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METHODS & DESIGNS

Intensity fluctuations produced by multimode lasers in combination with dielectric beam splitters

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The combination of an unpolarized multimode laser with standard dielectric beam control devices can give rise to large intensity fluctuations that can be troublesome in visual science experiments. A number of ways to avoid this problem are discussed.

This research note is directed to a specific gap in the current technical literature that is readily available to the behavioral researcher. In setting up a recent experiment, we encountered large unexplained intensity fluctuations in our laser-optical system. This system employs what is generally referred to as an unpolarized multiple-longitudinal-mode (TEM_{00q}) He-Ne laser (operating at a wavelength of 632.8 nm) in combination with dielectric optical path control devices (ordinary beam splitters and pellicles). For a beam reflected from a dielectric surface in this system, the light intensity was observed to vary by about 25% on a time scale of the order of minutes. This compares unfavorably with the less than 5% variability measurable directly from the laser output with no intervening dielectric surfaces at angles other than normal to the output beam (see Table 1). Table 1 shows that a totally reflecting aluminized surface will impart negligible intensity fluctuations to the reflected laser beam. On the other hand, where reflection is totally accounted for by an uncoated dielectric surface, the maximum fluctuation will be observed. The magnitude of the fluctuation varies approximately inversely with the percentage of reflection accounted for by nondielectric means such as partial aluminizing of the dielectric surface.

The existence of this problem is known to some involved in laser design and is a subject of current research (Duardo, Wang, & Hug, 1976). However, new users of lasers as a research tool may not be aware of this troublesome characteristic until they find themselves confronted with large intensity fluctuations for no discernible reason. Of course, a laser system exhibiting such fluctuations would prove difficult to adapt to many experimental situations. What is more important, a lack of awareness of the problem may introduce artifacts into designs where, for other reasons, the intensity is not being carefully monitored. This is a particular hazard since the laser specifications show that minimal intensity fluctuations should be expected. Yet even a 25% variation is not discernible when the beam is visually observed by scattering from a diffuse surface.

The explanation of this effect involves the nature of polarization of the multimode laser output (Yoshino, 1972) and the polarizing properties of reflection from a dielectric surface. The output of the "unpolarized" multimode laser often consists of several polarized components which slowly pass through the Doppler line (Duardo, Wang, & Hug, 1976; Mas, Blancher, & Roig, 1974; Berg, Note 1). This light, therefore, is not unpolarized in the sense that all polarizations are simultaneously represented. When incident on a dielectric surface at angles near the polarizing or Brewster angle (cf. Jenkins & White, 1957), the reflectivity for the beam may be substantially altered as its effective axis of polarization rotates relative to the plane of the reflecting surface. Since there are commonly only three to five principal modes in the usual laboratory laser of this variety, substantial variability in the reflected intensity can occur. Fluctuations in the transmitted beam also occur, but are of much less relative amplitude, as expected (see Table 1).

In fact, a similar problem of intensity variability will be found in systems employing a multimode unpolarized laser in conjunction with polarizing mechanisms other than dielectric reflection (e.g., dichroism, birefringence). Unless the polarizing agent can be oriented to select equally from the two orthogonally polarized laser output components, selective attenuation by the external polarizer, and therefore variable intensity fluctuations, will be produced in a manner analogous to the original problem.

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Table 1
Intensity Variability in Time as a Function of Reflecting or Transmitting Conditions of Optics and of Laser Type[a]

Surface Between Laser and Intensity Measuring Instrument[b]		Angle of Incidence (Deg)	Measured Average Percentage Intensity Variation[c] $[(I_{max} - I_{min})/I_{max}] \cdot 100$ Unpolarized Multimode He-Ne Laser[d]	Polarized Multimode He-Ne Laser[e]
Uncoated Glass Slide	Reflected Beam	45	22.8	1.5
Uncoated Glass Slide	Transmitted Beam	45	3.6	*
Uncoated Glass Slide	Transmitted Beam	90	1.5	*
100% Aluminized First Surface	Reflected Beam	45	2.0	1.8
35% Aluminized First Surface	Reflected Beam	45	7.7	*

a *Lasers: Coherent radiation, He-Ne (632.8 nm), 2.5 mW, longitudinal mode spacing 566 MHz; Model 80-S (unpolarized), Model 80-SP (polarized).*
b *In all cases, neutral density filters providing between .5 and 1.5 log units of attenuation were inserted normal to the beam.*
c *Over a period of the order of minutes depending on how long the laser has been on.*
d *Readings taken with a silicon solar cell (Centralab 110 CLVC) fed into a digital voltmeter (DVM) and counter (Beckman Eput and timer Model 6144); sample duration = .1 sec, sample rate = 1/2.5 sec^{-1}, 100 samples.*
e *Same solar cell and DVM as specified in d; sample duration = .1 sec, sample rate = 1/17 sec^{-1}, 100 samples.*
* *Reading not taken.*

Besides proper orientation of an external polarizer, which generally has the drawback of limiting usable output power, there are a number of technically feasible solutions to the problem. The simplest is to substitute a laser that produces a single nonrotating polarized output. Such lasers are commonly available and are usually constructed with windows at the Brewster angle internal to the resonant cavity of the laser (Siegman, 1971). The windows act to encourage oscillation with a particular polarization prescribed by the plane of the windows. Thus, all oscillating modes display the same polarization. This solution will be effective regardless of the polarizing procedures used in the external system. A second (partial) solution, applicable where only dielectric reflection is the polarizing agent, is to avoid reflectance angles close to Brewster's angle (e.g., 56 deg for refractive index 1.50). For this solution to begin to be effective, angles of incidence less than 30 deg are generally required. Intensity fluctuations can also be eliminated (or minimized) by the use of magnetic fields, quarter-wave plates, and specially oriented polarizers, as Mas, Blancher, and Roig (1974) have discussed.

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