A. Ostrovskiĭ, Abstracts of Papers presented at Fifth All-Union Conf. Nonlinear Optics, Kishinev [in Russian], Moscow State University 970).
S. Felber and J. H. Marburger, Appl. Phys. Lett. 28, 731 (1976).
. N. Lugovoĭ, Kvantovaya Elektron. (Moscow) 6, 2053 (1979) [Sov. J. uantum Electron. 9, 1207 (1979)].
. I. Talanov, Abstracts of Papers presented at Third All-Union Conf. on Nonlinear Optics, Erevan [in Russian], Moscow State University (1967).
[5]S. N. Blasov and V. I. Talanov, in: Reversal of Optical Radiation Wavefronts in a Nonlinear Media [in Russian], Institute of Applied Physics, Academy of Sciences of the USSR, Gorki (1979).

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# egular and stochastic self-modulation of radiation in a ring laser /ith a nonlinear element

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It is shown that a ring laser with a second-harmonic generator can double the number of stable states, resulting in self-modulation of the radiation. The system is described by a one-dimensional mapping that can be used to trace analytically the transition to stochasticity and to make universal calculations of those values of the bifurcation parameter at which the character of the self-modulation changes.

Random motion in dynamic systems with a small number of degrees of freedom that was first observed in Refs. 1 and 2 has been widely studied both experimentally and theoretically. In particular it has been shown that a possible method of transition to dynamic chaos is systematic doubling of the number of stable states of the system as a certain critical (bifurcation) parameter changes.[3] Similar behavior was studied in Refs. 4 and 5 where various types of nonlinear interferometer were analyzed and also in Refs. 6 and 7 where a single-mode laser with periodic loss modulation was investigated. The evolution of these nonlinear systems is described by differential-difference equations which are mainly analyzed numerically.

The present paper analyzes a system for cyclic generation of the second optical harmonic in the traveling-wave regime which, under certain conditions described below, is described by a simple one-dimensional mapping. This means that the transition to dynamic chaos via a chain of doubled steady states can be traced analytically. It is found that this stochasticity mechanism results in self-modulation of the first- and second-harmonic radiation, the modulation being random in the chaotic region and regular in the stable region. This regular regime is of some practical interest since amplitude modulation of ultrashort (for example, picosecond) optical pulses can be achieved in this system. This is difficult to realize by traditional methods.

The basic idea behind the proposed system (Fig. 1) involves a combination of a ring laser amplifier and a second-harmonic generator that introduces nonlinear losses into the system. We shall assume that conversion takes place under phase and group matching conditions: $(K_2 - 2K_1)d \ll \pi/4$ and $\tau_u \gg (U_1^{-1} - U_1^{-1})d$ and the dispersion and diffraction spreading is small, i.e., the Fresnel number is $N = a^2K_1/2\pi ln \gg 1$ and the optical thickness of the converter is $d \ll (\tau_u^2/2)(\partial^2K/\partial\omega^2)^{-1}$ (dispersion length). Here, $\tau_u$ is the duration of the input optical pulse; $a$ is the diameter of the optical beam; $l$ is the optical length of the ring; $n$ is the number of trips of the pulse in the system; $K_1$, $K_2$ are the wave numbers and $U_1$, $U_2$ are the group velocities of the first and second harmonics, respectively. Under these conditions, the amplitude of the electric field of the second-harmonic pulse at the exit from the converter 3 is related to the amplitude of the input (first harmonic) using the familiar expression:

$$E_{out}(t) = E_{in}(t)\,\mathrm{th}[\sigma d E_{in}(t)],$$

where $\sigma$ is the coefficient of nonlinear coupling of the first and second harmonics. We shall assume that a laser amplifier 2 has an instantaneous response, so that the condition

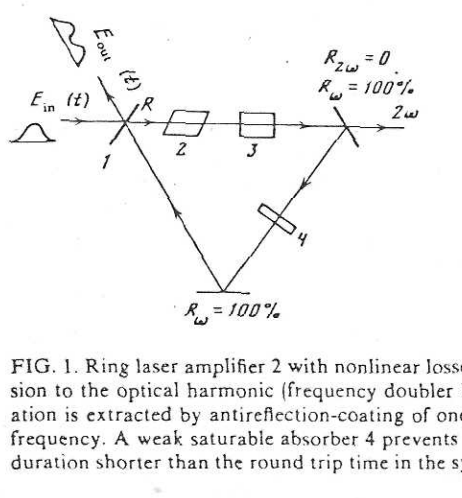


FIG. 1. Ring laser amplifier 2 with nonlinear losses as a result of conversion to the optical harmonic (frequency doubler 3). The harmonic radiation is extracted by antireflection-coating of one of the mirrors at this frequency. A weak saturable absorber 4 prevents spreading of a pulse of duration shorter than the round trip time in the system.

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