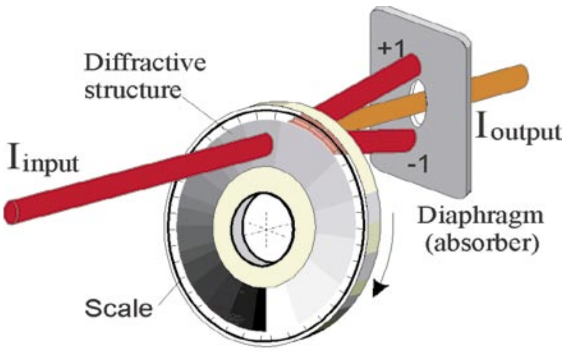
Diffractive Variable Attenuators

For High Power Lasers

Diffractive attenuators control the power of laser radiation using diffraction gratings. Since phase diffraction gratings do not absorb light they can be used for high-power laser radiation (cw, pulsed). Variation of grating parameters along the attanuator results in variable transmission at a given wavelength. Diffractive attanuators can be designed for deep UV till IR.

1. Principle of operation

Light beam passing through a diffractive grating is partially deflected into several diffractive orders, subsequently blocked by diaphragm. Thus zero order beam (does not change the direction of propagation) is attenuated. The intensity of output radiation I_{output} depends on the grating design and wavelength. Grating parameters determine the power of output radiation. The transmission coefficient of such an attenuator is $\eta = I_{output}/I_{input}$. Transmission varies from η_{max} to η_{min} by 340° rotation of attenuator wheel. Attenuation range is defined as $D = \eta_{max}/\eta_{min}$.



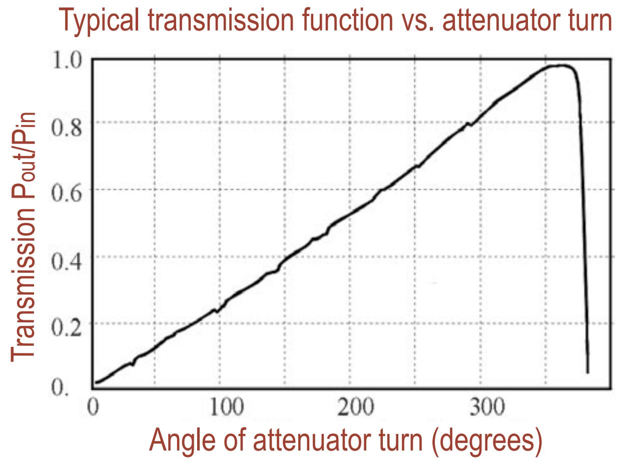
Principle operation scheme of high-power attenuator based on non-absorbing-phase diffractive gratings (etched in quartz).

2. Key features

- High power attenuator: Diffractive attenuators can control high power laser radiation, either pulsed or continuous (cw) laser beams due to non-absorbing phase gratings.
- Flexible design of transmission function: The dependence *h(j)* of the attenuator transmission on rotation angle *j* can be designed by computer for customer´s requirements.
- Low cost mass-fabrication: Laser lithographic methods allow one to produce attenuators by binary optics technology with significant price decrease for larger quantities.

3. Applications

- Beam-modulators for high power lasers (Nd:YAG-, Argon-, Excimer-...) ⟶ material processing, e.g. marking, scanner systems
- Beam-splitters with adjustable splitting coefficient and attenuation ⟶ laser-technology, photometry, optical research
- Holography: Intensity modulation of object/reference beam with neglectible wavefront distortion.



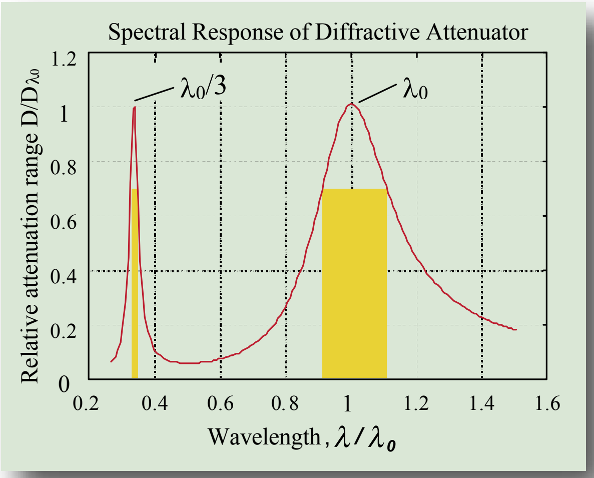
4. Specifications

Substrate

- material	UV grade fused silica
- surface flatness	$\lambda/4$ @ 532nm over clear aperture
- wedge	≤ 30 arcsec
- outside-, inside diameter	60 mm, 8mm
- thickness	4 mm
- clear aperture	10 mm
- front side	AR-coating, R<0.3%
- back side	diffractive grating (binary phase relief, 10µm)
Design wavelength	266nm, 355nm, 532nm, 800nm, 1064nm
- other wavelengths on request	
- transmission range	T_{linear} = 2% – 95% over 340°
- deviation from linearity	≤ 5%
- polarization	transmission not dependent on polarization!
Damage threshold	≥500 W/cm² -cw, ≥2 J/cm² with 10ns pulses

5. Spectral response

Although diffractive attenuators are optimized for λ_0, they will operate over a larger spectral range (λ_0±15%) with minor attenuation range decreasing. Thus 532nm attenuator with attenuation value $D(\lambda_0)=20$ can work at 633nm wavelength with $D=10$. Functional dependence of transmission function is remained the same. Notice that attenuator works also at 1/3 of design wavelength λ_0 , however has nearly zero effect at $\lambda_0/2$.



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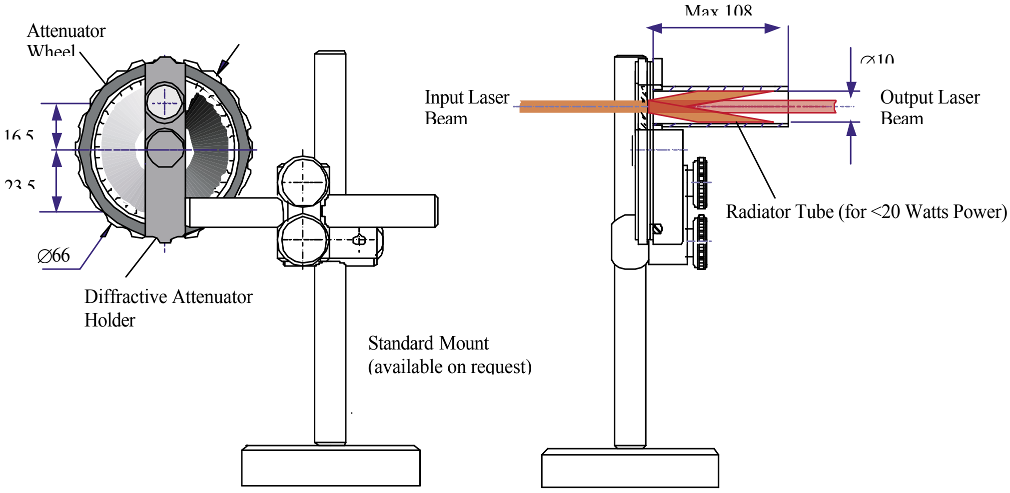
6. Attenuator Design and Operation

Attenuator includes diffractive attenuator wheel mounted in special holder and two tubes with maximum length of 108 mm (see figure). Tubes intend for blocking parasitic diffractive orders and absorbing of laser radiation. Tubes are suitable for less than 20 Watt average power dissipation. A special finned radiator is required for higher laser power.



7. Laser Safety

● Use safety glasses to protect your eyes against intensive laser radiation

● While working in IR-range (800 nm, 1064 nm) we strongly recommended to use Infrared-Viewers (S1-Photocathode). IR-detector cards are too intensive and can not visualize all diffracted and reflected beams

● The intensive beams diffracted in forward direction can be blocked using the radiator tubes (2 pcs attached). For laser beams P ≥ 5-10 Watt radiator tubes need cooling, e.g. by fan

● Attention! Intensive laser beams occur also in backward direction *
Carefully check for proper beam blocking.

** To learn about principles of diffractive attenuators one should use a visible laser beam with low intensity. Please note that diffraction angles and diffraction efficiency will differ with wavelength. In particular the attenuator will not work at all at half of design wavelength.*

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