

REFLECTING INTERFEROMETER BASED ON A MATCHED METALLIC FILM

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The devices recently proposed to separate one oscillation mode in optical resonators can be used in many cases also as independent interferometers. In particular, great interest attaches to the use of an interferometer with an absorbing film [1], which makes it possible to obtain in reflected light an interference pattern in the form of very narrow light fringes against a dark background; in the usual Fabry-Perot interferometer, such a picture is obtained only with transmitted light.

A diagram of the simplest interferometer with an absorbing film is shown in Fig. 1a. It is made up of a mirror with reflection coefficient r_2 (we shall henceforth assume $r_2 = 1$) and an absorbing metallic film. The thickness of the latter is much smaller than the wavelength λ . It can therefore be regarded as a surface conductivity σ on the boundary between media 1 and 2 with wave admittances Y_1 and Y_2 . One of these media is the substrate of the film. The dependence of the reflection coefficient R of such a system on the frequency ω has a form of maxima and minima alternating with a period $c/2\ell_2$ (c - velocity of light, ℓ_2 - distance from film to the mirror). It is possible to have R reach zero at the minima. To this end, σ must be equal to Y_1 - a case well known in electrodynamics. At such a choice of σ , the coefficient of reflection from the interferometer at normal incidence of the light is given by the formula

$$R = (1 + F \operatorname{tg}^2 \frac{\omega}{c} \ell_2)^{-1},$$

where $F = (2\sigma/Y_2)^2$. A shortcoming of the system of Fig. 1a is the small value of the sharpness factor F . Thus, even if a matched film is deposited on heavy flint with a refractive index 1.8, we get $F \approx 13$. This shortcoming can be overcome by increasing the conductivity σ (i.e., the thickness of the film) and simultaneously, to match it to the medium 1, using the customary microwave methods of impedance matching. In the optical region it is most convenient to use alternating quarter-wave layers of dielectrics with small and large refractive indices. This is shown in Fig. 1b, which shows three $\lambda/4$ layers with wave admittances Y_3 and Y_4 . In the case of an odd number k of matching layers, it is possible to increase the conductivity σ by $(Y_4/Y_1)^2(Y_4/Y_3)^{k-1}$ times and to increase F to several hundred even with a three-layer coating. The limit is imposed here by the impossibility of producing films with very large σ , and all the more thin ones.

Figure 1c demonstrates one more possibility of increasing the sharpness factor. Here a set of $\lambda/4$ layers is introduced between the film and the medium 2 and serves as an admittance transformer, "lowering" the input conductivity of the medium 2 (referred to the plane of the film). The conductivity of the film itself is in this case low and should be equal to the wave admittance of the medium 1. Calculation shows that in the case, say, of an even number k of layers we have $F = (2\sigma Y_4/Y_2 Y_3^k)^2$.

We have assumed throughout a real surface conductivity of the film. In practice films usually have also an imaginary admittance component, thereby complicating somewhat the matching with medium 1. To offset the imaginary part, it is possible to use an additional thin layer of dielectric, the

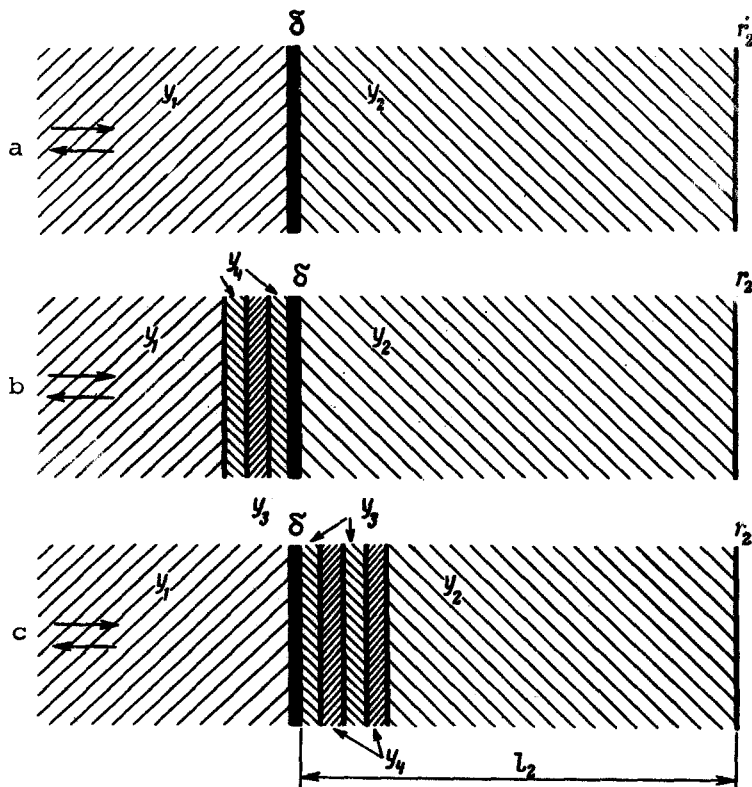


Fig. 1

thickness of which will no longer be a multiple of $\lambda/4$. If the matching to medium 1 makes allowance for the full admittance of the film, then all the formulas written out above for R and F remain in force, but σ must be taken to mean only the active component of the admittance.

The system of Fig. 1c was verified experimentally. To this end, a thin film of nickel with a transmission coefficient (approximately 0.37) such as match it to glass was deposited on the flat substrate of K8 optical glass (medium 1), and on top of the film there were sputtered four quarter-wave layers of cryolite (medium 3) and zinc sulfite (medium 4). Medium 2 was air. The transmission coefficient in a traveling wave was 0.82 on the side of the coating and 0.002 on the side of the substrate; the last figure is evidence of the high quality of matching of the nickel film to the admittance of the glass, in spite of the absence of special reactance compensators.

The second element of the inteferometer was a flat dielectric mirror parallel to the film and located at a distance ℓ_2 from it. The calculated value of F for such a system was 640. The light source was an He-Ne laser with a wavelength 6328 Å. To obtain equal-inclination lines, a lens was placed between the laser and the film, just as in the case of an ordinary Fabry-Perot inteferometer. The light reflected from the inteferometer was registered with the aid of an inclined beam-splitting plate.

Figure 2a shows equal-inclination rings obtained at $\ell_2 = 1.8$ cm. They have high contrast - the ratio of the maximum to minimum R is not less than 50. The widths of the light rings correspond to a sharpness factor not less than 80. On the whole, the interference pattern agrees with the expected one.

Figure 2b shows equal-inclination rings at $\ell_2 = 13$ cm. In this case it is easy to resolve individual laser modes spaced 150 MHz apart.

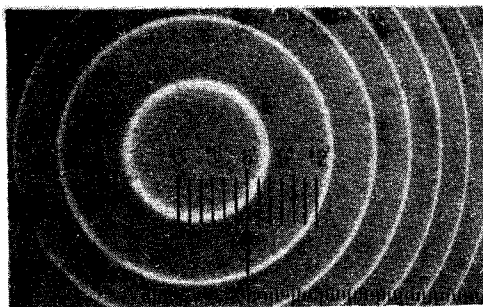
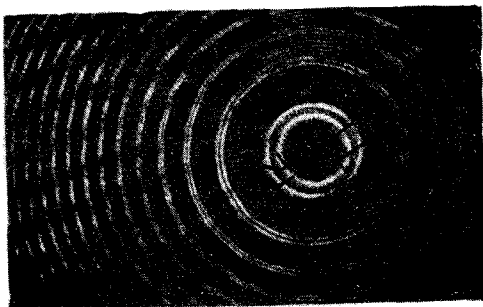


Fig. 2



From the point of view of the applications, the described interferometer differs from two-beam interferometers in that it produces a sharper interference pattern, and differs from ordinary Fabry-Perot interferometers in that the measurements can be made on the side of the light source. By varying the parameters of the coatings it is possible to make the interference fringes highly asymmetrical, and thus determine in principle the direction of the change of the phase difference. Under certain conditions, it is possible to replace the absorbing films in the described interferometer by light-scattering coatings prepared in accordance with [2].

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- [1] Yu.V. Troitskii and N.D. Goldina, ZhETF Pis. Red. 7, 49 (1968) [JETP Lett. 7, 36 (1968)].
- [2] Yu.V. Troitskii, Opt. Spektrosk. 27, 492 (1969).

INVESTIGATION OF RESISTIVE INSTABILITY EXCITED BY AN ELECTRON BEAM IN A SOLID-STATE PLASMA

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Collective interactions of beams of charged particles in a gas-discharge plasma have by not been thoroughly investigated both theoretically and experimentally. As to the interaction between beams of charged particles and a solid-state plasma, particularly a semiconductor plasma, experimental work in this field has just only started, in spite of the appreciable number of theoretical investigations. In [1] they observed experimentally the effect of excitation of helicons by an electron beam in a semiconductor plasma. Excitation of helicons by external fields was observed in [2]. The purpose of the present study was the experimental observation and investigation of the resistive high-frequency instability that should occur when beams of charged particles interact with a solid-state plasma. Such a study, besides being of purely