	3.2	200	a_1,b
523 00 070	24	300-900	25	210	Ø70	3.2	200	a_1
523 00 040	36	300-1170	25	210	Ø70	3.2	138	a_1
523 00 050	40	200-1200	25	210	Ø70	3.2	120	a_1
523 00 060	48	200-1400	25	210	Ø70	3.2	100	a_1
523 01 020	14	190-455	18.8	190	Ø70	2.8	360	a_2,c
523 01 030	24	190-820	25	190	Ø70	2.8	200	a_2,c
523 01 070	24	300-820	21.6	190	Ø70	2.8	200	a_2,c
523 01 040	37.8	285-1232	25	190	Ø70	2.8	133	a_2,c
523 01 090	37.8	500-1232	19.3	190	Ø70	2.8	133	a_2,c
523 01 060	76	600-2500	25	190	Ø70	2.8	65	a_2,c

Note:
a_n : these gratings are interchangeable (same geometry of use)
b : these gratings are blazed by ion etching (higher efficiency)
c : these gratings are imaging gratings
d : these gratings are ion-etched, laminar profile (suppression of the 2nd order)

Reference	Dispersion (nm/mm)	Wavelength range (nm)	Spectrum length (nm)	LA (mm)	Blank diam. (mm)	F / #	Groove density (l/mm)	Note
523 00 420	1.0	250-450	203	260	Ø50	5.1	1800	
523 00 410	1.1	440-510	62	330	Ø50	6.7	200	
523 00 430	1.4	100-400	210	240	Ø50	7.9	1340	
523 00 440	1.6	170-500	211	240	Ø30	7.9	1200	
523 00 730	4.6	395-705	68	231	Ø100	2.4	793	
533 00 110	5	200-360	32	223	Ø55	4.4	807	b
543 00 180	5	4160-4180	4	258	Ø70	3.9	376	d
533 00 450	7.1	200-350	21	115	44 x 44	2.3	900	
523 00 540	7.8	340-660	41	200	Ø90	2.3	600	
523 00 510	8	330-660	40	210	Ø108	2	540	
533 00 550	8.3	330-750	50	150	Ø38	4	800	b
543 00 170	9	175-400	25.1	153	40 x 40	4	580	d
523 00 690	9.4	200-350	16	93	Ø56	1.6	700	

Reference	Dispersion (nm/mm)	Wavelength range (nm)	Spectrum length (nm)	LA (mm)	Blank dim. (mm)	F / #	Groove density (l/mm)	Note
523 00 560	10	380-720	33.7	100	Ø50	2	900	
533 00 570	10	380-760	38	100	Ø32	3	950	b
533 00 890	15.5	190-800	29.6	58	25x25	2.2	785	b
523 00 210	15.6	800-1000	12.8	105.4	46x46	2.2	595	
533 00 580	16	340-690	24	145	Ø44	3.3	430	b
533 00 100	16	330-840	32	160	52x52	3.3	370	b
533 00 720	16	380-780	25	138	Ø50	2.8	457	b
533 00 670	23	340-800	19.7	89	30x30	2.8	440	b
533 00 130	24	190-800	25.4	210	Ø40	5.3	200	b
543 00 710	24	190-800	25	138	Ø50	2.8	298	b
523 00 150	25.1	1600-2200	23.9	148	40x40	3.7	267	d
523 03 120	25.5	190-800	24.6	90	Ø48	2	340	
523 00 470	27	400-950	20	85	Ø48	1.8	217	

Reference	Dispersion (nm/mm)	Wavelength range (nm)	Spectrum length (nm)	LA (mm)	Blank dim. (mm)	F / #	Groove density (l/mm)	Note
523 00 460	2	320-710	13.4	100	Ø50	2	310	
523 00 480	30	200-800	20	85	Ø48	1.8	200	
533 00 700	32	300-1100	25	138	Ø50	2.8	227	b
533 00 610	40	330-780	11.3	120	34x34	3.5	250	b
523 00 840	54	190-870	12.6	94	44x44	2	185	
523 00 630	59	380-720	6.4	38.4	32x32	1.5	320	
523 00 810	67	380-820	6.6	93	Ø54	1.8	143	
523 00 150	67.4	1600-2200	8.9	100.7	Ø54	2	130	
523 00 820	68	750-1180	6.4	93	Ø54	1.8	143	
523 00 530	106	350-1050	6.6	143	Ø42	3.4	65	

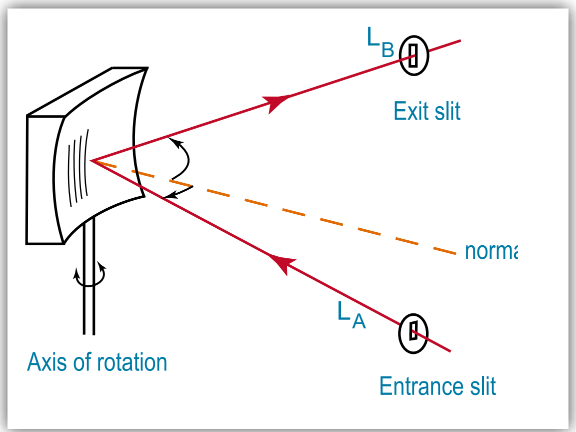
Monochromator gratings - Type IV

Using Type IV aberration-corrected monochromator Gratings, a single concave grating disperses, collimates and refocuses the light from the entrance slit onto the exit slit. Wavelength scanning is obtained through a simple rotation of the grating.

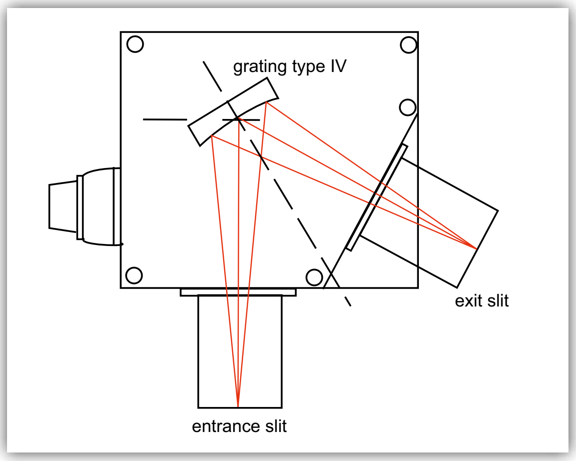
The groove spacing of these gratings is computer-optimized to produce high quality images with a minimum of astigmatism and coma, even at large numerical aperture. Compared with Czerny-Turner monochromators (equipped with one plane grating, one collimating mirror and one focusing mirror) Type IV aberration corrected monochromator gratings provide much better light collection efficiency and signal-to-noise ratio.

Relevant features

- Replica gratings from aberration corrected master gratings,
- Holographic Master can be blazed by Ion-beam etching method for higher efficiency,
- Ideal for robust, compact and low stray light monochromators
- Several references available some (not all are listed in the catalogue),
- Large range of dispersion available,
- Multiple spectral range from UV to IR,
- Coating: Al or gold.



Monochromator concave grating
LA: distance between the grating and the entrance slit
LB: distance between the grating and the exit slit
D: deviation angle
F/#: optical aperture



Example monochromator model H10-61
Optical aperture: F/3
Focal length: 100 mm
ACH grating: aberration corrected

Custom, aberration corrected, concave gratings

In addition to the standard lists of Type IV flat field and monochromator gratings, HJY currently produces specific aberration-corrected concave gratings to maximize performance for a given application.
In that case, using proprietary ray-tracing software, we optimize performance: resolution, throughput and signal to noise ratio. We need following data from our customers:

- Spectral range
- Configuration of use: monochromator or spectrograph
- Numeral aperture (F number) or size of grating
- Maximum overall dimension or maximum focal length
- Desired dispersion
- Desired resolution
- Entrance slit width and height or source geometry
- Minimum deviation: in general deviation has to be minimum to improve correction of astigmatism, so indicate possible minimum deviation when overall dimensions of source, sample chamber and detector are taken into consideration.
- At exit: if monochromator, exit slit width and height, and if flat field, length of detector, height and width of pixel.

List of Type IV aberration-corrected monochromator gratings

Gratings are replicated from our extensive inventory of high-quality master gratings. New gratings are frequently added; please inquire for your specific needs.

When blaze wavelength is indicated (blaze column), it means that this grating has been blazed by ion etching and presents high efficiency
Ruled area: extends to within a 2-4 mm border around the grating edge.

Spectral range (nm)	Dispersion (nm/mm)	Groove density (l/mm)	Deviation D (deg)	IA	IB	Blank dim.	F	Blaze	Order	Reference
190 - 800	8	1200	61.6	100	94.0	32 x 32	3	250	1	532 00 110
250 - 800	8	1200	61.6	100	94.0	32 x 32	3	350	1	532 00 120
300 - 1200	12	800	61.6	100	94.0	32 x 32	3		1	522 00 130
300 - 800	8	1200	61.6	100	94.0	32 x 32	3	450	1	532 00 130
400 - 1600	16	600	61.6	100	94.0	32 x 32	3		1	532 00 140
800 - 3200	32	300	61.6	100	94.0	32 x 32	3		1	522 00 150
190 - 900	4	1200	61.6	200	187.9	40 x 45	4.2	250	1	532 00 210
200 - 1000	4	1200	61.6	200	187.9	40 x 45	4.2	350	1	532 00 220
300 - 1100	4	1200	61.6	200	187.9	40 x 45	4.2	450	1	532 00 230
350 - 1200	6	800	61.6	200	187.9	40 x 45	4.2		1	522 00 260
400 - 1600	8	600	61.6	200	187.9	40 x 45	4.2		1	522 00 230
400 - 2100	10	450	61.6	200	187.9	40 x 45	4.2		1	522 00 270
800 - 3200	16	300	61.6	200	187.9	40 x 45	4.2		1	522 00 240
100 - 300	4	1200	64	200	187.9	40 x 45	4.2		1	522 00 250
175 - 520	0.5	1500	61.2	1232	1000	42 x 42	26		1	522 00 470
200 - 800	2.2	1484	46.4	335	303	Ø 150	2.2		1	522 00 450
200 - 800	7	950	40	136	151	Ø 32	4.2	250	1	532 00 520
250 - 750	2.2	1500	56	300	320	58 x 58	4.6		1	522 00 460
350 - 800	2.2	1484	46.4	335	303	Ø 150	2.2		1	522 00 490
380 - 740	9	1800	38	201	184	90 x 90	2		1	522 00 510
400 - 1100	9	670	27	150	150	50 x 50	3		1	522 00 540
400 - 1200	3.3	1000	46.4	335	303	Ø 150	2.2		1	522 00 480
480 - 800	0.5	2000	3	1000	1000	110 x 110	8		1	522 00 410
1000 - 2400	9.6	500	41.3	191	184	Ø 70	2.5		1	522 00 600
1100 - 2500	8	600	30	210	160	Ø 110	1.9		1	522 00 530
1200 - 2400	3	570	38	201	184	90 x 90	2		1	522 00 500
5000 - 10000	64	100	38	108	113	60 x 70	1.6		1	542 00 160

Ruled plane gratings

HORIBA Jobin Yvon has produced a wide range of ruled master gratings from which we manufacture high precision replicas.

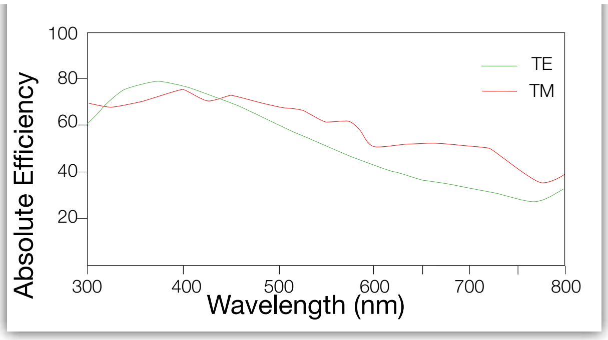
Dimensions of our high-precision replica gratings typically range from 25x25 mm up to 120x140 mm.

On page 35, we indicate the blaze angle (a) which is given by the formula:
$2a \sin\alpha = k\lambda_B$, where a is the groove spacing, k is the diffraction order (usually k=1) and λ_B is the blaze wavelength (in Littrow configuration).

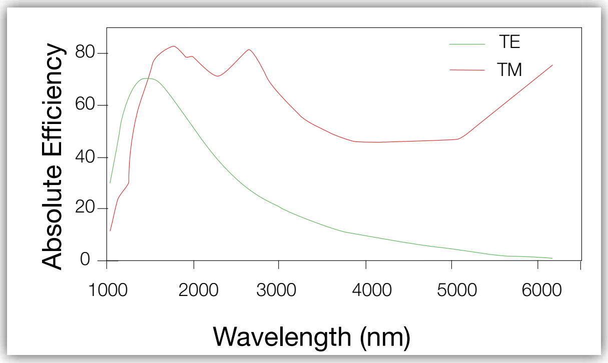
Relevant features

- Replica gratings from ruled master gratings,
- High absolute efficiency,
- Substrate materials: Fused silica, Zerodur, Pyrex, …
- Large range of groove densities: from 20 to 1800gr/mm,
- Multiple spectral range: from UV to IR,
- Available dimensions: many references up to 120x140x20mm,
- Coating : Al.

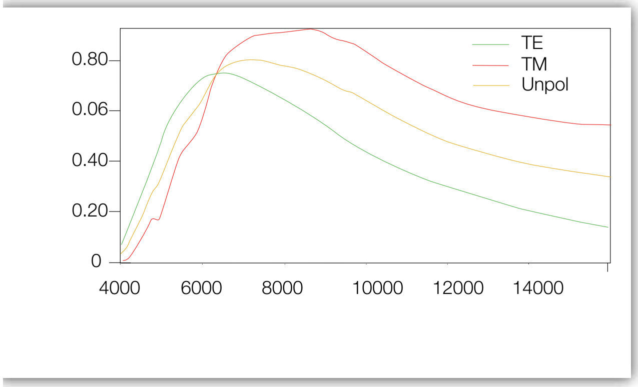
Typical efficiency performance of ruled plane gratings



510 12; 600 l/mm; blaze 400 nm



510 21; 300 l/mm; blaze 2 µm



510 37; 75 l/mm; 5-16 µm

NOTE: These efficiency curves are absolute theoretical efficiencies, calculated using rigorous electromagnetic theory, taking into account the true groove profiles of manufactured gratings measured with an atomic force microscope (AFM). These curves are for reference only and do not indicate grating specifications.

Custom master ruled gratings for CO_2 lasers

HORIBA Jobin Yvon offers master ruled plane gratings optimized at 10.6 micron for CO_2 lasers (531 40 010).

- Ruling density is 150 l/mm
- Coating: gold
- Substrate material: stainless steel
- Substrate dimension: 25 mm diameter on 25x25 mm
- Absolute efficiency: higher than 95% for TM polarization over 9 to 11 µm wavelength range

List of ruled plane gratings (1/2)

Groove density (l/mm)	Blaze wavelength	Blaze angle	Max replica dimension (mm)	Reference
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
1800	500 nm	26°45’	90 x 90 x 16	510 02
1800	630 nm	34°32’	68 x 68 x 9	510 03
1200	250 nm	8°38’	58 x 58 x 10	510 04
1200	330 nm	11°25’	58 x 58 x 10	510 05
1200	400 nm	13°53’	58 x 58 x 10	510 06
1200	500 nm	17°27’	58 x 58 x 10	510 07
1200	630 nm	22°12’	58 x 58 x 10	510 08
1200	750 nm	26°45’	58 x 58 x 10	510 09
1200	1 µm	36°52’	58 x 58 x 10	510 10
900	350 nm	9°00’	90 x 90 x 16	510 91
900	550 nm	14°20’	58 x 58 x 10	510 93
900	1.5 µm	42°27’	76 x 76 x 16	510 97
600	300 nm	5°10’	110 x 110 x 16	510 11
600	400 nm	6°54’	110 x 135 x 25	510 12
600	500 nm	8°38’	120 x 140 x 20	510 13
600	750 nm	13°00	90 x 90 x 16	510 14
600	1 µm	17°27’	120 x 140 x 20	510 15
600	1.5 µm	26°45’	110 x 110 x 16	510 16
600	2 µm	36°52’	110 x 110 x 16	510 17
300	250 nm	2°09’	110 x 110 x 16	510 50
300	500 nm	4°18’	120 x 140 x 20	510 18
300	600 nm	5°10’	120 x 140 x 20	510 19
300	1 µm	8°38’	110 x 110 x 16	510 20
300	2 µm	17°27’	110 x 110 x 16	510 21
300	3 µm	26°45’	120 x 140 x 20	510 22
300	4 µm	36°52’	120 x 140 x 20	510 23
150	500	2°09’	110 x 110 x 16	510 49
150	1.2 µm	5°10’	110 x 110 x 16	510 24
150	2 µm	8°38’	110 x 110 x 16	510 25
150	4 µm	17°27’	120 x 140 x 20	510 26
150	5 µm	22°01’	120 x 140 x 20	510 27
150	6 µm	26°45’	120 x 140 x 20	510 28
150	8 µm	36°52’	110 x 110 x 16	510 29
120	2.5 µm	8°39’	110 x 110 x 16	510 30
120	5 µm	17°27’	120 x 140 x 20	510 31
120	7 µm	26°45’	120 x 140 x 20	510 32

List of ruled plane gratings (2/2)

Groove density (l/mm)	Blaze wavelength	Blaze angle	Max replica dimension (mm)	Reference
100	450 nm	1°17'	110 x 110 x 16	510 48
100	3 µm	8°38'	110 x 110 x 16	510 33
100	6 µm	17°27'	120 x 140 x 20	510 34
100	9µm	26°45'	120 x 140 x 20	510 35
75	4 µm	8°38'	110 x 110 x 16	510 36
75	8 µm	17°27'	110 x 110 x 16	510 37
75	12 µm	26°45'	110 x 110 x 16	510 38
60	10 µm	17°27'	90 x 90 x 16	510 39
60	15 µm	26°45'	110 x 110 x 16	510 40
50	12 µm	17°27'	110 x 110 x 16	510 42
50	18 µm	26°45'	110 x 110 x 16	510 43
50	24 µm	36°52'	110 x 110 x 16	510 44
40	22.5 µm	26°45'	90 x 90 x 16	510 45
30	30 µm	26°45'	90 x 90 x 16	510 46
20	45 µm	26°45'	76 x 76 x 16	510 47

Ruled plane gratings are replicated from our extensive inventory of high-quality master gratings. New gratings are frequently added; please inquire for your specific needs.

Ruled area: extends to within a 2-4 mm border around the grating edge.

Standard substrate material is Pyrex; on request, substrates including fused silica, Zerodur, ULE, metals, or other materials can be considered.

Standard coating is aluminium. On request, $AlMgF_2$, gold or platinum are also available for an additional cost.

Grating size table

Size code	Blank size
020	25 x 25 x 8
050	34 x 34 x 10
070	30 x 40 x 10
080	44 x 44 x 10
090	40 x 60 x 10
330	50 x 50 x 6
110	58 x 58 x 10
120	68 x 68 x 9
140	76 x 76 x 16
150	90 x 90 x 16
160	80 x 110 x 16
180	110 x 110 x 16
190	110 x 135 x 25
200	120 x 140 x 20

Dye laser and wavelength selection gratings

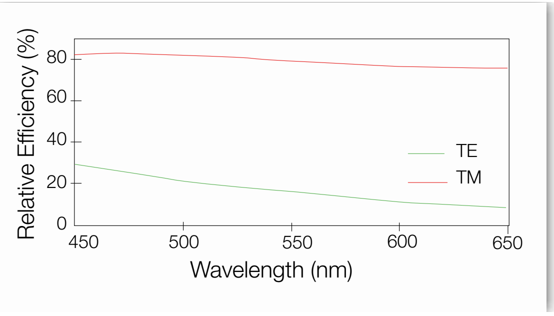
HORIBA Jobin Yvon has developed two types of gratings for dye lasers and wavelength selection: L series (Littrow configuration) and G series (grazing incidence configuration).

These holographic gratings are optimized for efficiency when used with TM radiation.
Standard gratings are aluminum coated. Gold coating is offered upon request, to improve efficiency above 600 nm.

L series (Littrow)

Grooves (l/mm)	Spectral range (nm)	Angular dispersion (nm/mrad)	Relative eff. at max (%)	Reference
3600	280 - 380	22	69	524 01
3000	300 - 550	28	69	524 02
2400	450 - 650	30	82	524 03
2000	480 - 650	43	69	524 04
1800	500 - 900	48	90	524 05
1500	600 - 1000	53	69	524 06

Size code	Blank size
070	30 x 40 x 10
090	40 x 60 x 10



G series (grazing)

Our grazing incidence gratings have been optimized for very high resolution when used with very large angles.

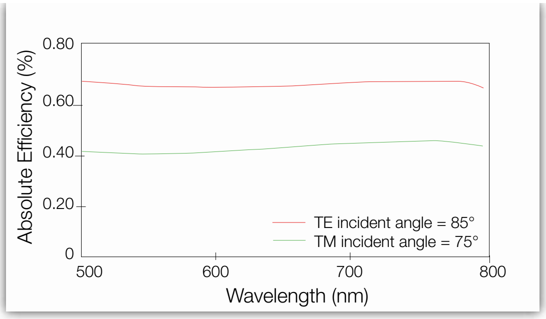
Grooves (l/mm)	Spectral range (nm)	Reference
3600	330 - 500	524 11
2400	500 - 800	524 12
1800	300 - 900	524 13

Size code	Blank size
260	17 x 58 x 10
270	30 x 110 x 16
280	35 x 140 x 20

Efficiency curves are very flat, and specific blaze wavelengths are not specified. Efficiency vs incidence angle is available upon request.

Ruled area: extends to within a 2-4 mm border around the grating edge.

Standard substrate material is Pyrex; on request, substrates including fused silica, Zerodur, ULE, metals, or other materials can be considered.
Standard coating is aluminum. On request, $AlMgF_2$, gold or platinum are also available for an additional cost.



NOTE: These efficiency curves are absolute theoretical efficiencies, calculated using rigorous electromagnetic theory, taking into account the true groove profiles of manufactured gratings measured with an atomic force microscope (AFM). These curves are for reference only and do not indicate grating specifications.

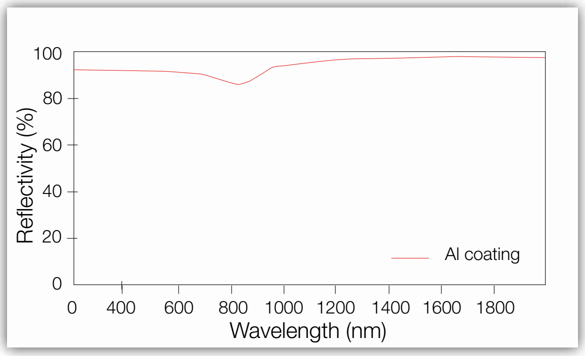
Coatings

Gratings and mirrors

Depositions of reflective metallic coatings are performed with cryogenic evaporation in our production laboratory warrantying grating performance.
Gratings are provided with a standard aluminum coating. Other standard coatings (to improve reflectivity in certain spectral ranges) may also be requested.

We suggest:

- Above 6000 Å : IR gold
- Between 1500 Å to 6000 Å: Al
- Between 1150 Å and 1650 Å : Al+MgF_2
- Below 1000 Å : UV gold or platinum or nickel



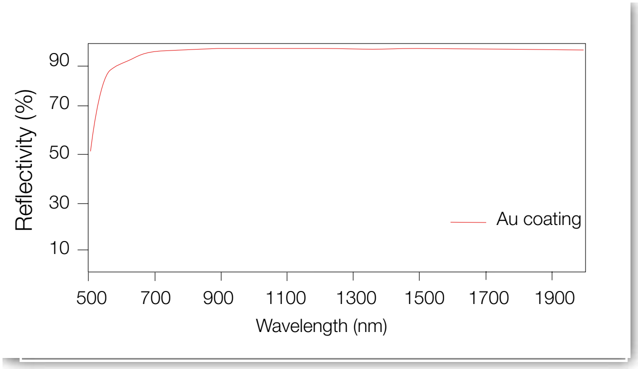
Reflectivity for Al coating
incident angle = 0°, unpolarized light

VUV & soft X-ray gratings

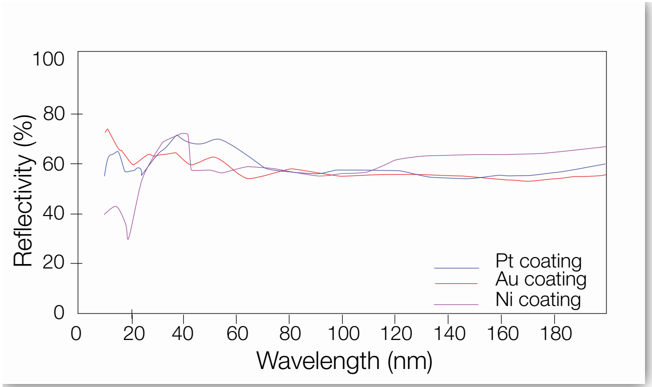
Reflectivity depends on the light beam incidence angle. HJY can help you review reflectivity and efficiency values according to your incidence angle and wavelength range.

Ordering information

Al + MgF_2 (optimized 1216-1610 Å)	50 000 001
IR Gold	50 000 003
UV Gold	50 000 004
UV Platinum	50 000 005

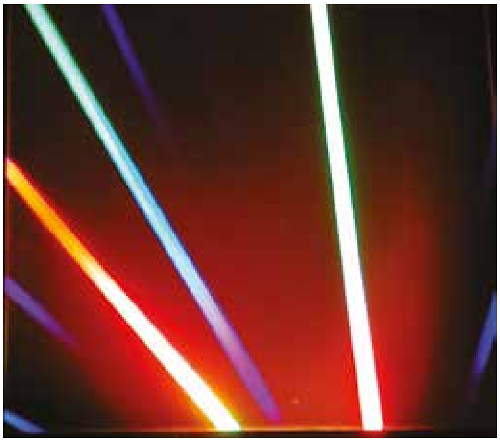


Reflectivity for Au coating
incident angle = 0°, unpolarized light



Example of reflectivity for different metallic coating
incident angle = 80°, unpolarized light

These reflectivity curves are for reference only and do not represent coating specifications.



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