tern parallel to the junction plane of these lasers exhibits two side lobes in addition to the main center peak indicating that there also exists a certain amount of antiguiding similar to that which occurs in narrow (6 μm) oxide-defined stripe lasers.[8] The overall divergent angle $\theta_{\parallel}$ at full width at half-maximum measured from these stabilized patterns is $\sim 23°$. The corresponding value $\theta_{\perp}$ perpendicular to the junction plane is $\sim 25°$.

One important feature of these diodes is the extremely high quantum efficiency. The measured external differential quantum efficiency was about 40–45% per facet from Fig. 2 as compared to the 20–30% for normal double heterostructure lasers[9] and 30–40% for buried heterostructure lasers.[1] We believe that the high efficiency is obtained because of large spreading of the optical field in the low absorption cladding $Ga_{0.6}Al_{0.4}As$ layers which results from the thin active layer. According to our estimation, $\sim 80\%$ of the total mode power is contained in the cladding layers. A thin active layer also favors high output power operation because the threshold power level for catastrophic mirror damage is increased when the optical field is distributed across more of the mirror facet. For these devices, linear, kink-free *L-I* characteristics were observed up to cw power of 40 mW from each uncoated mirror facet. A thin active layer also results in a less divergent output beam[10] which is desirable for coupling the laser output to a single-mode optical fiber.

In summary, we have demonstrated high-power, high-efficiency, low-threshold, large T_0, single-mode, deep Zn-diffused narrow stripe double heterostructure GaAs/GaAlAs lasers. This simple structure has high quality laser characteristics that can be compared individually to a variety of more complicated structures, none of which has all of these qualities. The results suggest that the combination of planar diffusion and uniform MOCVD growth is suitable for a reproducible and high-yield low-threshold fiber optic source.

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Fresnel reflection and transmission at a planar boundary from media of equal refractive indices

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Some interesting properties of the Fresnel equations governing the reflection of plane electromagnetic waves at an interface between differing media are presented. The phenomenon of reflection that is independent of angle of incidence is shown to be theoretically possible if the media possess different magnetic permeabilities.

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Consider a plane interface separating two media of real indices of refraction n and n', where $n^2 = \epsilon\mu$ and $n'^2 = \epsilon'\mu'$, for ϵ,ϵ' being the dielectric constants of the media and μ,μ' the magnetic permeabilities. Consider a plane electromagnetic wave of the form $\mathbf{E}_0 e^{i\mathbf{k}\cdot\mathbf{x} - i\omega t}$ incident onto the interface at an angle i from the unit normal pointing out of the interface into the incident medium. Here $\mathbf{k}$ is the propagation vector for the plane wave and ω is the angular frequency. The intent of this letter is to bring attention to an interesting special case of reflection and transmission of electromagnetic radiation from an interface.

The imposition of boundary conditions at the interface gives the familiar Snell law of refraction when all phase factors are equated, i.e., $n \sin(i) = n' \sin(r)$, where r denotes the angle of the transmitted wave.[1] Further, the imposition of continuity of the tangential components of the fields **E** and **H** yields the well-known Fresnel coefficients which relate the ratio of the reflected and transmitted field amplitudes to the incident field amplitudes. There are two possible polarizations: p polarization for the electric field vector parallel to the plane of incidence and s polarization for the electric field perpendicular to the plane of incidence. For each polarization the Fresnel coefficients, for reflected and transmitted amplitudes, are in general different.

The analysis of the Fresnel formulae is well documented in the literature; curves depicting the behavior of the reflected field amplitudes and phase change upon reflection for a large variety of cases are given in Ref. 2; curves for the reflectance, phases, and the behavior of the Brewster angle are presented in Ref. 3. (In this latter reference, the author defines three Brewster angles, and discusses how they behave for the case where the reflection medium possesses nonzero extinction.) However, most studies usually make the assumption that the magnetic permeabilities of the two media have a ratio of unity, i.e., $\mu/\mu' = 1$. This is a very good assumption throughout the visible spectrum, though may not be in the far infrared or millimeter domain.

An unusual situation occurs if we set the real indices of refraction equal, $n = n'$. Contrary to intuition, in the general form of the Fresnel coefficients there may still be nonzero reflectance from the interface as this equality is equivalent to the ratio

$$\mu/\mu' = \epsilon'/\epsilon. \tag{1}$$

Equality of the indices also says that the phase velocity of the electromagnetic radiation is the same in each medium since $v_p = c/n$ and $v_p' = c/n'$, and hence $v_p = v_p'$. Also, there is no refraction at the interface since from Snell's law $i = r$ (this also follows from the equality of phase velocities). However, the electromagnetic admittances of the two media, defined to be $y^2 = \epsilon/\mu$ and $y'^2 = \epsilon'/\mu'$, are not equal. Equality of the indices also gives the result (from the Fresnel coefficients) that the reflectance from the interface is a constant, independent of polarization, and independent of the angle of incidence. The reflection coefficient is given by

$$r = (y - y')/(y + y'), \quad i < \pi/2, \tag{2}$$

and the transmission coefficient is $t = 1 + r$ (in the absence of extinction in both media). This result is quite intriguing.

Though it appears that r is a constant for all angles of incidence, and hence t also, the analysis breaks down as we approach grazing incidence, i.e., as $i \rightarrow \pi/2$. We can see what happens by examining the general Fresnel equations where we let $n' = n + \delta$, for δ defined to be a small perturbation parameter that becomes vanishingly small. If we define r_s as the reflectivity for the s polarization and r_p as the reflectivity for the p polarization, then Fresnel's formulae take on the form

$$r_s = \frac{\mu'/\mu - (1 + 2\delta/n \cos^2 i + \delta^2/n^2 \cos^2 i)^{1/2}}{\mu'/\mu + (1 + 2\delta/n \cos^2 i + \delta^2/n^2 \cos^2 i)^{1/2}} \tag{3a}$$

and

$$r_p = \frac{\mu/\mu' - [n/(n+\delta)\cos i][1 - n^2 \sin^2 i/(n+\delta)^2]^{1/2}}{\mu/\mu' + [n/(n+\delta)\cos i][1 - n^2 \sin^2 i/(n+\delta)^2]^{1/2}}. \tag{3b}$$

In Fig. 1 are illustrated a variety of cases for the quantity $R_s = r_s r_s^*$, and in Fig. 2 we show several cases for $R_p = r_p r_p^*$. Note that for each polarization there may exist a Brewster angle, and if $\delta < 0$, the Brewster angle is followed by a jump to unity reflectance as the critical angle is passed for R_p.[4] Further, as $\delta \rightarrow 0$ we observe that the Brewster angle and subsequent jump to unity (either at the critical angle, or at grazing incidence) becomes more and more compressed toward $i = \pi/2$. When $\delta = 0$, the curves becomes singular at $i = \pi/2$ as the limit $\delta/\cos^2 i \rightarrow \infty$. It should be pointed out, however, that for a real physical situation it is unlikely that $\delta = 0$, but would possibly be very small.

Another interesting case that we should point out, which is well known,[5] is when the electromagnetic admittances of both media are equal, or equivalently

$$\mu'/\mu = \epsilon'/\epsilon. \tag{4}$$

Hence the reflectance is the same for both polarizations and is zero at normal incidence. As the angle of incidence increases the reflectance increases and goes to unity as grazing incidence is reached. If $\epsilon' < \epsilon$, the phenomenon of total internal reflection occurs when $i \geqslant \sin^{-1}(\epsilon'/\epsilon)$.

For all of the above situations, the magnetic permeabilities of the media must satisfy the condition that their ratio is

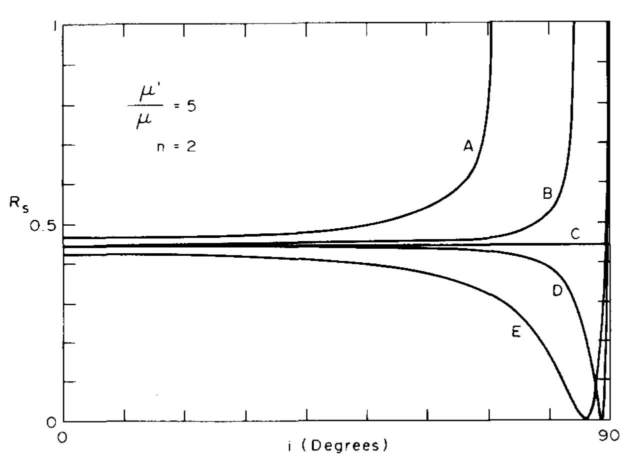

FIG. 1. Reflectance curves for s-polarized radiation. Here various values of δ are given: A: $\delta = -0.1$, B: $\delta = -0.01$, C: $\delta = 0.0$, D: $\delta = 0.01$, E: $\delta = 0.1$.

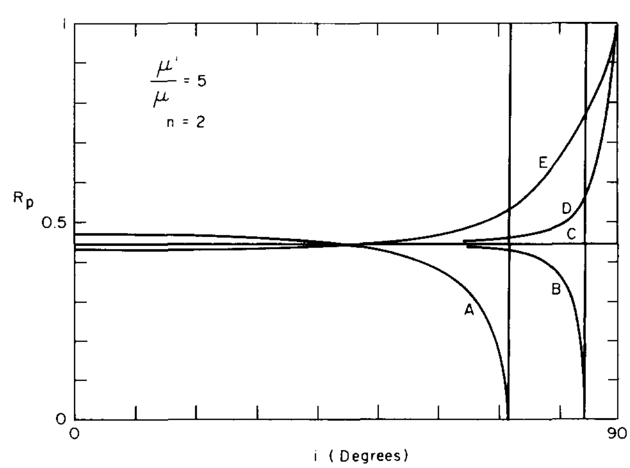

FIG. 2. Reflectance curves for p-polarized radiation. Here various values of δ are given: A: $\delta = -0.1$, B: $\delta = -0.01$, C: $\delta = 0.0$, D: $\delta = 0.01$, E: $\delta = 0.1$.

not unity, and such that relations (1) or (4) are satisfied. If, as is true with all known materials in the visible spectrum, $\mu' = \mu$, then conditions (1) or (4) cannot be satisfied, unless, of course, there is no interface. It is the author's desire that some of the observations in this letter will find some interest amongst millimeter wave and far infrared researchers. One interesting application may be in the design of mechanical or electrically driven optical switches. For example, from Fig. 2 we notice that the jump from the Brewster angle to critical angle occurs over an interval less than one degree. This, in effect, is analogous to an "on-off" state. Further, if the intrinsic media constants can be electrically tuned, it may be possible to rapidly switch from one curve to the other without recourse to mechanical means.

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Interference enhanced Kerr spectroscopy for very thin absorbing films

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A new method of obtaining polar Kerr spectra from very thin highly absorbing films ($\alpha > 10^4$ cm^{-1}) is described. The technique which is termed interference enhanced Kerr spectroscopy is shown theoretically to produce a gain in the Kerr intensity of $10–10^3$ (depending on the optical constants of the material) over that expected from a thick sample. The potential of the method is demonstrated theoretically using MnBi data and experimentally using an amorphous Tb-Fe alloy. The use of this interference technique for studies of other mode conversion phenomena is also mentioned.

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Polar Kerr spectroscopy is a powerful probe of the electronic properties of materials and has contributed to the understanding of the band structures of substances as different as transition metals,[1] garnets,[2] ferrites,[2] and semiconductors.[3] In this letter, we describe an experimental technique, termed inteference enhanced Kerr spectroscopy (IEKS), that allows polar Kerr measurements on very thin absorbing films. Its potential is demonstrated here by calculations using crystalline[4] MnBi as a model thin film material and by experimental measurements on an amorphous Tb-Fe alloy.[5] The results show that the gain obtained is sufficient to suggest that measurements of ferromagnetic or ferrimagnetic films with thicknesses of less than 1 nm are routinely possible, opening the area of magnetic phenomena in very thin films to optical study. Measurements on very thin nonmagnetic films in reasonable laboratory fields should also be feasible.

A schematic of the IEKS sample and illumination arrangement is shown in Fig. 1. In Kerr spectroscopy, plane polarized light ($E \parallel x$) is incident normally on a sample with spontaneous or field induced perpendicular magnetization M. The reflected light then has the regular component r_x and a magneto-optically induced component $r_y (|r_y| \ll |r_x|)$. Clearly the state of polarization of the resultant reflected beam depends on the magnitude and phase of r_x and r_y, and in general there is a Kerr rotation and ellipticity. In the IEKS configuration, the magnetic thin film is deposited on a transparent dielectric film that itself rests on an opaque reflector, to form what may be called a trilayer device. The thicknesses of the sample and transparent dielectric films are adjusted so that $r_x = 0$. This occurs because the ray reflected directly by the sample is exactly canceled by light which has suffered at least one reflection from the back reflector. To

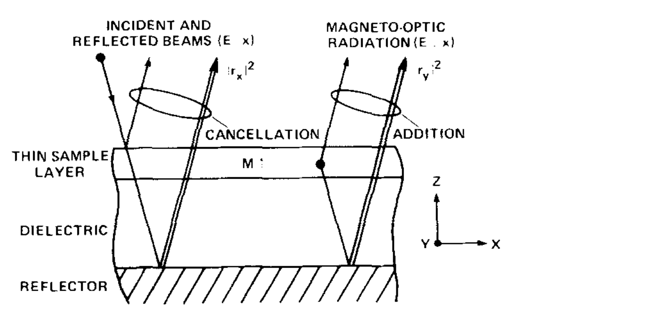

FIG. 1. Schematic representation of the trilayer configuration is shown. The incident beam is plane polarized with $E \parallel x$. The beam reflected with $E \parallel x$ can then be considered to consist of two beams—one from the thin sample, the other from a superposition of all beams having at least one bounce from the reflector. Similarly, the polar Kerr radiation, which has $E \perp x$, can be considered to consist of the back emitted radiation plus radiation having at least one bounce from the reflector. The trilayer parameters are adjusted for appropriate interference of these beams.

