Stimulated-Raman self-conversion of Nd^{3+} laser light in double tungstenate crystals

K. Andryunas, Yu. Vishchakas, V. Kabelka, I. V. Mochalov, A. A. Pavlyuk, G. T. Petrovskiĭ, and V. Syrus
Institute of Physics, Academy of Sciences of the Lithuanian SSR

(Submitted 16 September 1985)
Pis'ma Zh. Eksp. Teor. Fiz. **42**, No. 8, 333–335 (25 October 1985)

A stimulated-Raman self-conversion of Nd^{3+} laser light has been observed in $KY(WO_4)_2$ and $KGd(WO_4)_2$ crystals. Specifically, the emission of Nd^{3+} at the fundamental wavelength $\lambda = 1.06\,\mu$m in active elements of crystals of this type is accompanied by the emission of Raman components in the spectral interval 0.97–1.5 μm.

Stimulated-Raman laser oscillators and amplifiers are used extensively and effectively to control the characteristics of laser beams.[1,2] In most cases, however, the stimulated-Raman conversion is achieved in a "passive" arrangement; i.e., the laser active element and the stimulated-Raman converter are different parts of the optical system. In the present experiments, in contrast with other studies, the stimulated-Raman conversion occurs in an "active" arrangement, by which we mean that the active element of the laser doubles as the stimulated-Raman converter for its own emission (in other words, the active element is a multifunction optical material).[3]

As the active medium for the emission and stimulated-Raman conversion of the laser light we selected crystals from the family of double tungstenates of alkali and alkaline-earth ions activated with neodymium (3 at. %): $KY(WO_4)_2$ and $KGd(WO_4)_2$. For the experiments we use active elements 5 mm in diameter and 50 mm long oriented along the [010] crystallographic direction. The pulse repetition frequency is varied from single pulses to 10 Hz.

Figure 1 shows the optical arrangement of a picosecond laser with stimulated-Raman self-conversion. An ethanol solution of the dye 3274-u is used as a passive shutter. A single pulse is obtained in an external-resonator arrangement.[4] The pulse length is determined from the autocorrelation function found by the method of noncollinear generation of the second optical harmonic. The wavelength of the laser light is determined with an MDR-23 monochromator, and the spectral width is determined with a spectrograph with a diffraction grating with 300 lines/mm. The output energies are measured calorimetrically, with an IMO-2N calorimeter, and photoelectrically, with energy-calibrated FD-7G photodiodes. The threshold pump energies for the fundamental-wavelength laser oscillator in the free-running regime are 13 and 12 J, and those in the mode-locked regime are 20 and 18 J, for the $KY(WO_4)_2$:Nd^{3+} and the $KGd(WO_4)_2$:Nd^{3+}, respectively. The output energy of the train of picosecond pulses in the single-mode regime is on the order of 5 mJ for both crystals, while the output energy in the single pulse is 0.6 mJ for the $KY(WO_4)_2$:Nd^{3+} and 0.5 J for the $KGd(WO_4)_2$:Nd^{3+}. The length of the pulse at the fundamental wavelength is 11–12 ps for both crystals, with a spectral width of 1.8 cm^{-1}. The emission at the fundamen-

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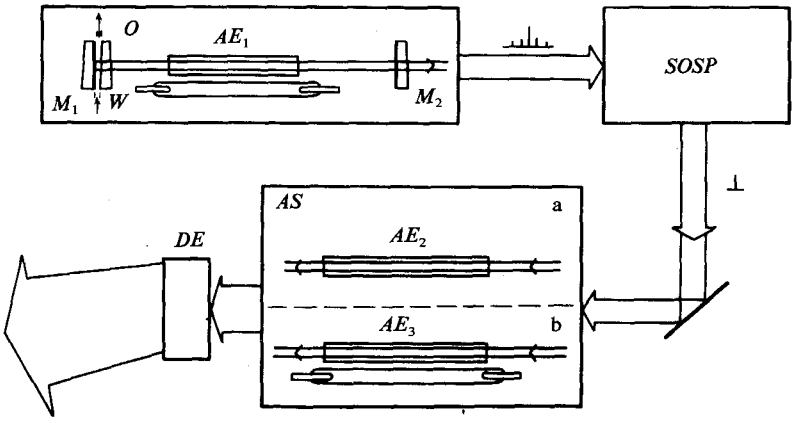

FIG. 1. The optical arrangement. *O*: Oscillator-(stimulated-Raman self-converter). M_1—100% mirror at the wavelength $\lambda = 1.06$ μm; *W*—flow-through wedge-shaped cell with a modulation dye; M_2—wedge-shaped glass substrate; *AE*—active element. *SOSP*: System for discriminating a single pulse. *AS*: Amplifier system. a—(Stimulated-Raman-converter)-amplifier (in the absence of pumping of the *AE*); b—(amplifier for light at the fundamental wavelength)-(stimulated-Raman converter)-amplifier (with pumping of the *AE*, $E_p = 30$ J). *DE*: Dispersive element.

tal wavelength in crystals of this type is accompanied by the generation of stimulated-Raman components, which are formed as a result of an interaction of photons with $\lambda = 1.06$ μm with vibrational modes of the host in the active element. The frequency of the Stokes shift for the $KY(WO_4)_2$:Nd^{3+} crystals is 901 cm^{-1}. Emission is observed in the form of two Stokes components and one anti-Stokes component.

A study of the efficiency of the stimulated-Raman self-conversion was carried out for single pulses in $KY(WO_4)_2$:Nd^{3+} crystals in three optical arrangements (Fig. 1). The pulse is taken from the beginning of the train. (1) Oscillator-(stimulated-Raman self-converter). The energy of the light at the fundamental wavelength ($\lambda = 1.0688$ μm) is $\eta = 92\%$ of the total output energy. The energy converted into the first Stokes component[1)] ($\lambda_{1S} = 1.1827$ μm) is $\eta_{1S} = 6.14\%$; the energy in the second Stokes component ($\lambda_{2S} = 1.3237$ μm) and that in the anti-Stokes component ($\lambda_{aS} = 0.9749$ μm) are $\eta_{2S} < 0.15\%$ and $\eta_{aS} < 1.5\%$, respectively. (2) [Oscillator-(stimulated-Raman self-converter)] + [(stimulated-Raman-converter)-amplifier]. In this arrangement we find $\eta = 42\%$, $\eta_{1S} = 37\%$, $\eta_{2S} = 16\%$, and $\eta_{aS} < 5\%$. (3) [Oscillator-(stimulated-Raman self-converter)] + [(fundamental-wavelength amplifier)-(stimulated-Raman converter)-amplifier]. The total output energy is 11 mJ, $\eta = 66.6\%$, $\eta_{1S} = 30\%$, $\eta_{2S} = 2.65\%$, and $\eta_{aS} = 0.63\%$.

We used the $KGd(WO_4)_2$:Nd^{3+} crystals to study the efficiency of the stimulated-Raman self-conversion in a train of picosecond pulses. The Stokes shift for these crystals is 889 cm^{-1}. We detected three Stokes components and one anti-Stokes component. In the oscillator-(stimulated-Raman self-converter) we used a composite active element containing two $KGd(WO_4)_2$:Nd^{3+} laser crystals, 5 mm in diameter and 50 mm long and 4 mm in diameter and 50 mm long. (1) Oscillator-(stimulated-Raman self-converter): ($\lambda = 1.0672$ μm) $\eta = 96.1\%$, ($\lambda_{1S} = 1.1805$ μm)

$\eta_{1S} = 3.84\%$, ($\lambda_{2S} = 1.3207\,\mu$m) $\eta_{2S} = 0.045\%$. (2) [Oscillator-(stimulated-Raman self-converter)] + [(stimulated-Raman converter)-amplifier]: $\eta = 82.43\%$, $\eta_{1S} = 16.58\%$, $\eta_{2S} = 0.96\%$, $\eta_{3S} = 0.03\%$.

We note in conclusion that a stimulated-Raman self-conversion of laser light should be observed in a long list of tungstenate and molybdate crystals. In particular, in the course of the present study we observed an effective stimulated-Raman self-conversion accompanying emission in the crystals $KLa(MoO_4)_2:Nd^{3+}$ and $NaLa(MoO_4)_2:Nd^{3+}$. The length of the pulse at the fundamental wavelength in this case was 5–6 ps, and the length of the pulse at the first Stokes component was 1.5–2.5 ps with a conversion efficiency up to $\eta_{1S} \sim 40\%$. The results of this study immediately demonstrate that multifunction materials of this type can be used to fabricate multicolor picosecond-range lasers for studying ultrafast processes.

We wish to thank N. V. Ionina for assistance in some of the experiments.

[1)]When a pulse is singled out from the middle of the train, the efficiency of the conversion into the first Stokes component reaches 35%, and that of conversion into the second Stokes component reaches 1.2%.

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[3]Invention Declaration No. 3814601/25, Affirmative Decision of the All-Union Scientific-Research Institute of State Patent Experts, 4 February 1985.

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Translated by Dave Parsons