Design Ideas

Infrared Attenuator Uses Diffraction Principle

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Alignment and analysis of intense infrared beams (e.g. from CO_2 lasers) require taming of the power. Many applications in laser jobshops or research laboratories require level setting — ideally without affecting key beam characteristics such as mode, polarization, direction, or divergence.

An attenuator has long been missing for medium and high-power CO_2 lasers. For example, it has been impossible to view the mode structure, let alone the focal spot, of a high-power continuous-wave CO_2 laser with such practical imaging devices as fluorescent displays or pyroelectric detector arrays. Traditionally, attenuators have been based on the physical principles of absorption and reflection.[1] Existing commercial attenuators using absorbing or reflecting dielectrics suffer from thermal lensing effects at moderate powers. But even at low power levels, the performance of such devices is limited by beam offset and beam deviation from residual wedges. Reflecting dielectrics give homogeneous attenuation only for well-collimated beams. In this case the attenuation is, furthermore, strongly dependent on polarization.

A novel attenuator principle uses diffraction from regularly perforated thin metallic sheets (Fig. 1). This approach can fulfill many of the desired requirements. Most importantly, the diffractive attenuator has a remarkably high power-handling potential. A recently introduced commercial version[2] has been specified to powers of 200 W c.w. and 10 J pulsed, in a compact, easily installed device with a l9-mm clear aperture. Higher power capabilities are technically feasible. Water cooling is recommended when c.w. or quasi-c.w. powers exceed 30 W.

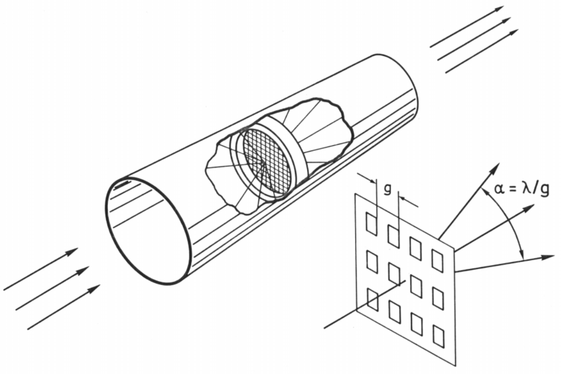

Figure 1. Schematic view of the diffractive attenuator operation principle shows how an input beam is scattered from a regularly perforated metal sheet. The many diffracted beams can not emerge but are intercepted and rejected by absorption on the inside walls of the housing tube. Only the zeroth-order diffracted beam emerges as an undeviated, attenuated output beam.

The initial insertion loss of the device is zero. Attenuation is produced by flipping in one or more of the diffracting metal sheets. The input radiation is scattered in the interior of the device (Fig. 1). Out of dozens of diffraction orders only a single one can escape to the outside: the zeroth scattered order transmitted exactly in the forward direction. All the other beams are intercepted and absorbed by the inside walls. The mere thinness of the metal sheet and the absence of any substrate guarantee that the forward beam does not suffer a deviation or offset: no defocusing or pattern change of even an arbitrary complicated mode can occur.

The attenuation factor has been designed to be near 5 db per element, equivalent to a power transmission of 31.6%. With the five elements provided, the maximum attenuation is 25 db equivalent to 0.3% transmittance. Since the input beam is nearly normally incident on a structure of square symmetry, the attenuation does not depend on the input polarization. In other words, any polarization is genuinely preserved in the output beam, be it linear, circular, or arbitrarily elliptical.

The high reflectivity of metal keeps the diffracting sheets from absorbing much energy, so the device has a high power handling capability. The diffraction loss and the diffraction angles $\alpha = n\lambda/g$ depend on the period g of the perforation pattern.[3,4] Overly large values of g are avoided, because the interception of near-forward scattered orders would require an inconveniently long device. For CO_2 laser wavelengths, g-values between 30 and 100 µm are best. When several such sheets are inserted, a precise relative orientation is essential to avoid multiply diffracted false beams. A suitable design must efficiently suppress any back reflection toward the laser. Diffractive attenuators make fairly broadband devices: they can be considered essentially flat over the 9- to 11-µm region, as Figure 2 indicates.

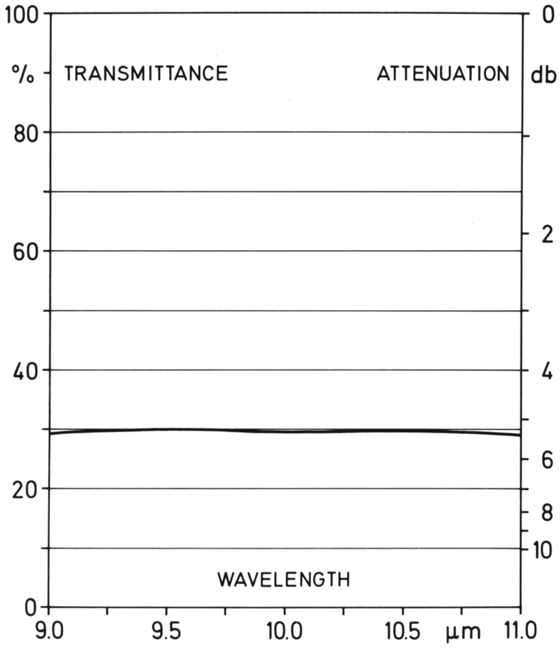

Figure 2. Attenuation *vs* wavelength of a single diffractive attenuator element. The performance is essentially flat over the range of CO_2 laser wavelengths.

Applications of the attenuator are as varied as applications of the CO_2 laser. In our laboratory we have developed the attenuator for nonlinear optics studies with TEA CO_2 lasers. The task is to measure the intensity dependence of saturable absorbers over a dynamic range of three orders of magnitude. The presence of an additional probe beam requires a very high degree of alignment stability.

At present, the attenuator is routinely used to set the output level of a commercial system consisting of a 40-W c.w. CO_2 laser pumping a far-infrared gas laser. Alignment using liquid crystal or fluorescent imaging displays is done at about 400 mW (-20 db): optical pumping of low-threshold transitions is done at 13 W (-5 db) or 4 W (-10 db) to avoid multifrequency emission from cascading transitions.

In general, the attenuator is as practical as any other accessory to any CO_2 laser in the laboratory. Permanently installed where the beam exits from the laser, the attenuator facilitates test and setup procedures by reducing the power level. Thus a typical output power of 10-100 W may be set near to near 1 W for setup. When needed, the full power becomes instantly available by flipping out attenuator elements. This action is much more satisfactory than the long warmup and readjustment times associated with the procedures that reduce the laser's output power by reducing the discharge current.

The attenuator offers the experimenter flexibility to adapt various detector or device specifications to a given laser output. A typical problem is the limited dynamic range of linear response in a given detector. The attenuator is also useful when characterizing detector response, which stems from the large dynamic range of accurate attenuation and the absence of any imposed beam deviation.

The diffractive attenuator with 0- to 25-db dynamic range can fill a gap for taming medium and high power c.w. and TEA CO_2 lasers. It should be useful in industrial and laboratory applications, ranging from optics testing and laser machining to spectroscopy and laser chemistry.

References

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