NONLINEAR EFFECTS IN THE TRANSMISSION OF HIGH-POWER CONTINUOUS LIGHT BEAMS THROUGH MEDIA

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The transmission of a neodymium-doped yttrium garnet cw laser (YAG-Nd) beam is studied experimentally. The power of the laser reaches 30 W and the wavelength is 1 μ. The investigated media have a negative temperature derivative of the index of refraction and defocus beams of ordinary profile (such as water and Plexiglas). The self-focusing of the beam obtained in the experiments has a reduced intensity near the axis (so-called "banana" self-focusing) in vertical and horizontal transmission through water and Plexiglas. A "combined" focusing of a beam by the thermal track of another beam is investigated by sending a red gas laser beam along the tubular track of an infrared beam and focusing the former. A "staining method" is used to visualize the nonlinear reaction of high-power invisible infrared beams based on the addition of a visible beam of the same profile. Practical applications are discussed.

THIS paper reports on new experiments with nonlinear effects obtained in the passage of a high-power infrared beam through various media. In the experiments we used a cw laser employing yttrium-aluminum garnet with neodymium (YAG-Nd) and yielding an invisible infrared light beam with a wavelength of 1.06 μ and a power of up to 30 W. The main object of interest was the "tubular" beam with reduced intensity near the axis obtained with the aid of a small screen or by darkening a glass plate in the center of the beam.

The media in which nonlinear effects were investigated had a negative total temperature derivative of the refraction index: $dn/dT < 0$. This means that they belong to the class of media that is the most widespread and of greatest practical interest (all gases and liquids, some solids). As the principal media we selected the following: water as the representative of liquids ($\lambda = 1\ \mu$ emission absorption coefficient $\kappa \approx 0.1\ \text{cm}^{-1}$), and plexiglas as the representative of solids ($\kappa \lesssim 0.1-0.05\ \text{cm}^{-1}$).

1. Combined focusing. We investigated the focusing of one beam by the thermal track of another. The waveguide or lens in a solid was generated by a hollow invisible beam of a high-power infrared laser. A red beam from a helium-neon gas laser was sent along the axis of the hollow beam by means of an inclined plate placed beyond the screen. The screen displayed a redistributed intensity of the red beam and a bright central point (Fig. 1 a, b). These experiments confirmed the possibility[1] of using the thermal track of a beam to focus or direct another beam.

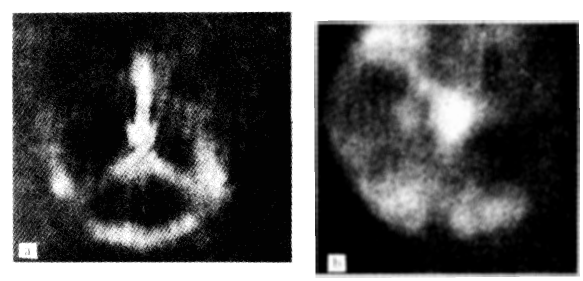

FIG. 1. Photograph of the profile of a red beam passing along the thermal track of a tubular infrared beam in water (a) or in Plexiglas (b).

2. Self-focusing of a beam with reduced intensity near axis ("banana" focusing). The "banana" self-focusing was first observed[2-4] in a solid, i.e., Plexiglas with various plate thicknesses (4 and 40 cm) where the image was recorded 50 cm from the edge of the Plexiglas (so-called "external" self-focusing). The effect was observed through an infrared videoscope and photographed directly on film in camera body with removed lens through infrared filter (Fig. 2 d). When the beam was interrupted the bright spot in the center vanished in 1–2 sec.

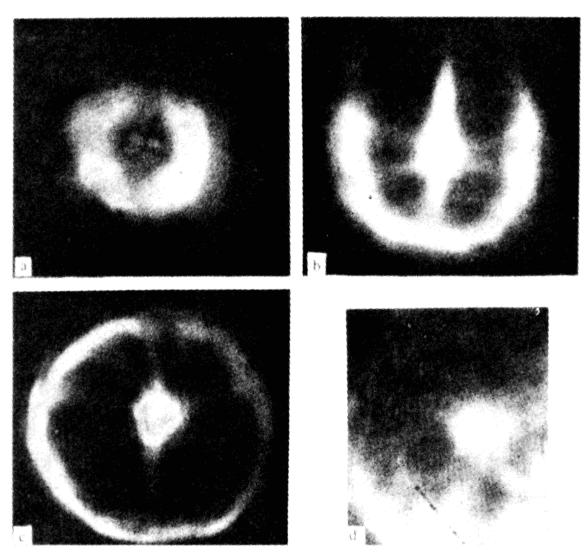

FIG. 2. Photograph of the profile of an infrared beam incident directly on film: a–initial profile, b–profile after horizontal passage through water, c–profile after vertical passage through water, d–profile after passage through Plexiglas. Center shows area of increased intensity.

We also observed "banana" self-focusing in ordinary and distilled water free of any absorbing additives at the natural emission absorption wavelength of $\lambda \approx 1\ \mu$ in water. The focusing pattern was sharp and quickly established (~ 0.3 sec). The main experiments were performed at the power level of 10—15 W. We investigated both the horizontal (Fig. 2 b) and vertical (Fig. 2 c) transmission of the beam through water. Intensity increase in the beam center was observed along a distance from 0.5 to 5 mm indicating a large extent of the focusing caustic (there was no attempt to achieve an intensity distribution for a point focus).

3. The staining method. To observe nonlinear refraction of a high-power invisible beam it was mixed with a weak visible beam of approximately the same profile and divergence. This "visualization" of the cw beam was achieved and it yielded various nonlinear effects. We note that "visualization" by harmonic staining is not only of little effect with low-intensity cw lasers but also is inaccurate in reproducing the behavior of the main beam, not so much because of large chromatic aberration but because of the difference in the distribution and directivity between the fundamental frequency and its harmonic. (In our case for staining purposes we used the red beam of a helium-neon laser with $\lambda = 0.63\ \mu$, whose profile and divergence could be varied independently).

The above research broadened the range of phenomena of nonlinear optics due to the heating of media by cw laser beams.

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