LAMBDA RESEARCH OPTICS, INC.

Radial Polarizer for CO_2 Laser Systems

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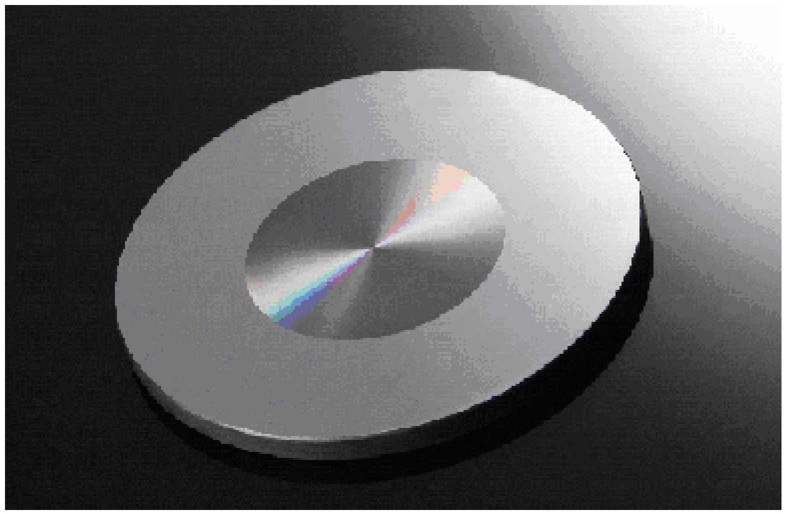

GIRO is a revolutionary product. By exchanging the rear cavity mirror of the CO_2 resonator with the GIRO, the laser emits a radial polarized CO_2 beam. This radial polarized energy is better absorbed by mild steel than circular polarized energy. This effect will improve the cutting speed using the same amount of power since more power is now entering into the melt. So go ahead and upgrade your CO_2 laser system. Upgrade with GIRO.

Benefits of GIRO

* Easy upgrade kit is available. No modification to your laser system is required
* Improve cutting speed with your existing laser system
* Enormous economic benefit compared to a traditional laser power upgrade

Specifications

* GaAs substrate material
* Diameter: 1.0” ~ 1.5” with Clear Aperture 20mm ~ 30mm
* Thickness: 3.0mm ~ 5.0mm
* Radially etched pattern on Flat surface. R > 98.5% for radial polarization
* 40/20 polished surface with AR coating R < 0.25% @ 10.6µm on other side

For more information, please contact our Sales Team at 714-327-0600 or lambda@lambda.cc

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THE INSTALLATION AND USE OF THE Radial Polarizer (RP)

A diffraction grating is usually made by ruling a number of parallel and equidistant grooves in a dielectric substrate. The grating will split an incoming (laser) beam in a number of transmitted and reflected beams. The angles under which the incident beam is being diffracted into the different transmitted and reflected beams are determined by the grating equation. This equation assumes a limited number only of diffraction angles as solutions. The incident beam is labeled as the zero-th order beam. The diffracted beams are denominated as the first, second ...order beams in reflection or transmission. In case that the period of the grating is of the same order of magnitude as the wavelength of the incident beam, typically only 4 to 5 angles are possible. If the scope is further narrowed to so-called sub-wavelength gratings, this number reduces to 2 or 3.

The RADIAL POLARIZER is a sub-wavelength dielectric grating which generates just **one** diffracted beam, specifically the zero-th order reflected beam. The optical functionality of the RADIAL POLARIZER is hence that it acts as a partial reflector for the incident light. The most salient feature of the RADIAL POLARIZER however is its polarization selectivity.

The Fresnel equations for the reflectivity coefficients of a plane wave incident on a dielectric interface, dictate that under normal incidence the reflection of a p-polarized wave is equal to the reflection of an s-polarized wave. The dielectric mirror hence has no polarization selective reflectivity at all. Suppose now that the laser beam is incident on the RADIAL POLARIZER. If the refractive index, grating period, filling factor and depth of the grooves are chosen appropriately, the optical functionality of the RADIAL POLARIZER becomes:

- **R> 99% for polarization perpendicular to the grooves of the grating**
- **R< 3% for polarization parallel to the grooves of the grating**

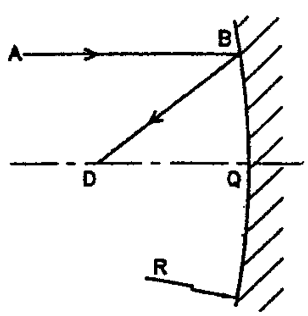
This RADIAL POLARIZER is hence a (nearly) total reflector with extremely high polarization selectivity under zero angle of incidence.

If now the grooves are etched into the dielectric as concentric circles, this device will very well reflect radiation which polarization is perpendicular to the circles, hence which is radially oriented outward from the common center of all these circles.

The active side of the RADIAL POLARIZER is provided with concentric grooves, forming a radial diffraction grating. *It hence acts as a total reflector under zero angle of incidence, for radially polarized incident light.* Its other side is curved (convex) and provided with a low absorption AR-coating at 10.6 micrometer. This convex side is optically equivalent to the concave side of a regular cavity mirror, as we will now explain.

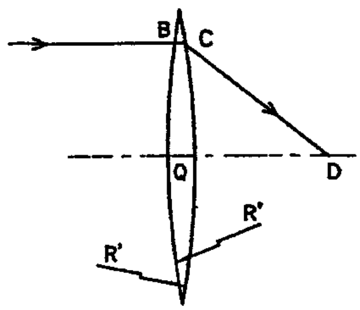
Consider a concave (cavity) mirror having radius R, on which a ray AB, parallel with the optical axis is incident. This ray is reflected towards the focal point D of the mirror, see fig. 1.

Figure 1



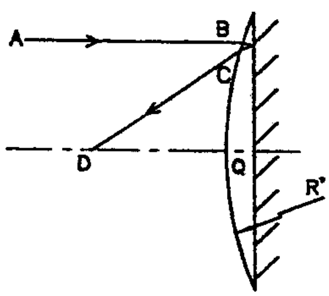
This mirror is now replaced by a bi-convex lens with focal length f=R/2 and with radii R', see fig. 2. In this figure, it is clear that DQ=f=R/2

Figure 2



This bi-convex lens is now on its turn replaced by a plano-convex lens where the plano side has been made totally reflective, see fig.3.

Figure 3



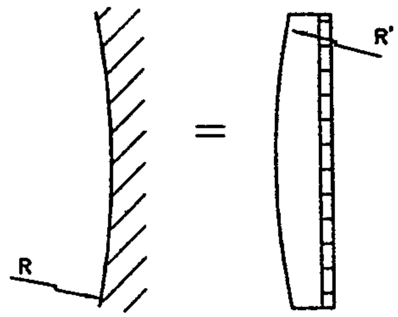
The radius R' of the convex side of this plano-convex lens is determined by the lens' makers formula: $1/f=(n-1)(1-R'-1/R')$ for the bi-convex lens of fig. 2, where n is the refractive index of the lens substrate material. These relations lead to **$R'=2(n-1)f= (n-1)R$.**

Example: n=3.2 for GaAs at 10.6 micron. A cavity mirror of 20m concave is corresponding to a RADIAL POLARIZER with a convex side of 2.2x20=44m.

Ray tracing in the RADIAL POLARIZER:

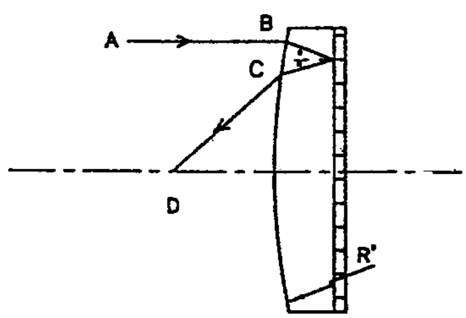
The RADIAL POLARIZER is acting as a plano reflector (= a flat mirror) with a plano-convex lens installed just in front of it, see fig. 4.

Figure 4



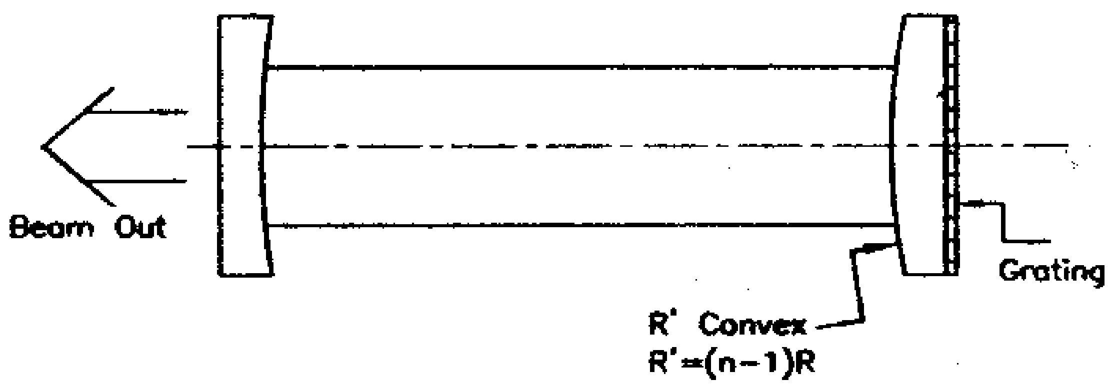
The equivalent ray trace of fig.3 in the RADIAL POLARIZER device is given in fig. 5.

Figure 5



Finally, we have to consider the functionality of the RADIAL POLARIZER as end mirror in a laser resonator. Inside the resonator, only self-reproducing rays are possible: they must reflect back on themselves after one round-trip in the cavity. This necessarily means that the ray incident on the RADIAL POLARIZER grating is incident under zero degrees, see

Figure 6



HANDLING OF THE RADIAL POLARIZER

The RADIAL POLARIZER is an intra-cavity optical component, and should be treated and handled as such. The side with the AR coating must be pointing towards the resonator. This means that the AR layers are in fact part of the resonator and that the laser light is incident from the inside of the RADIAL POLARIZER onto the grating.

The AR side of the RADIAL POLARIZER can be cleaned with very pure acetone, following the standard optics cleaning procedures. The grating side should only be cleaned by blowing a jet of dry air over the corrugations.

INSTALLATION

The RADIAL POLARIZER replaces the rear cavity mirror of the resonator. Because its reflectivity is not 100% but slightly lower, some leakage light will escape through the component, which can be used as on-line power monitor signal.

ALIGNMENT

The cavity is aligned with a visual laser (HeNe or diode), by first bore sighting the beam onto the mechanical resonator axis. Then the RADIAL POLARIZER is installed, with the AR side pointing towards the cavity. The reflection from the alignment laser is obtained from this AR side, NOT from the grating side.

Eventual folding mirrors in the cavity should be zero-phase total reflectors.

The center of the radial grooves is aligned relative to the center of the RADIAL POLARIZER substrate to better than 10 micrometer. *It is our experience that this center should carefully coincide with the mechanical axis of the resonator.*

COOLING

The RADIAL POLARIZER will slightly warm up, due to intrinsic absorption in the GaAs. However, because of the ring-shaped mode, the temperature distribution over the substrate will be nearly homogeneous. This is contrary to the heating of an output coupler by a Gaussian transmitted beam, where the center will have a higher temperature than the edge and where in this way the thermal gradient creates a thermal lens in the substrate.

The RADIAL POLARIZER should be cooled as careful as an output coupler. It might be necessary to redesign the rear-mirror mount of the resonator, in order to cope with this requirement.

The actual thickness of the Radial Polarizer has been standardized for the moment on 3 mm. This is a compromise between a thin substrate to minimize bulk absorption and a thick substrate to maximize mechanical strength (no deformation due to the atmospheric pressure).

OPTIMIZATION OF THE MODE SHAPE

Depending on the inner diameter of the discharge tubes and on the resonator length, it might be required to install an intra-cavity aperture to obtain a pure ring mode, by spatial filtering.