THE FOCUSED FABRY-PEROT RESONATOR AND ITS APPLICATION TO PLASMA DIAGNOSTICS

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The planar Fabry-Perot resonator is a well-known device, both in the optical region and at millimeter wavelengths. Culshaw (ref. 1) has demonstrated the excellent performance that may be obtained in the millimeter wavelength band and has indicated that such resonators would be very attractive at even shorter wavelengths (ref. 2). Several years ago one of the authors proposed a focused Fabry-Perot resonator in which the plate would be spherical in shape and would be located along constant phase contours in the field of a focused antenna (see Figure 1). Attempts to operate such a device failed, probably due to the fact that the very high mechanical and control requirements were not met. Culshaw (ref. 2) quite independently, has discussed a similar focused resonator, but apart from indicating that it might resonate, no estimated performance figures were given. More recently, he has published (ref. 3) a detailed theoretical analysis of the planar resonator and has shown that it is exactly equivalent to the focused resonator. The authors have recently successfully operated a focused resonator, and the details of this work will be described in this paper.

Focused microwave probes have been used with great success to determine the ionization properties of wakes behind projectiles fired in ballistic ranges. The major feature of these probes lies in the degree of confinement of the focal field, which can be made less than the dimensions of wakes of interest. For projectile bore diameters of 20 mm., wavelengths in the millimeter region have to be used. In some cases the frequencies will be far removed from the plasma frequencies and probe sensitivity will be limited. In an effort to improve this sensitivity the focused Fabry-Perot resonator was investigated. It was thought that if a high-Q, focused, free-space cavity could be built the following could be achieved.

a. The small dimensions of the probing beam would be maintained.

b. The sensitivity of the system would be improved according to the Q.

   A simple way of looking at this is to imagine that the Q is a measure of the number of times that a given wavefront is effectively bounced backwards and forwards between the cavity plates without attenuation. Consequently each time the wavefront passes through, say, a tenuous plasma located in the focal region, it suffers a phase shift, depending on the plasma properties; and the phase shift is proportional to the effective number of passes (and so depends on the Q).

c. The cavity plates could be located at a distance from the flow field so that any interaction between the cavity and flow field would be negligible.

The configuration of the proposed free-space, focused, Fabry-Perot resonator is shown in Figure 1. Two thin, perforated, spherical, metallic plates, which have very high reflectivity, are located in the field of a focused lens system in regions where the constant phase contours are spherical. It was expected, by, analogy with the planar resonator, that the Q would be extremely high. However the sphericity of the plates would have to be held within .0005" for a frequency of 70 Gc.

The free-space, focused cavity has been operated successfully recently and the measured Q's are between 80,000 and 100,000. The transmission and reflection curves are shown in Figure 2.

An interesting feature of the Fabry-Perot resonator is that it appears to function as a super-gain antenna, in that the beamwidth of the incident illumination is decreased on passing through the resonator. Evidence of this has been noted with the focused resonator.

In the paper all of the above material will be discussed in detail. In addition the application of the focused resonator to plasma diagnostics will be covered, together with practical performance figures.

REFERENCES

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High Resolution Millimeter Wave Fabry-Perot Interferometer

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IRE Trans. MTT, Sept. 1962, p. 331.

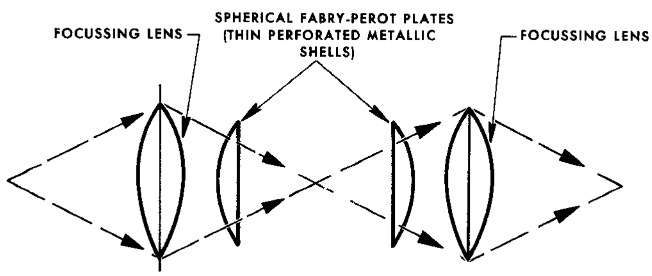
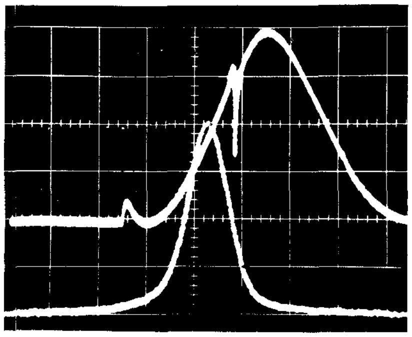


Fig. 1 Proposed Focused Fabry-Perot Resonator



a. Top Trace.
Reflection: Fabry-Perot mode superimposed on mode of cavity with a Q of 1300.
Time base. 500 μsec/cm. or 22.4 μsec/Mc

b. , Transmission through Fabry-Perot as a Function of Frequency.
Time base. 10 μsec/cm or 22.4 μsec/Mc

Note: Vertical scale not linear. Q was measured at half-power points u an attenuator and was found to be about 100, 000.

Fig. 2 Reflection and Transmission for Free-Space Focused Resonator as a Function of Frequency.

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