THEORY OF PLANE WAVE REFLECTION AND REFRACTION BY THE NONLINEAR INTERFACE

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Abstract: This report includes a review of published as well as recent results. In previous papers a new kind of optical bistability was proposed which is connected with reflection and refraction of light by a single surface on a nonlinear medium without a resonator or feedback; its first experimental observations were made recently by Smith et al. The main conditions required for its existence are very exact matching of the optical densities of both media and almost grazing incidence of light. These effects are available for positive nonlinearity as well as for negative nonlinearity. In the last case, it is possible to excite a new kind of nonlinear wave (longitudinally inhomogeneous travelling waves) which could provide a phenomenon of strong nonlinear parallax of refracted rays along the interface. For more simple observation and some applications of reflection bistability, the use of an electro-optic element as an "artificial" nonlinearity can be proposed; this light-feedback method is analogous to that used in hybrid devices. Our last result is connected with a proposition for a new way to realize reflection bistability which consists of application of single-mode optical waveguides (one of which must be nonlinear) rather than using two semi-infinite media. This allows us to avoid the secondary effects of self-focusing and self-bending of bounded refracted beams of light in a nonlinear medium. At the same time it conserves all features of the main phenomenon of reflection bistability.

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I. INTRODUCTION

In a number of articles published in recent years a new class of effects in nonlinear optics was investigated, which arose under special conditions (1976) of almost grazing incidence of strong light on the interface between a linear and nonlinear medium whose susceptibilities are very close to each other. All possible effects, in particular bistability, in such cases are caused by competition between linear mismatch of susceptibilities of these media and a nonlinear component; under the above conditions this competition can lead to a strong change of interface reflection even if the nonlinear component is small (as it usually is in nonlinear optics).

This mechanism provides the main difference between such phenomena and known optical bistability. At the present time, the known bistable optical devices are comprised of a Fabry-Perot interferometer filled with a nonlinear medium, first proposed by Seidel and Szöke et al. in 1969 and first observed by Gibbs, McCall and Venkatesan in 1974. (One can see a detailed survey of this development in Ref. 19.) In these systems, the bistability is due to the presence of a resonator (interferometer) which provides a feedback. The media used might have resonant saturating absorption or Kerr-nonlinearity; it was also proposed to use a phase transition in the resonant system of two-level atoms. Use of resonators or resonance causes these devices to be strongly selective to the frequency of the incident light.

In contrast to these, the present paper is concerned with phenomena not involving resonance and therefore might use a broad spectrum of light. Interaction of light with matter in this non-resonant arrangement can give rise to a number of new effects (besides bistability) which are of physical interest as well as of importance to applications and, moreover are not possible in resonators.

Effects due to nonlinear interface reflection predicted by the plane wave theory include the following:

1) multistability and hysteresis jumps in reflection coefficient
2) change and scanning of the refraction angle and reflection coefficient by varying the intensity of incident light
3) total bleaching of interface by incident light with definite intensity
4) change of penetration depth of the field into reflecting medium in the regime of total internal reflection (TIR)
5) excitation of nonlinear waves of a new kind (so called longitudinally inhomogeneous travelling waves - LITW and effects connected with LITW, namely
6) strong nonlinear self-parallax of refracted rays along the