# Conversion of He–Ne laser radiation from $\lambda = 3.39$ $\mu$m to the 330.5 nm band in sodium vapor

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Radiation of $\lambda = 3.39$ $\mu$m was converted to the 330.5 nm band in sodium vapor via resonant pumping of the $3s$–$5s$ transition by a $\lambda = 602.4$ nm dye laser.

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The problem of converting weak IR radiation to the optical and near-ultraviolet bands, i.e., to the region of maximum sensitivity and low inertia of the photoreceivers, is of great scientific and applied significance. Since transparent gaseous nonlinear media are available for practically any region with large wavelength and aperture, and the synchronism conditions can be controlled for any frequency interval, the use of such media is promising for the solution of this problem.

As of now we know only two experimental papers on the conversion of IR radiation is gaseous media. Thus, Bloom *et al.*[1] have successfully converted the radiation of a $CO_2$ laser to the near UV band. Stappaerts *et al.*[2] converted an image from the 2.9 $\mu$m band to the 455.8 nm region in Cs vapor. The 2.9 $\mu$m radiation source was a pulsed parametric laser using an $LiNbO_3$ crystal. Many schemes for the conversion of radiation from the bands 1.06, 3.39, 10.6 $\mu$m to the visible and near ultraviolet bands were proposed in[3–6].

We report here an experimental verification of one of the predicted possibilities. For the first time ever, we have converted weak emission of a cw He-Ne laser with a

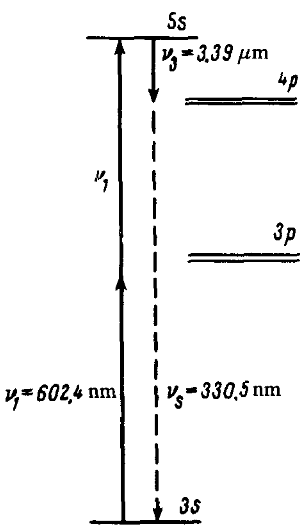


FIG. 1. Scheme of the sodium-atom energy levels that make the main contribution to the conversion.

  

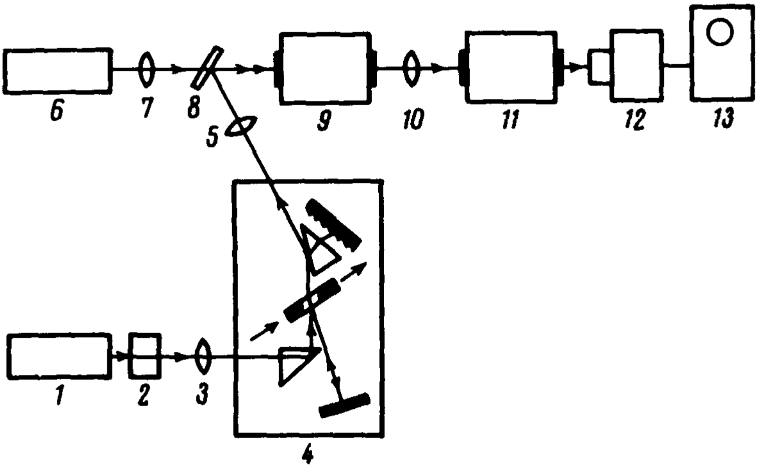


FIG. 2. Block diagram of experiment: 1—Nd:YAG laser; 2—$LiNbO_3$ crystal; 3,5,7,10—focusing systems: 4—rhodamine-B dye laser, 6—He-Ne laser; 8—semitransparent plate; 9—cell with sodium vapor; 11—DMR-4 monochromator; 12—14ÉLU-FS photomultiplier; 13—S1-31 oscilloscope.

cubic nonlinear gaseous medium to the 330.5 nm region in sodium vapor. In addition to illustrating the extensive possibilities of conversion of IR radiation by cubic nonlinearities of gaseous media for spectroscopic purposes, this problem is also of interest from the point of view of measuring the emission frequencies in the optical band, since this He-Ne laser frequency can presently be measured with high accuracy.

We used for the conversion the strong $3_s - 5_s$ two-photon sodium transition (Fig. 1). The difference frequency $\nu_s = 2\nu_1 - \nu_{IR}$ turned out to be close to the frequency of the allowed $3_s$–$4_p$ transition. The pump $\nu_1$, which was at resonance with the two-photon transition, was the emission of a 602.4-nm rhodamine-B dye laser. The power of this laser at the indicated wavelength was 5 kW, and the line width was 2 $cm^{-1}$. The experimental setup is shown in Fig. 2. The second harmonic of the neodymium-garnet laser was used to pump the dye laser. A semitransparent plate mixed the 3.39-$\mu$m beam with the dye-laser radiation. The power of the $\lambda = 3.39$ $\mu$m beam at the entrance to the cell was 1 mW. Both beams were fed into a metallic heated cell with sodium and helium vapor. The helium has no effect on the conversion processes, and merely prevents the sodium vapor from condensing on the cell windows. The vapor was condensed on a stainless-steel grid placed along the cell walls. The grid served as a wick to return the liquid condensate to the heating zone. The focusing systems were used for partial matching of the wavefronts of the interacting beams. The converted radiation was separated with a DMR-4 monochromator and was registered with a 14ÉLU-FS electron multiplier and S1-31 oscilloscopes. The length of the active medium in the cell was about 4 cm.

Figure 3 shows the dependence of the signal amplitude at 330.5 nm on the temperature of the cell with the sodium vapor. The peak of the signal was observed at 425 °C, corresponding to a vapor concentration $10^{16}$ $cm^{-3}$ and a sodium vapor pressure 0.7 Torr.

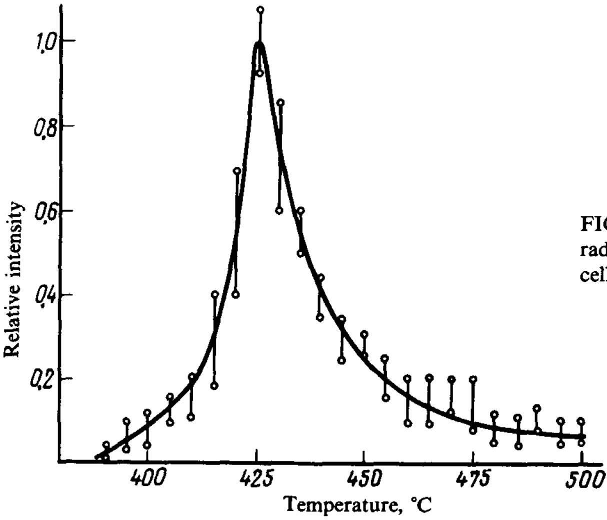


FIG. 3. Relative amplitude of converted-radiation signal vs the temperature of the cell with the sodium vapor.

An estimate shows that the efficiency of the conversion of the weak IR signal $\lambda = 3.39\ \mu m$ amounts to about $10^{-5}$–$10^{-4}$. In this experiment, no special measures were taken for an exact matching of the confocal parameters of the beams, to a narrowing of the line width, and to an increase of the dye-laser pump power. Optimization of these parameters will increase the conversion coefficient.

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