[1] N. G. Basov, P. G. Kryukov, V. S. Letokhov, Yu. M. Matveets, and S. V. Chekalin, ZhETF Pis. Red. 10, 479 (1969) [JETP Lett. 10, 308 (1969)].
[2] T. Deutsch, Appl. Phys. Lett. 7, 80 (1965).
[3] R. H. Pantell and R. L. Kohn, IEEE J. QE-2, 306 (1966).
[4] V. S. Letokhov, Zh. Eksp. Teor. Fiz. 54, 1392 (1968) [Sov. Phys.-JETP 27, 746 (1968)].
[5] Rene Dandliker, A. A. Grutter, and Heinz P. Weber, IEEE J. QE-6, 687 (1970).
[6] N. G. Basov, O. M. Krokhin, G. V. Slizkov, S. I. Fedotov, and A. S. Shikanov, Zh. Eksp. Teor. Fiz. 62, 203 (1972) [Sov. Phys.-JETP 35, 109 (1972)].

HIGHLY EFFECTIVE GENERATION OF THE SECOND AND FOURTH HARMONICS OF HIGH-POWER PICOSECOND PULSES

V. D. Volosov, V. N. Krylov, V. A. Serebryakov, and D. V. Sokolov
S. I. Vavilov Optics Institute
Submitted 27 November 1973
ZhETF Pis. Red. 19, No. 1, 38 — 41 (5 January 1974)

We report experimental realization of the theoretically maximal coefficient for the conversion of laser emission into the second harmonic, and also high-efficiency generation of the fourth harmonic of picosecond pulses (efficiencies 80 and 30%, respectively).

Much attention has been paid of late to high-efficiency generation of higher harmonics of ultrashort light pulses, in view of the definite promises offered by powerful sources of ultraviolet radiation for the solution of the problem of controlled thermonuclear fusion.

Although it has been theoretically demonstrated that almost all the fundamental-frequency radiation can be converted into the second harmonic [1], this possibility has not been realized experimentally even in high-power laser beams. To effect such a conversion it is necessary to satisfy a large aggregate and requirements with respect to the beam and crystal parameters. In powerful picosecond lasers, the principal limitation are effects of group delay of the fundamental-frequency and harmonic waves, so that the efficiencies attained to date do not exceed 50% [2].

We note that the optimal pulses for the initiation of a thermonuclear fusion reaction are of subnanosecond duration [3]. In addition, at durations exceeding several dozen picoseconds, the harmonic-generation is a quasistatic process, i.e., without a group delay, since real nonlinear crystals are much shorter than the quasistatic length L_τ at which delay effects become significant ($\ell_{cryst} \ll L_\tau = \tau_u(u_2^{-1} - u_1^{-1})^{-1}$, where τ_u is the pulse duration, and $u_{1,2}$ are the group velocities of the fundamental and of the harmonic). Obviously, the subnanosecond range is the most favorable for attaining maximum efficiency in the generation of optical harmonics.

A block diagram of our setup is shown in Fig. 1. Here I is a master laser operating in the nano- and picosecond pulse regime, II is a preamplifier with a circuit that shapes a single pulse (∿200 psec) from a light train or of 10 psec duration from a smooth pulse [4], III is a chain of amplifiers, and IV is the frequency converter.

The resonator of the master laser, with a base 1850 mm, had a near-semiconfocal configuration. The exit mirror was a plane-parallel plate 0.7 mm thick. To increase the reproducibility of the generated pulses [5], and also to lengthen them to ∿ 200 psec, we placed two thin selector plates inside the resonator. The Q-switch was a cell with polymethine dye No. 3955 in nitrobenzene.

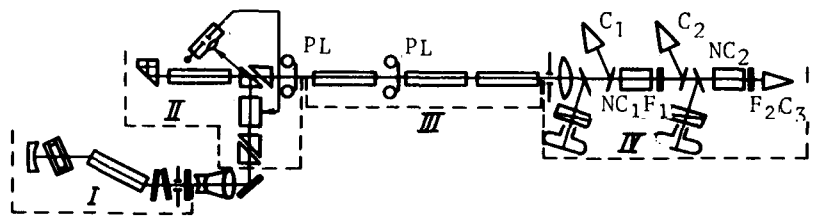

Fig. 1. Block diagram of experimental setup.

The weak signal of the master laser was amplified in a two-pass preamplifier, and then in a chain of three amplifiers in which the active elements were cut at an angle to eliminate self-excitation. For the same purpose, we used decouplers based on the bleachable film BF [6]. The diameter of the beam leaving the amplifiers was 30 mm. A round diaphragm of 15 mm diameter was placed in front of the converter, as well as a long-focus lens to decrease the beam divergence from 4' (the spherically diverging wave was shaped by a telescope after leaving the master laser to increase the self-focusing threshold in the amplifier) to 1'20".

The second harmonic was generated in nonlinear KDP and $LiIO_3$ crystals, while the fourth harmonic was generated in KDP and ADP crystals (designated NC_1 and NC_2 in Fig. 1). Plane-parallel plates were used to divert part of the radiation to Fabry-Perot interferometers to register the spectra of the laser and of the harmonics. The laser and harmonic energies were measured with calorimeters C_1, C_2, and C_2, respectively. The frequency separation of the radiation was with the aid of calibrated filters F_1 and F_2.

Since the linearly polarized radiation of the amplifier experienced appreciable depolarization in the amplifier (up to 30%), we used for the second-harmonic generation both the OO-E interaction, which is traditional for the generation of picosecond-pulse harmonics, and the OE-E interaction. For subnanosecond pulses of 200 psec and power 3 GW/cm^2 in the OO-E interaction the efficiency of conversion into the second harmonic reached 40% in KDP of 40 mm length (see Fig. 2), but only 18% in $LiIO_3$ of 12 mm length. The relatively low efficiency in $LiIO_3$ is due to the low stability of the crystal to the radiation at the harmonic frequency, which made it impossible to excite the harmonic precisely in the synchronism direction.

For a more complete utilization of the laser radiation in the OE-E interaction, the KDP crystal was oriented by us in such a way that the plane of its principal cross section made an angle 45° with the plane of predominant polarization. In this case the entire laser emission took part in the second-harmonic generation, regardless of the degree of its depolarization. An unprecedented efficiency of ∿80% was reached in a crystal 40 mm long (Fig. 2), which agrees well with the theoretical value ∿75% calculated with allowance for the dissipative losses in the crystal.

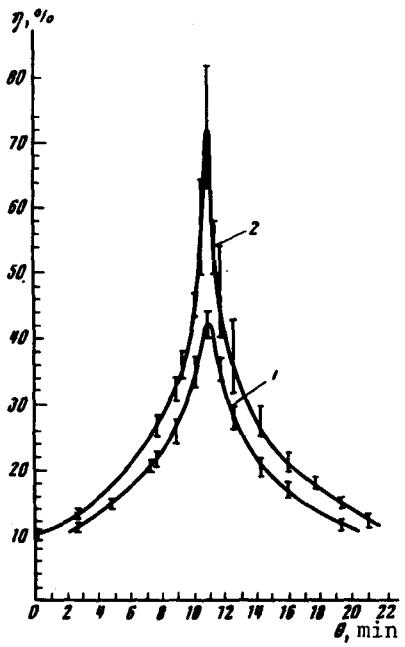

Fig. 2

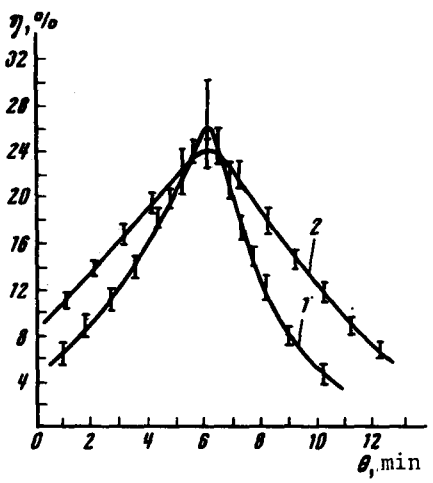

Fig. 3

Fig. 2. Angular dependence of the efficiency in second-harmonic generation.

Fig. 3. Angular dependence of the efficiency in fourth-harmonic generation.

The results on fourth-harmonic generation in KDP and ADP crystals 40 and 12 mm long, respectively, are shown in Fig. 3. The maximum efficiency reached 30%.

An investigation of the spectral characteristics has shown that when the second harmonic is generated the spectrum broadens from 3 Å at the fundamental frequency to 7 Å at the harmonic frequency. Calculation has shown that when the second harmonic is excited in the field of a monochromatic wave (the spectral width of the synchronism is defined by the expression $\delta\theta = 5.56/K(d\theta/d\ell)\ell$, where $d\theta/d\ell$ is the dispersion of the synchronism direction, and K is a parameter proportional to the birefringence; $\delta\theta = 30$ Å for KDP), then the generation of the fourth harmoni is essentially nonmonochromatic ($\delta\theta \sim 1$ Å). This explains the relatively low level of the efficiency of conversion into the fourth harmonic.

The optical strength of the KDP crystal was investigated in focused beams of the fundamental and the harmonic. The breakdown thresholds were 23 and 17 GW/cm , respectively.

[1] S. A. Akhmanov and R. V. Khokhlov, Problemy nelineinoi optiki (Problems of Nonlinear Optics Nauka, 1964.
[2] N. G. Basov, A. R. Zaritskii, S. D. Zakharov, et al., in: Kvantovaya elektronika No. 5, 63 (1972) [Sov. J. Quant. Electr. 2, 439 (1973)].
[3] N. G. Basov and O. N. Krokhin, Vestnik AN SSSR 6, 55 (1970).
[4] M. P. Vanyukov, V. I. Kryzhanovskii, V. A. Serebryakov, and A. D. Starikov, Kvantovaya electronika No. 5, 69 (1971) [Sov. J. Quant. Electr. 1, 489 (1972)].
[5] M. P. Vanyukov, V. I. Kryzhanovskii, et al., Opt. Mekh. Prom. No. 12, 31 (1972).
[6] V. I. Abdeeva, M. A. Al'perovich, M. P. Vanyukov, et al., Kvantovaya elektronika No. 2, 69 (1971) [Sov. J. Quant. Electr. 1, 166 (1971)].

NONLINEAR ABSORPTION OF ELECTROMAGNETIC ENERGY IN AN ISOTROPIC FERROMAGNET

V. M. Gryanik
L. D. Landau Institute of Theoretical Physics, USSR Academy of Sciences

Submitted 27 November 1973
ZhETF Pis. Red. 19, No. 1, 42 — 43 (5 January 1974)

It is shown that the electromagnetic dissipation at low frequencies in an isotropic ferromagnet near the phase transition curve is essentially nonlinear even in weak alternating fields.

It was shown in [1] that an isotropic ferromagnet is described in the hydrodynamic approximation, in a range of fields and temperatures such that $|M - M_S| \ll M_S$ ($HT^{-2} \ll 16\pi^2 c^3 M_S^5$) by the thermodynamic potential

$$\Phi = f(M_s^2) + \frac{A}{3}|M - M_s|^3 - \mathbf{MH}, \qquad A = 16\pi^2 c^3 M_s^3 T^{-2}, \tag{1}$$

where $\vec{M}$ is the density of the magnetic moment, $\vec{M}_S$ is the density of the spontaneous magnetic moment, c is a constant proportional to the exchange integral, and $\vec{H}$ is the external magnetic field. The cubic term describes the contribution from the long-wave fluctuations that are strongly developed near the phase-transition curve. Its concrete form is closely connected with the principle of conservation of the magnetic moment, a principle that is asymptotically exact for homogeneous fluctuation, and is locally correct in volumes $T/M_S H \ll V \ll R_c^3$ ($R_c = \sqrt{cM_S/H}$ is the correlation radius).

Particular interest attaches to the low-frequency dynamics of these fluctuations. Its characteristic features can be explained by considering an isotropic ferromagnet placed in a homogeneous constant field and in an alternating field $|\vec{h}| = h \sin \omega t$ parallel to it. Owing to the strong exchange interaction, a local equilibrium is rapidly established in selected volumes, at least when $\omega \ll \gamma H$. The time variation of the magnetic moment is then determined by the Landau-Lifshitz equation of motion

$$\dot{\mathbf{M}} = -\gamma[\mathbf{M} \times \mathbf{H}_{eff}] + \mathbf{R}, \tag{2}$$