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## LASER BASED ON RAMAN SCATTERING IN LIQUID NITROGEN

A. Z. Grasyuk, V. F. Efimkov, I. G. Zubarev, V. I. Mishin, and V. G. Smirnov
P. N. Lebedev Physics Institute, USSR Academy of Sciences
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An important parameter of a coherent-radiation source is its brightness ($W/cm^2 sr$). A promising method of increasing the brightness of such a source is to transform its emission into generation by means of stimulated Raman scattering (SRS). We report here for the first time an increase of brightness in a liquid (liquid nitrogen) Raman laser [1)].

It was observed in [1-2] that SRS in liquid nitrogen makes it possible to transform effectively the radiation of a ruby laser into Stokes components. No noticeable effect of stimulated Mandel'shtam-Brillouin scattering (SMBS) and self-focusing was observed in this case, this being due to their higher threshold pump intensities compared with SRS. In organic liquids these thresholds are of the same order as those of SRS. Therefor SRS in these liquids is accompanied as a rule by SMBS and by self-focusing. This apparently explains why it is impossible to obtain an increase in brightness in Raman lasers using these liquids [3,4]. This effect is observed only in gaseous hydrogen [5], in which the SRS threshold is much lower than the SMBS and self-focusing thresholds.

A block diagram of the experimental setup is shown in Fig. 1. The pump source is a Q-switched ruby laser with a rotating prism. An off-axis pumping scheme was used, i.e., the light beam of the pump propagates at a certain angle to the axis of the Raman-laser resonator. Such a scheme makes it possible to separate spatially the pump and generation light beams. The temporal characteristics of the pump and generation were investigated with the aid of FEK-09 coaxial photocells with a high-speed oscilloscope. The spatial distribution of the generation was fixed with a photographic camera (PC), and the angular distribution was measured with interchangeable diaphragms D located in the focal plane of the lens $L_2$ of focal length 2 m. The radiation energy was measured with calorimeters $C_1$ and $C_2$. A selective filter $F_2$ was used to separate the Stokes components $\lambda_1 = 0.828\ \mu$ and $\lambda_2 = 1.026\ \mu$.

1) We shall henceforth use for brevity the term "Raman laser" in place of "laser based on stimulated Raman scattering."

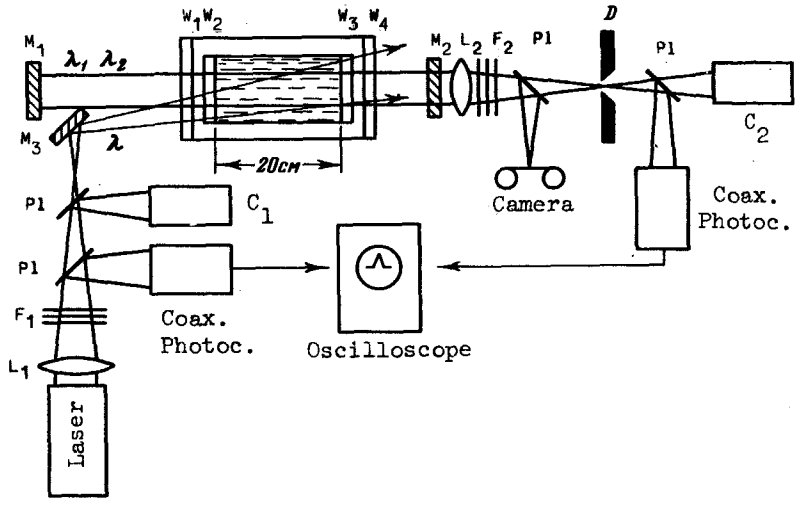


Fig. 1. Block diagram of setup for the investigation of a Raman laser. RL - Q-switched ruby laser. $L_1$ - focusing lens. $F_1$ - filter regulating the pump energy. Pl - beam-splitting plates. $M_3$ - rotating mirror. $M_1$ and $M_2$ - mirrors of Raman-laser cavity. ($M_1$ - reflectance 97% at $\lambda_1$ and $\lambda_2$; $M_2$ - glass plate.) $W_1$ - $W_4$ - windows of cell with liquid nitrogen. $L_2$ - lens with focal distance F = 2m. $F_2$ - selective filter separating $\lambda_1$ and $\lambda_2$. $C_1$ and $C_2$ - calorimeters. D - diaphragm for the measurement of the angular distribution of the generation energy. $\lambda$, $\lambda_1$, $\lambda_2$ - wavelengths of the pump and the first and second Stokes components respectively ($\lambda$ = 0.6943 μ, $\lambda_1$ = 0.828 μ, $\lambda_2$ = 1.026 μ).

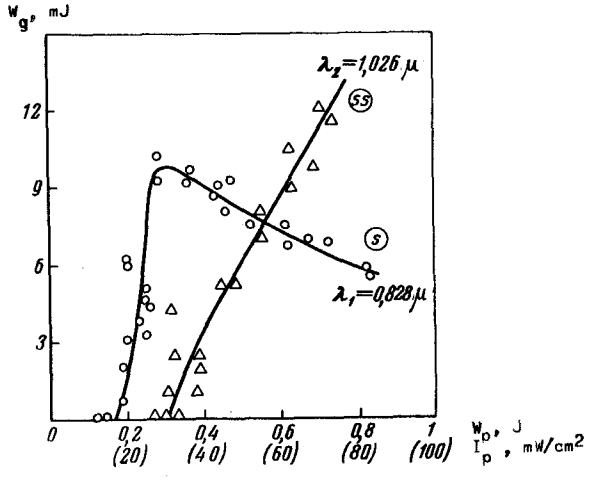


Fig. 2. Dependence of the generation energy $W_g$ of the Raman laser at the first ($\lambda_1$ = 0.828 μ) and second ($\lambda_2$ = 1.026 μ) Stokes components on the pump energy $W_p$ (and intensity $I_p$).

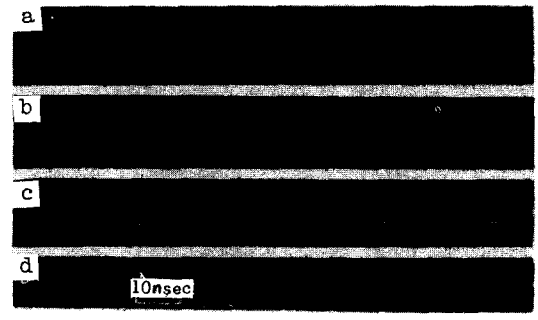


Fig. 3. Oscillograms of the pump and of the transformed radiation: a - pump; b - generation at the first Stokes component ($\lambda_1$ = 0.828 μ); c - generation of the second Stokes component ($\lambda_2$ = 1.026 μ); d - emission of the first Stokes component in the direction of pump-radiation propagation.

Figure 2 shows energy values, typical of the generation regime, of the first ($\lambda_1$ = 0.828 μ) and second ($\lambda_2$ = 1.026 μ) Stokes components as functions of the pump energy and intensity. It is interesting to note that the growth of the first Stokes component ($\lambda_1$) stops when generation sets in at the second component ($\lambda_2$), after which the first component begins to decrease. This phenomenon is connected with the kinetics of the interaction of these components in the Raman laser.

Figure 3 shows oscillograms of the pump and generation at the first and second Stokes components. A characteristic feature of the Raman laser is the oscillatory character of its radiation. The period of these oscillations is of the order of $2L/c$, where $L$ is the resonator length and $c$ is the speed of light.

The generation divergence $\theta_g$ was $\theta_g = (5 - 6) \times 10^{-4}$ rad, which is approximately three times larger than the diffraction limit and one tenth of the divergence of the unfocused pump beam ($(5 - 6) \times 10^{-3}$ rad).

The coefficient of energy conversion into Stokes components under lasing conditions was 3 - 5%. Such a relatively low value of the conversion coefficient can be attributed to the excessively short pump pulse, the duration of which (at half the height) corresponds only to several passes of the light in the resonator. This is apparently insufficient to establish the stationary regime and to form a narrow generation directivity pattern. In the solid angle in which the pump was concentrated (and in the direction of the pump propagation) the coefficient of conversion into Stokes components reached 50%. The pump and Raman-laser parameters are compared for one of the experiments in the table. It is seen from the table that the brightness of the Raman laser is much higher than the brightness of the pump source.

Table

| No. | Source | Pulse energy W, J | Beam cross-section area S, $cm^2$ | Pulse duration τ (at base), nsec | Beam divergence θ, rad | Ratio of Raman-laser brightness ($B_g$) to pump brightness ($B_p$), $\frac{B_g}{B_p} = \frac{W_g \tau_p S_p (\theta_p)^2}{W_p \tau_g S_g (\theta_g)^2}$ |
|---|---|---|---|---|---|---|
| 1 | Pump: ruby laser $\lambda$ = 0.6943 μ | 0.3 | 1.1 | 75 | $5 \times 10^{-3}$ | 60 |
| 2 | Raman laser $\lambda_1$ = 0.828 μ $\lambda_2$ = 1.026 μ | $10^{-2}$ | $9 \times 10^{-2}$ | 35 | $6 \times 10^{-4}$ | |

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## INFLUENCE OF THE PURITY OF SUPERCONDUCTING NIOBIUM ON THE SHAPE OF THE MAGNETIZATION CURVE

V. R. Karasik, L. A. Nisel'son, I. V. Petrusevich, A. I. Shal'nikov, and I. Yu. Shebalin
P. N. Lebedev Physics Institute, USSR Academy of Sciences
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A stretching of the magnetization curve is a characteristic of niobium, the only representative of superconductors of the second type among individual substances. It is important to ascertain the degree to which this property is the consequence of unavoidable contamination with nitrogen and oxygen in the case of niobium, which is a chemically very active metal, and also a consequence of the accompanying tantalum.

The magnetic properties of pure niobium in the superconducting state were investigated in detail in [1], but the investigated samples contained up to 0.0175 wt.% tantalum.

To obtain even purer samples, we used a setup for simultaneous thorough purification of niobium pentachloride and its subsequent reduction to the metallic state [2,3].

The initial $NbCl_5$, containing 0.15% tantalum, was rectified twice in a column with 30 actual plates (the data of the analysis of the rectified $NbCl_5$ are listed in the table), and

| Impurities relative to the metal in $NbCl_5$ | Analysis method | Sensitivity of analysis method (mass %) | Analysis data (mass %) |
|---|---|---|---|
| Ta | Activation | $1 \times 10^{-6} - 1 \times 10^{-7}$ | $2.6 \times 10^{-5}$ |
| Si | Spectral | $2 \times 10^{-3}$ | not observed |
| Al | " | $5 \times 10^{-4}$ | " |
| Fe | Chemical-spectral | $5 \times 10^{-4}$ | " |
| Ti | " | $1 \times 10^{-4}$ | " |
| Bi | " | $1 \times 10^{-5}$ | " |
| Cd | " | $2 \times 10^{-5}$ | " |
| Zn | " | $5 \times 10^{-5}$ | $1 \times 10^{-5}$ |
| Cu | " | $2 \times 10^{-6}$ | $1 \times 10^{-5}$ |
| Mn | " | $5 \times 10^{-6}$ | not observed |
| Pb | " | $1 \times 10^{-5}$ | " |
| Co | " | $1 \times 10^{-5}$ | " |
| Ni | " | $1 \times 10^{-5}$ | " |
| In | " | $1 \times 10^{-5}$ | " |
| W | Chemical | $2 \times 10^{-3}$ | " |
| Mo | " | $5 \times 10^{-4}$ | " |