AMPLIFICATION OF AN ULTRASHORT PULSE IN A TWO-COMPONENT MEDIUM

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A generator of ultrashort pulses (USP) of light with a saturable absorber usually emits a train of pulses with energy not higher than 10^{-2} J in one pulse [1]. Attempts to increase the USP energy by trying a denser absorber or increasing the pump to threshold ratio encounter considerable experimental difficulties. In practice, therefore, USP generators operate therefore with small initial absorption in the absorber and with a small pump to threshold ratio. To obtain USP with energies on the order of 10 - 20 J and power 10^{12} W, it is necessary to use a multistage amplification system with a gain higher than 10^3 [2]. Such a setup is quite complicated, owing to the danger of self-excitation, accumulation of distortion in the amplifying rods, difficulties of obtaining uniform gain distribution,etc. In addition, linear amplification is obtained because of the low energy of the input pulse, so that only an insignificant fraction of the stored energy is emitted. All these difficulties are further aggravated by the instability of the master USP generator, whereby the time picture of the radiation is poorly reproducible [3]. This is why the generation of USP of high energy is still a complicated problem.

To increase the USP energy, to improve the operating stability, and to make more effective use of the energy stored in the amplifier, a USP amplification system was developed using a stable two-component medium (amplification medium and a nonlinear absorber with fast relaxation of the transparent state), which makes it possible to obtain a train of USP with a total energy on the order of 10 J and at an energy of the order of 1 J in each USP.

The idea of an experiment is as follows: An amplifying medium with sufficiently high gain ($\sim 10^2$) and a dense nonlinear absorber are placed in a ring system. The total loss, in the case of a weak signal, exceeds the gain and therefore the system does not become self-excited. A weak pulse attenuates in such a system, but a pulse saturating the absorber, to the contrary, is exponentially amplified. The exponential growth of the USP energy is limited by the saturation of the amplifying medium. The fast relaxation of the absorber after passage of the USP ensures attenuation of the additional pulses and background accompanying the input ultrashort pulses.

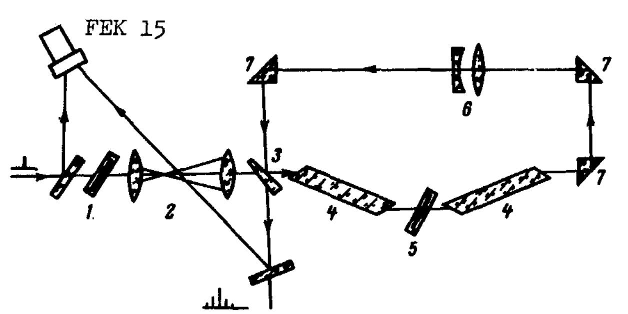


Fig. 1. Experimental setup

The experimental setup is shown in Fig. 1. The input USP (energy 10^{-3} - 10^{-2} J) is separated from the train of pulses from a laser with a nonlinear absorber [4, 2], is passed through a cell 1 with a saturable dye (initial transmission T_{init} = 10 - 15%), telescope 2 that expands the beam diameter threefold, wedgelike plate 3 with transmission T = 80%, and enters the ring system. The amplifying medium consisted of two rods 4 of neodymium

Fig. 2. Oscillogram of input pulse (arrow) and output pulses (period 19 nsec)

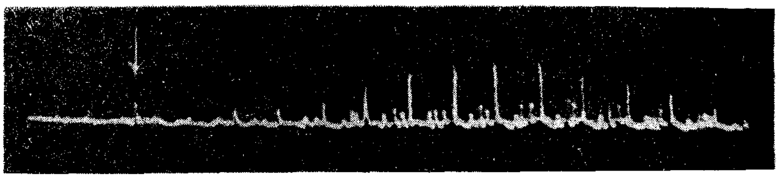
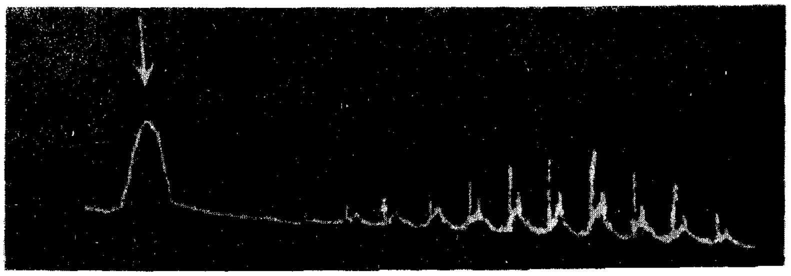


Fig. 3. Oscillogram of input pulse (complex waveform, arrow) and output pulses (period 19 nsec)



glass 600 x 20 mm with a calculated gain per pass K ≈ 200. Cell 5 filled with polymethine dye No. 3955 had an initial transmission T_{init} ≈ 0.5%. The objective 6 inside the ring system served to compensate for the distortion occurring when the rods are pumped. Instead of mirrors, which are damaged by the strong USP field, we used rotary total internal reflection mirrors 7. Additional transmission losses of the diverting plate 3 and the Fresnel reflection from the elements prevented self-excitation of the system. The passage time was 19 nsec. The input and amplified pulses were registered in a single sweep of the I-2-7 oscilloscope with the aid of an FEK-15 coaxial photocell. We measured simultaneously the total energy of the train of output USP.

The oscillogram of Fig. 3 shows the input USP and the train of output pulses. The total output energy was 4.5 J, and the energy of the maximal pulse was 0.6 J. The maximum train energy that could be obtained with this setup reached 18 J. In the case when the input pulse had a complex waveform, the amplification separated the most intense USP. This process can be seen in Fig. 3. The structure of the input pulse was not resolved.

Thus, a two-component stable USP amplifier, which constitutes essentially a laser with a nonlinear absorber below threshold controlled by an external pulse, produces a train of USP with energy higher than 10 J and with a single USP energy higher than 1 J.

An investigation of the described USP amplification scheme will make it possible to study the behavior of a saturable absorber in a very strong light field, and also the processes that limit the growth of the USP power.

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