Laser Power Control Units

Laser capability to accomplish extremely precise tasks by applying high power impact within tiny spatial domain, e.g. diffraction limited spot, has lead laser power control to become an important variable that helps to optimise yield and secure successful completion of the task. There are various methods to control the power of solid state lasers which will be reviewed in this article.

The simplest way to control laser output power is by controlling its gain medium pump power and in DPSS lasers it means adjustment of the current feeding laser diode. However such way of power control cannot ensure smooth and continuous laser power control because of several reasons. First of all, changing laser diode current introduces temperature shift in the diode which changes the band gap between conduction and valence bands, thus central wavelength of the pump is shifted, altering the conditions in solid state gain medium. In case of CW operation this string of related events introduce fluctuations in laser output power and it takes time to stabilize the power again. But if the laser is pulsed (e.g. passively Q-switched), not only the output power fluctuations are introduced, but also PRR and pulse duration would be altered with changing the pump power. What is more, when laser diode current is changed during the operation, additional degradation mechanisms emerge [1]. Thus this type of power control is only acceptable for the least power-sensitive applications.

Extra-cavity laser power control is yet the most popular method of laser power management, for instance absorbing neutral density glass filters are useful to discretely attenuate relatively low power beams and are quite effective up to 1 J/cm^2 energy densities within the nanosecond regime. ND filters provide rather even attenuation over wide spectral range from UV to NIR. Quite similar are reflective neutral glass filters which are coated with metallic layer that transmits a portion of the radiation while reflecting and absorbing the rest of it. Advantage provided by metallic semi-reflecting

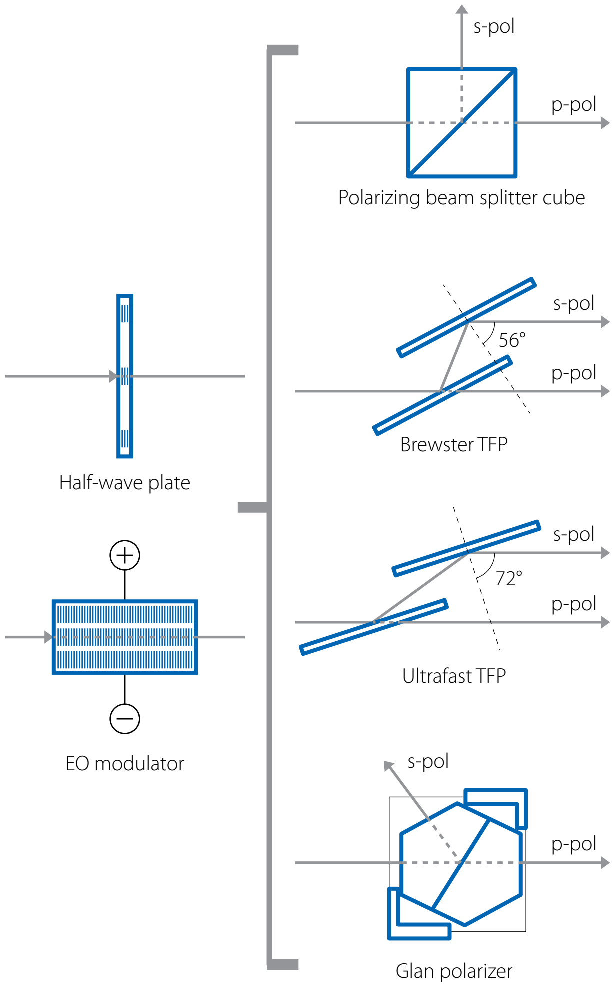

Fig. 1. Options of polarization manipulation based attenuator.

coating is the possibility to deposit thickness gradient of metallic layer allowing continuously variable density along filter cross-section.

Laser sources with polarized output provide subtile attenuation option – output power control through manipulation of the polarization. Such method incorporates polarization rotator and polarizer. Polarization rotator is usually a waveplate or electro-optic (EO) modulator that rotates input polarization. Then the beam passes onto the polarizer, where orthogonal polarizations S and P are separated into two separate S and P polarized beams. Intensity ratio between the two beams is controlled by polarization

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rotator which can be either a waveplate or an EO modulator. The EO modulator can turn input beam polarization by 90° within tenths of picosecond [2], which makes it applicable in pulse picking/cavity dumping applications, but this comes at cost of complicated controller which must cope with voltage of several kV, thus it is used only for applications were fast open-shut rates are mandatory. If the waveplate is used as polarization rotator, it must be physically turned which slows down the polarization rotation but such scheme can be realized in both – manual and motorized control and the latter could provide MIN-MAX attenuation within few hundredths of a millisecond. Polarizing optics come in a huge variety readily available on the market, which allows to assemble attenuators with distinct features serving particular applications. For instance: separation of 90° angle between S and P polarizations can be realized by using polarizing beamsplitter cube, if parallel output beams are needed, two parallel Brewster polarizers could be used, for femtosecond lasers – broadband optics like achromatic waveplates and „ultrafast“ 72° angle of incidence polarizers would help to preserve pulse duration, mid-IR region can be accessed by employing appropriate materials and optics production technologies, e.g. mid-IR waveplates and Yttrium orthovanadate (YVO_4) or Tellurite (TeO_2) Glan polarizers. Attenuators, operating under polarization control principle provide numerous advantages over other methods, firstly – the dynamic attenuation range 0.04–99% can be achieved, and no less important is laser damage threshold of the optics which can be up to 20 J/cm^2 [3]. However, only polarized sources can be managed in this principle, which means, that unpolarised lasers need to be fitted with another power control solution.

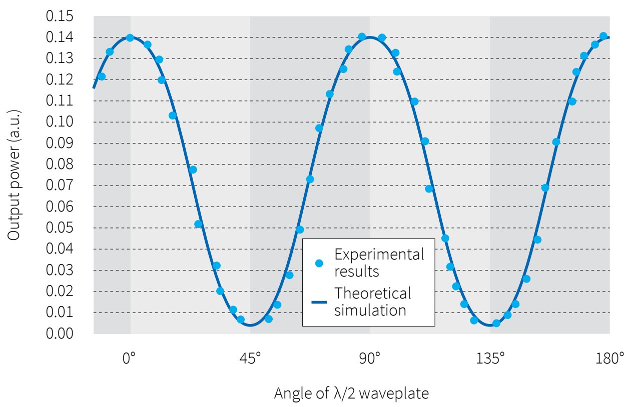

Fig. 2. Example of performance provided by attenuator comprising a waveplate and a polarizer.

Unpolarised laser sources also have several options for attenuation. Attenuator principle relying on Fresnel reflection will be reviewed. Knowing the Power-Amplitude relation $P = (A)^2$ reflected power at the interface between two transparent homogeneous media is defined by equations [4]:

$$R_s = \left(\frac{n_1 \cos\theta_1 - n_2 \cos\theta_2}{n_1 \cos\theta_1 + n_2 \cos\theta_2}\right)^2 ; \; R_p = \left(\frac{n_2 \cos\theta_1 - n_1 \cos\theta_2}{n_2 \cos\theta_1 + n_1 \cos\theta_2}\right)^2$$

Were R_s and R_p is reflected power of S and P polarizations, n_1 and n_2 are refractive indices of intersecting media, θ_1 is angle of incidence, θ_2 is angle of refraction.

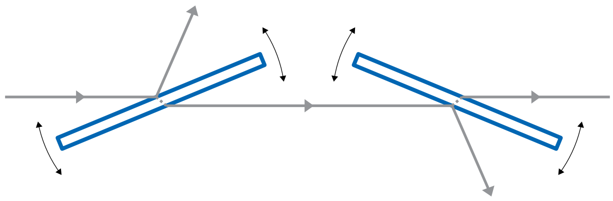

Fig. 3. Principle of two plate based attenuator – two opposite direction rotating plates dump energy to the housing while maintaining collinear output.

Such attenuator comprises two uncoated glass plates which are positioned in a chevron configuration. As Fresnel reflections are dependent on angle of incidence, changing the angle between the plates also changes the power of transmitted radiation. Glass plates being uncoated determine that laser induced damage threshold of the attenuator is equal to damage threshold of the glass material which makes it, in principle, the most damage resistant external attenuator. Another advantageous feature of this product is operation in broadband spectral range, which means that even the power of supercontinuum sources can be effectively controlled by the solution. However, the main disadvantage of the product is that it cannot be used with ultrafast laser sources due to relatively thick dispersive media which leads to pulse temporal elongation. Another drawback is that the minimum losses of the setup are rather high. As Fresnel reflections cannot be avoided (for instance UVFS reflects >3% at 1064 nm at normal incidence [5] thus the maximum transmission of such system is usually no more than 90%. Also it is worth mentioning, that the beam after this attenuator becomes polarized and the higher the attenuation, the more dominant is the P polarization at the output.

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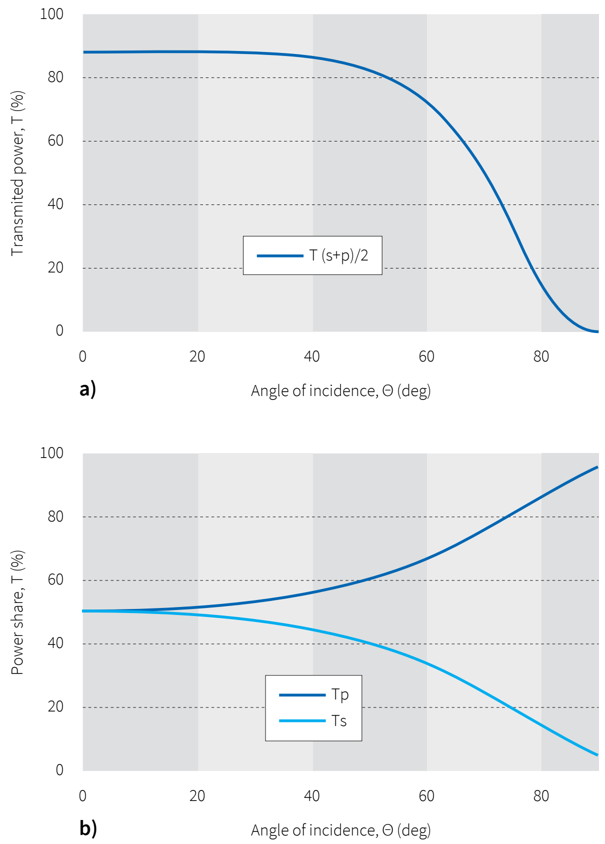

Fig. 4. Attenuation properties of two uncoated UVFS plate based attenuator operating at 1064 nm. **a)** attenuation dependence on AOI, **b)** transmitted beam polarization consistence.

In summary, external laser output control units are:

Incident polarization insensitive:

- Variable neutral density filters
- Fresnel reflections based attenuator

Incident polarization sensitive:

- Electro optical modulator + polarizer
- Waveplate + polarizer

Altechna offers the following continuously variable attenuation solutions:

- Circular Variable Neutral Density Filters
- Manually variable waveplate + polarizer attenuators
- Motorized wavepalte + polarizer attenuators

References

[1] photonics.gsfc.nasa.gov/tva/meldoc/sources1.pdf

[2] www.rp-photonics.com/cavity_dumping.html?s=ak

[3] www.altechna.com/lidt

[4] www.rp-photonics.com/fresnel_equations.html

[5] refractiveindex.info/?shelf=glass&book=fused_silica&page=Malitson