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MEASUREMENTS OF THE LONGITUDINAL COMPONENT OF THE ELECTROMAGNETIC FIELD AT THE FOCUS OF A COHERENT BEAM

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In a recent paper, Boivin and Wolf[1] have published a detailed analysis of the structure of the electromagnetic field in the region of the focus of a coherent beam which emerges from an aplanatic imaging system. Since their analysis was not limited to a scalar diffraction theory, they were able to exhibit the vectorial features of the focused beam. As a result, it was found that the field has a strong longitudinal component in certain regions in the neighborhood of the focus. The purpose of the present note is to report measurements of this longitudinal field in a wide-aperture microwave lens system where direct probing of the spatial variations of the field is possible.

The apparatus used is similar to that described previously.[2,3] It consists of a 34.5-Gc/sec (8.7-mm wavelength) microwave system and a double convex polystyrene lens 27 cm (~31 wavelengths) in diameter. The surfaces of the lens are contoured to produce an aberration-free image 27 cm from the lens surface when a source is positioned 27 cm from the opposite lens surface. The lens is supported in an aperture in a large metal screen which also serves as the exit pupil of the system. This exit pupil is located 32 cm from the focal plane so that the angle subtended by the lens diameter at the focus is 46° (i.e., in the notation of reference 1, $\alpha = 23°$).

The source of radiation was an open-ended rectangular wave guide (3.5×7 mm inside dimensions, fed from a klystron (~50-mW) source. The field at the focus was scanned with a similar open-wave-guide receiver leading to a calibrated crystal detector and recorder. The recorder was connected with a servo link to the receiver scanning mechanism so that the spatial variations of the signal could be recorded directly. The orientation of the receiving wave guide could be adjusted to detect either the longitudinal or transverse electric field intensity (I_L and I_T, respectively) by coupling to the TE mode of the wave guide. When examining the longitudinal field, the receiving wave guide was oriented to minimize possible cross coupling of the transverse field arising from slight misalignments of the system [see inset of Fig. 1(a)].

In Fig. 1(a) superimposed results are shown for scans of the transverse and longitudinal field intensities in the focal plane. The scan was made in the direction of the incident-field electric vector (i.e., $\varphi = 0$ in reference 1). The field intensities I_T and I_L (proportional to the squares of the electric field amplitudes) are shown, on a decibel scale, as a function of the transverse position in the beam. In Fig. 1(b) are shown several similar scans of I_L for a series of positions on both sides of the focal plane. These curves are displaced along the vertical axis to provide a relief map of the longitudinal field intensity in the focal region (for $\varphi = 0$).

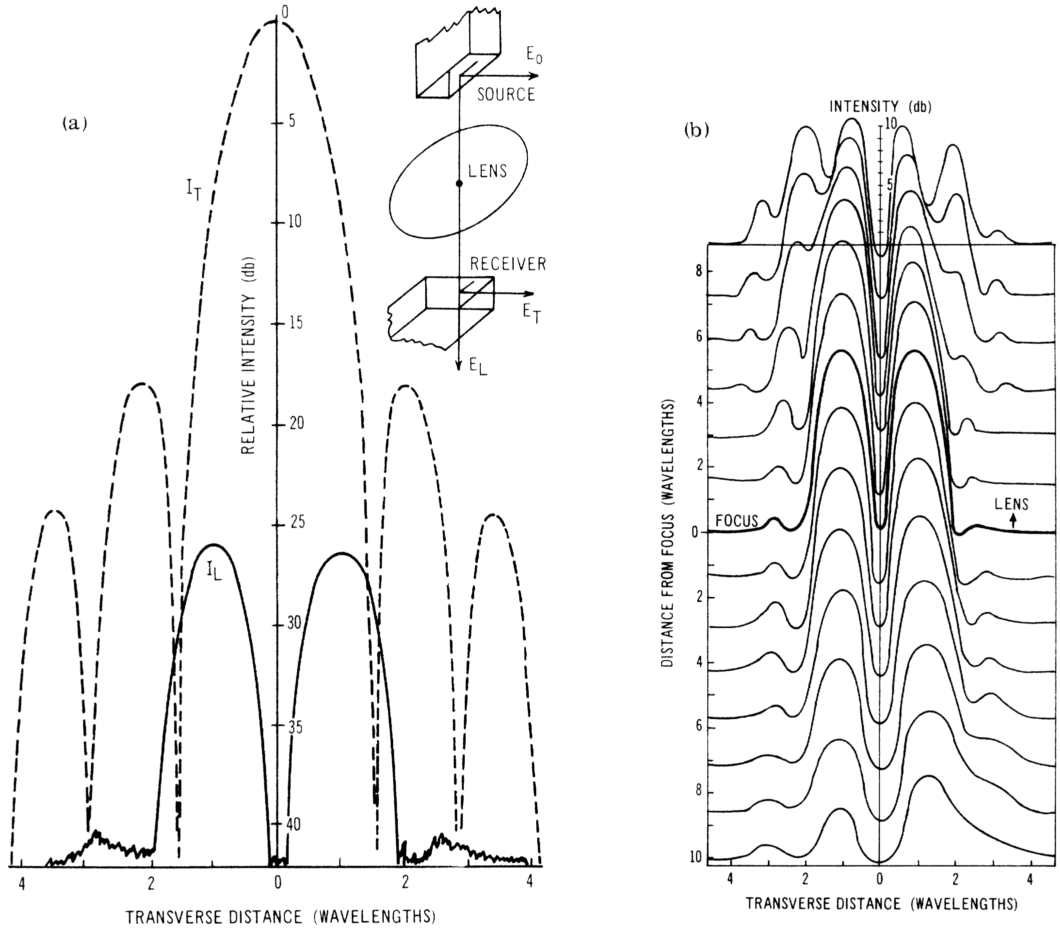

Fig. 1. (a) Variations of the transverse and longitudinal electric field intensities (I_T and I_L, respectively) in the focal plane. Scan is in direction of the E vector of the source (i.e., $\varphi = 0$). Source and receiver orientation for measuring I_L are shown in the insert. (b) Scans of the longitudinal field intensity in the $\varphi = 0$ direction near the focus.

In Fig. 2 a contour map of I_L in the focal plane is shown. This figure was plotted from a series of scans across the focal plane, and shows the field intensity in decibels with respect to the peak value of I_L. In this figure, the contours have been plotted for only the two primary peaks, since for the smaller peaks the signal-to-noise ratio was insufficient to allow accurate plotting.

Since Boivin and Wolf have given computations only for $\alpha = 45°$ and the experiments are for $\alpha = 23°$, it is not possible to make a complete comparison, but, in general, the results of Figs. 1 and 2 are in good agreement with the theoretical predictions. The "dipole" nature of the field contours in Fig. 2 is essentially identical to that shown in Fig. 5 of reference 1 for the central lobes. The longitudinal field intensity is seen to have a "zero" value at the focus and in the $\varphi = \pi/2$ direction, but to show a series of peaks symmetrically placed on opposite sides of the optic axis in the $\varphi = 0$ direction.

Scaling the results of reference 1 for the present system indicates that the maximum value of I_L should occur in the $\varphi = 0$ direction at about 0.9 wavelengths from the axis, and this is very close to the experimentally measured position shown in Figs. 1 and 2. The relative positions of the maxima and minima of I_T and I_L shown in Fig. 1(a) are also in good agreement with the theory.

A large difference between the theory and experiment, however, is found in the relative peak magnitudes of I_L and I_T. Whereas the peak longitudinal field amplitude computed by Boivin and Wolf is about 28% of the peak transverse field amplitude, the measured value (Fig. 1) is only about 5%. This is not unexpected, however, since the computations were

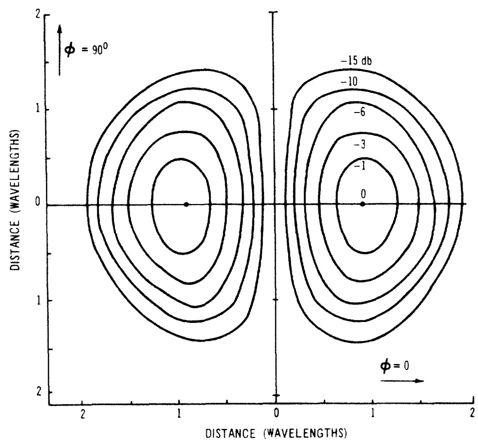

FIG. 2. Contours of the longitudinal field intensity, I_L, in the focal plane.

for a wider aperture system, and the experimental measurements will undoubtedly show some errors arising from field perturbations caused by the receiver.

The results of Fig. 1(b) show the increasing complexity in the variation of I_L on moving away from the focus. The small asymmetries with respect to the axis are caused by the scanning direction being slightly off parallel with the $\varphi = 0$ direction. The patterns are not symmetric with respect to the focal plane since, at the microwave frequency used, the focus is only 31 wavelengths from the lens and motions of several wavelengths along the axis are not negligible.

In addition to the results shown in Figs. 1 and 2, some measurements have been made with sources having nonuniform amplitude distribution across the lens. Since microwave beams can be "shaped" rather conveniently, measurements at microwave frequencies could be used to obtain information on the longitudinal field distribution for focused laser beams having more complex amplitude distribution.

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[1]A. Boivin and E. Wolf, Phys. Rev. 138, B1561 (1965).

[2]A. Carswell and C. Richard, to be published.

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OBSERVATION OF THE SPECTRUM OF LIGHT SCATTERED FROM A PURE FLUID NEAR ITS CRITICAL POINT*

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This Letter presents recent measurements of the spectral distribution of light scattered quasielastically from a pure fluid (SF_6) near its critical point. We present data on the half-width of the spectrum of the light scattered 14° away from the incident direction: (a) along an isochore very close to the critical isochore over a temperature range $1\times10^{-5} \leq (T-T_c)/T_c \leq 6\times10^{-3}$, and (b) along the gaseous portion of the coexistence line over a temperature range $-6\times10^{-4} \leq (T-T_c)/T_c < 1\times10^{-5}$.

The scattering is produced by entropy fluctuations which decay very slowly in the critical region. As a result, the spectrum of the scattered light is extremely narrow (~10–10^4 cps). To observe such narrow spectral lines we have developed a novel "square-law" or "self-beating" spectrometer.[1] Figure 1 is a schematic diagram of this spectrometer. It consists of three parts: (1) the light source, (2) the scattering cell and light-collecting optics, and (3) an electronic system for spectral analysis. We used a Spectra-Physics model 115 helium-neon laser with ~5-mW output power as the light source. While the spectral output of this laser consists of about six longitudinal modes spaced 250 Mc/sec apart near 6328 Å, the feature limiting the resolution of this spectrometer is the intrinsic spectral width of the light in each mode. This is less than ~2 cps. The laser beam passes through the scattering cell where the temperature is controlled to ±0.003°K with a servo-stabilized bath. Temperature was measured with a platinum resis-