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ON MINIMISING REFLECTION LOSSES FROM LASER WINDOWS

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Abstract

The use of multiple-beam interference is discussed as a means of reducing reflection losses from optical components in laser systems.

Energy losses due to reflection from the surfaces of optical components is a familiar problem in optics design. Two common techniques for reducing this loss are the use of multi-layer coatings or, for polarised light, incidence at Brewster's angle.

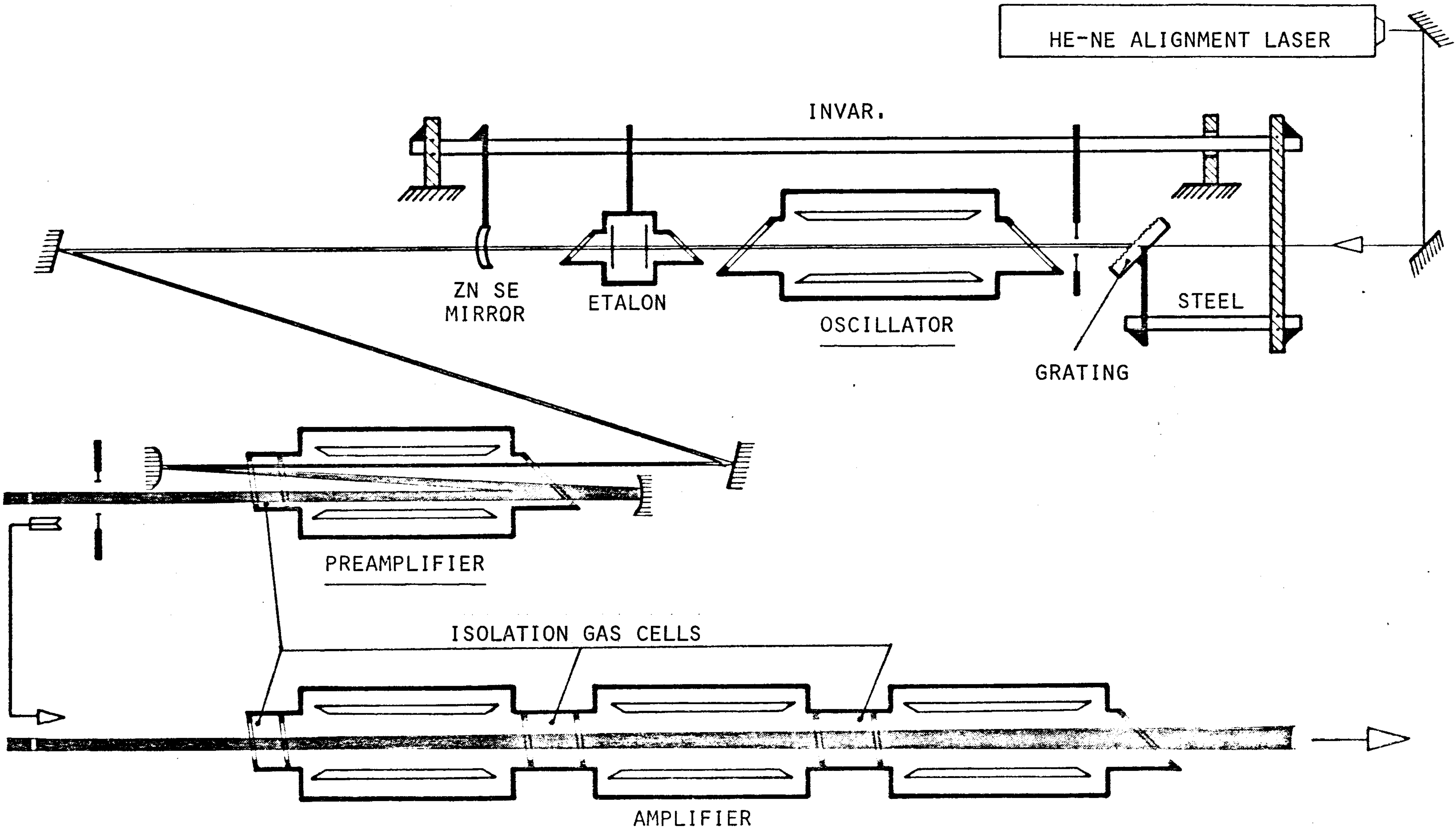
There are instances when these techniques are not readily applicable, take for example large diameter CO_2 lasers. Brewster's angle for salt is 55^o. The cost of very large salt windows can be prohibitive. No satisfactory multi-layer coating exists that will withstand high powers. The problem becomes acute if isolation gas cells are used between stages, since the energy lost can become large.

Consider the system illustrated in Figure 1. This device has been constructed in our laboratory for the optical pumping of gases; it is representative of a large CO_2 laser chain of amplifiers. The beam traverses 32 surfaces (not counting those in the oscillator);each of these surfaces has an average loss of about 4% and would result in a total energy loss exceeding 72 %. In fact, we shall show that for a given window the loss can amount to considerably more than the average value.

The reflectivity, R,of a single dielectric surface for normal incidence is given by

$$R = \left(\frac{n - 1}{n + 1}\right)^2$$

where n is the refractive index of the material.



ø = 45 mm

E = 25 JOULES ($\lambda = 9.6\ \mu m$)

Fig. 1 CO_2 laser system for optical pumping

However, to calculate the transmission of a dielectric having two parallel surfaces (and of negligible absorption), the effects of multiple-beam interference (Tolansky 1970) must be considered.

The transmission, T, as a function of thickness, t, and incidence angle, θ, is

$$T = \frac{1}{1 + \frac{4R}{(1-R)^2} \sin^2 \frac{(2 \pi nt)}{\lambda} \cos \theta} \tag{2}$$

the well-known Airy formula. We plot in Figure 2a this function for a material of thickness 6.5mm and refractive index 1.44. The transmission varies from 0 to 12%.

Thus to maximise the transmission through a window we should arrange for the thickness to be an integer number of half wavelengths. Unfortunately, to polish windows to a specific thickness is costly. However, t', the optical thickness, can be conveniently varied by a small change in the angle of the incident beam. Figure 2b illustrates this. The modification to the profile of Figure 2a arises from the cosine dependence of t' on θ. To obtain the maximum transmission through a laser window we adopt the following procedure. A chopped c.w. laser beam of appropriate wavelength is passed through the CO_2-laser chain. The angle between each of the windows and the beam is then fine tuned for maximum transmission. An example is shown in Figure 2c, measured in the laboratory.

../5

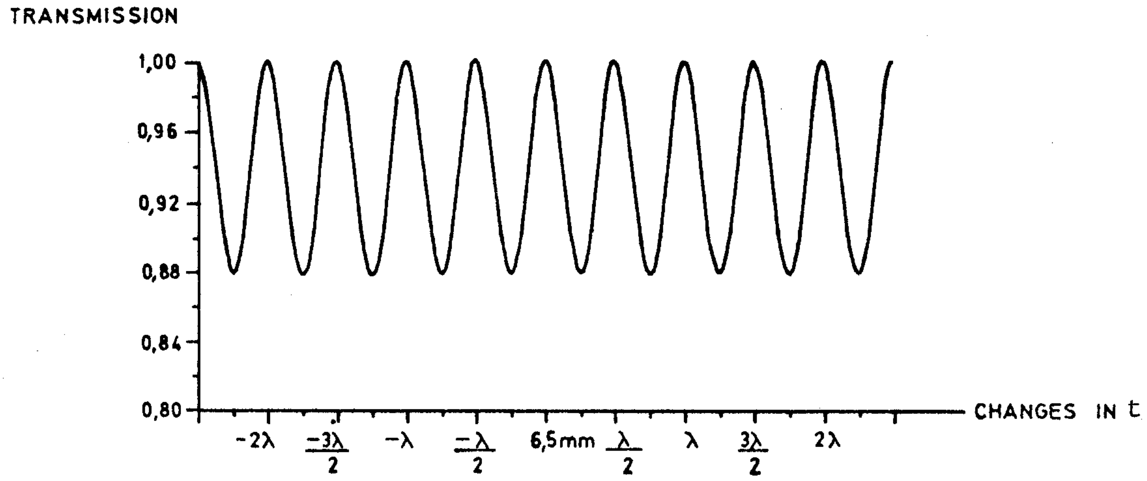


Fig. 2a. The Airy function, eq. 2, showing the transmission, T, for $n = 1.44$, $\lambda = 9.6\mu m$ and $t = 6.5mm$ (nominal) for small changes in t. $\theta = 0^o$.

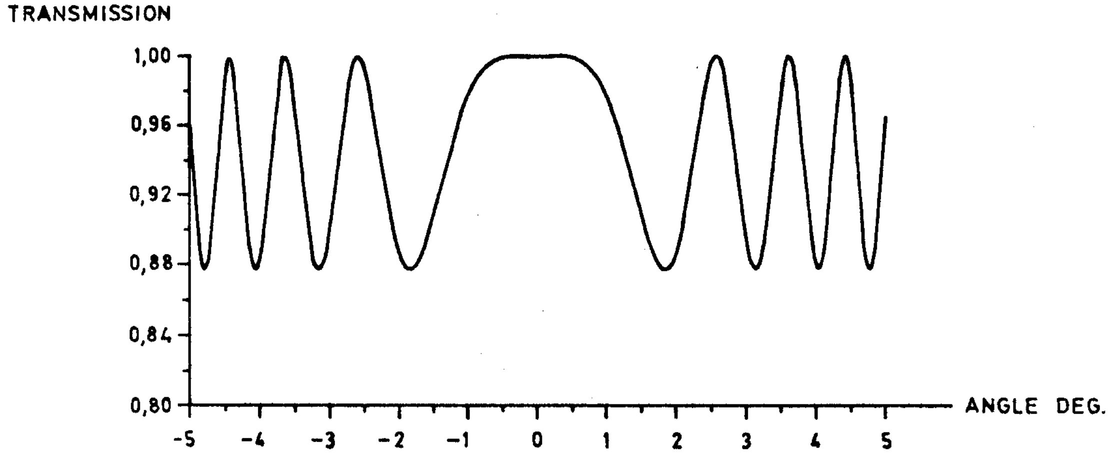


Fig. 2b. As for Figure 2a, but showing the effect on transmission of small changes in the angle of the incident beam.

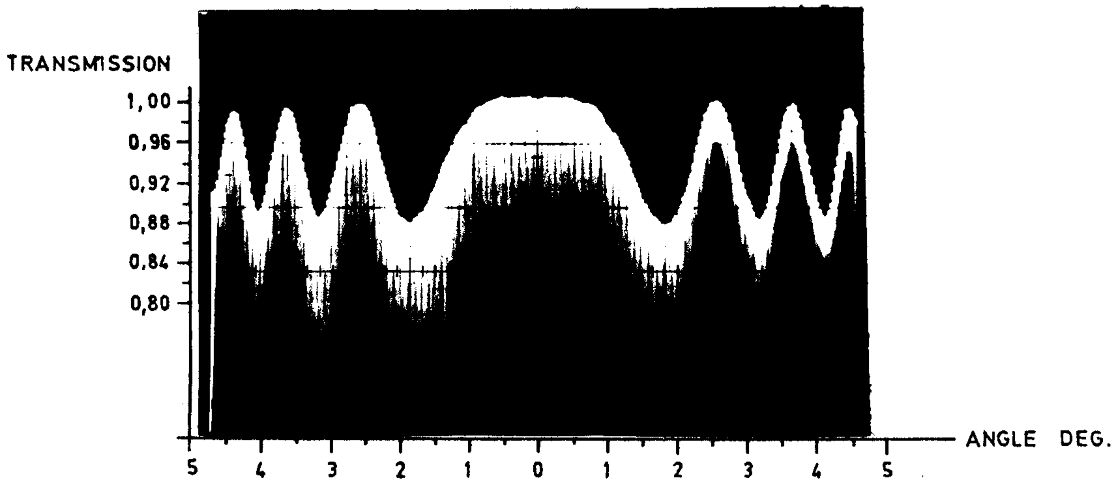


Fig. 2c. The measured transmission of a KCl plate of thickness 6.5mm for small changes in the angle of the incident beam. $\lambda = 9.6\ \mu m$.

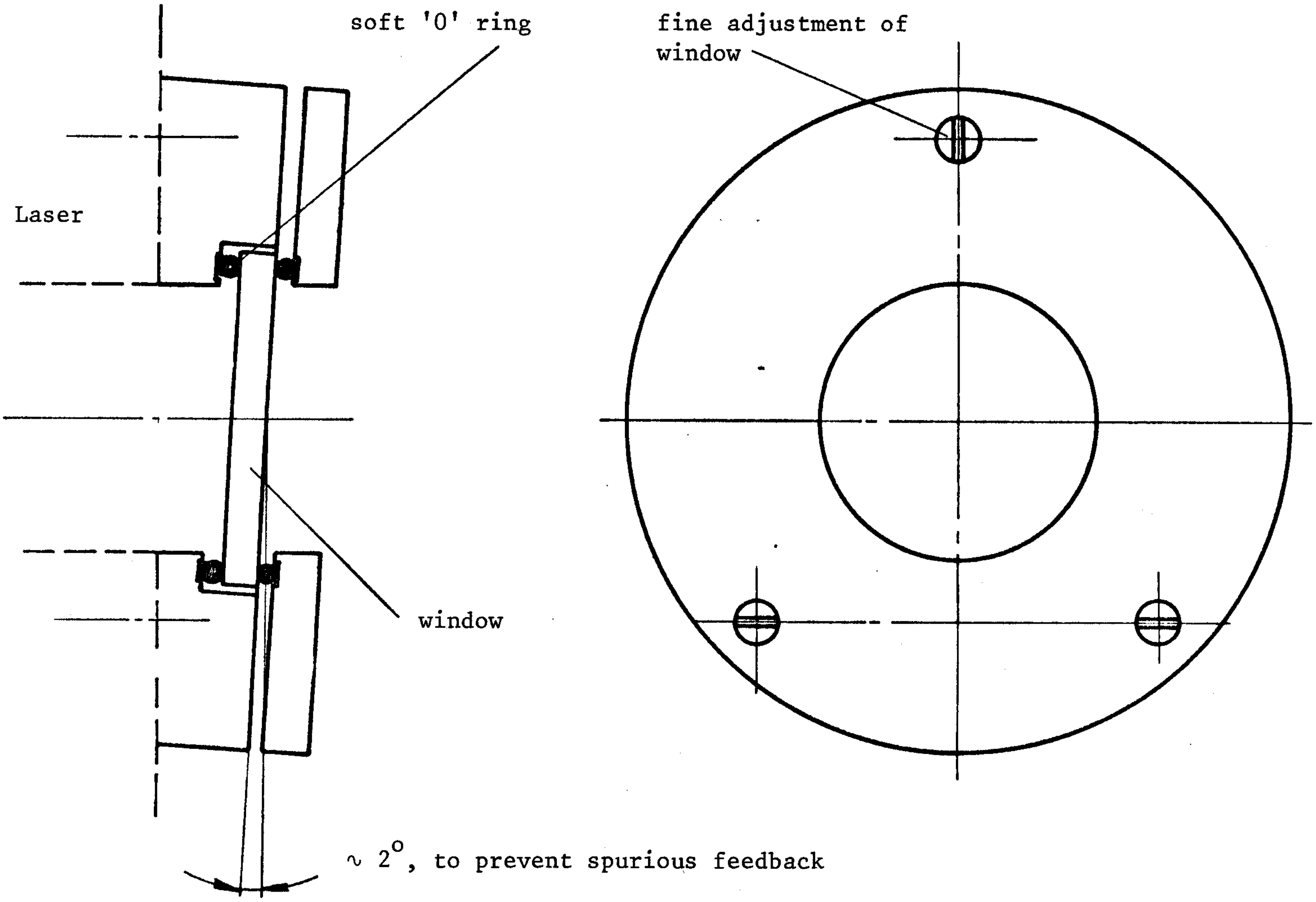


Fig. 3. A simple window mount having ∓ 1° adjustment.

There is enough 'play' on a soft 'O' ring for the necessary fine-tuning. A convenient mount for the window is shown in Figure 3. Note that the window is pre-tilted by ∿ 1 - 2° to prevent feedback should the window become mis-aligned. This implies that in fine-tuning the window is tilted so as to increase the angle of incidence.

To summarize, we have shown that by using the well-known physics of the Fabry-Perot etalon it is possible to much reduce energy losses from window reflections. The technique avoids the need to incline the window at Brewster's angle, which is costly for large apertures.

../7

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Reference

Tolansky S., Multiple-Beam Interference of Surfaces and Films Dover Publications (1970).

../8

Figure captions

1. CO_2 laser system for optical pumping

2a. The Airy function, eq. 2, showing the transmission, T, for $n = 1.44$, $\lambda = 9.6$ µm and $t = 6.5$mm (nominal) for small changes in t.

2b. As for Figure 2a, but showing the effect on transmission of small changes in the angle of the incident beam.

2c. The measured transmission of a KCl plate of thickness 6.5mm for small changes in the angle of the incident beam. $\lambda = 9.6$ µm.

3. A simple window mount having ∓ 1° adjustment.