Conversion of IR image into violet image in potassium vapor

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The conversion of an IR image (3.66 μm) into a violet image (0.40 μm) with brightness intensification has been achieved for the first time in a stimulated parametric four-wave process in potassium vapor.

Zemskov *et al.*[1] have shown that the violet light excited in a stimulated parametric four-wave mixing in potassium vapor on the transition $5P_{3/2} \to 4S_{1/2}$, with a frequency $\omega_v = 24\ 720\ \text{cm}^{-1}$ ($\lambda = 0.40\ \mu\text{m}$), reproduces the spatial configuration of the cross section of the beam of exciting light, consisting of the light from a ruby laser (ω_r) and the first Stokes component of the stimulated Raman scattering of this light in nitrobenzene (ω_S). In this process, two pump photons at $\omega_r = 14\ 400\ \text{cm}^{-1}(\lambda = 0.69\ \mu\text{m})$ and $\omega_S = 13\ 055\ \text{cm}^{-1}(\lambda = 0.77\ \mu\text{m})$ convert into a photon of IR light near the transition $6S_{1/2} \to 5P_{3/2}$, with the frequency $\omega_{IR} = 2734\ \text{cm}^{-1}(\lambda = 3.66\ \mu\text{m})$, and a photon at ω_v. It must be assumed that the IR light and, correspondingly, the violet light may be intensified substantially as a result of hyper-Raman scattering, which sends a potassium atom from the $4S_{1/2}$ level to the $5P_{3/2}$ level: $\omega_{hR} = \omega_{IR} = \omega_r + \omega_S - \omega_v$ (Ref. 2). In the present letter we show that when seed light at the frequency ω_{IR}, with a spatially modulated beam cross section, is sent into a cell holding potassium vapor, one can achieve a similar modulation of the beam of violet light leaving the cell.

The two-photon excitation of the potassium vapor was carried out as in Ref. 1. The exciting light was directed without focusing into two cells, each 20 cm long, holding potassium vapor, in succession. The intensities of the exciting light components were $I_R^{(2)} = 15\ \text{MW/cm}^2$ and $I_S^{(1)} = 1\ \text{MW/cm}^2$ in the first cell and $I_R^{(2)} = 8\ \text{MW/cm}^2$ and $I_S^{(2)} = 0.3\ \text{MW/cm}^2$ in the second. The first cell served as a source of seed light components at ω_v and ω_{IR}, while the second served as an amplifier.

Preliminary studies showed that the gain k, defined by

$$k = \frac{I_v^{(1,2)}}{I_v^{(1)} + I_v^{(2)}},$$

where $I_v^{(1)}$ and $I_v^{(2)}$ are the intensities of the violet light of the first and second cells separately, and $I_v^{(1,2)}$ is the intensity of the light of the two cells together, depends strongly on the presence of the seed light at ω_{IR}. Figure 1 shows k as a function of the density of the potassium vapor in the second cell, $N_K^{(2)}$, for the case of seed light at (a) ω_{IR} and ω_v and (b) only at ω_v (the light at ω_{IR} was cut out by an appropriate filter).

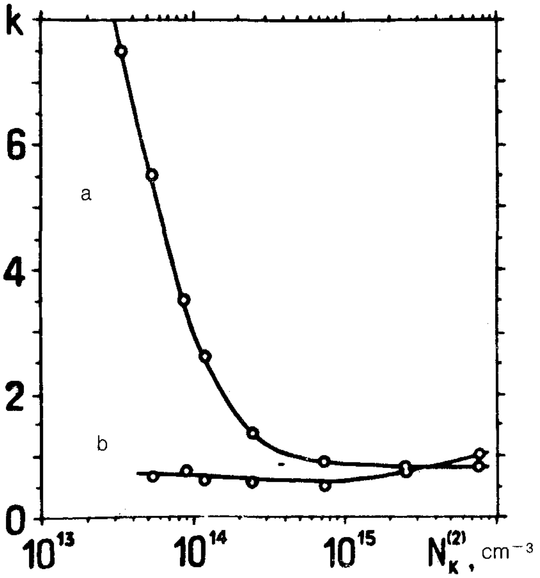

FIG. 1. The gain k as a function of the potassium vapor density $N_K^{(2)}$ in the case in which there is seed light at (a) ω_{IR} and ω_v and (b) at ω_v only.

The potassium vapor density in the first cell, $N_K^{(1)}$, was 10^{12} cm^{-3}. According to estimates, this density corresponds to $I_v^{(1)} \approx 0.1$ W/cm^2. In our experiments, an amplification was observed beginning at $N_K^{(2)} = 5 \times 10^{12}$ cm^{-3}, but there are no points on the curves at $N_K^{(2)} < 3 \times 10^{13}$ cm^{-3} because of the limited sensitivity. The apparatus

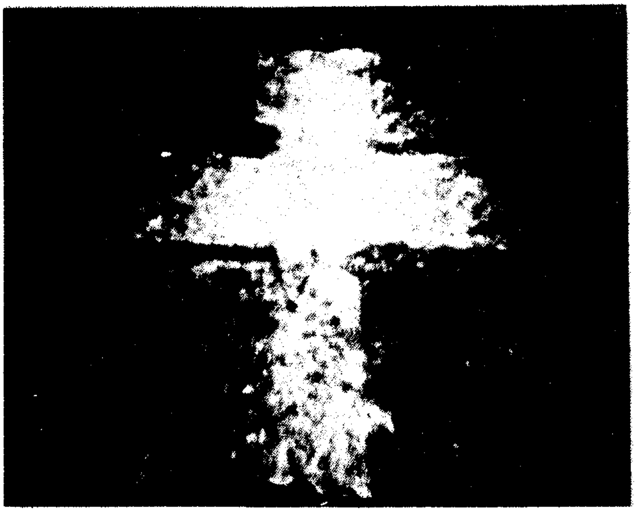

FIG. 2. Sample of the spatial structure of the cross section of a violet light beam during spatial modulation of a beam of IR light.

which we used made it possible to detect light with an energy $> 10^{-8}$ J (a power > 1 W). Consequently, at $N_K^{(2)} < 3 \times 10^{13}$ cm^{-3} it was not possible to measure $I_v^{(2)}$ or, correspondingly, k.

On the basis of this study we determined the optimum conditions for image conversion: $N_K^{(1)} = 10^{12}$ cm^{-3}, $N_K^{(2)} = 10^{13}$ cm^{-3}. Since the values of $I_v^{(1)}$ and $I_v^{(2)}$ under these conditions lie below the detection threshold, we can offer only an order-of-magnitude estimate: $k \sim 50$. For a spatial modulation of the beam of seed light at ω_{IR}, we placed a BS-15 light filter between the cells. Four square glass plates were cemented to this filter. The transmission of this object for the light at ω_r, ω_s, and ω_v was close to 100%, while that for the light at ω_{IR} was $\approx 70\%$ in the regions without the glass and $< 0.1\%$ in the regions with the glass. To detect the violet image, we imaged the plane of the exit window of the second cell onto RF-3 photographic film with an objective. The exciting light components were completely removed by an SZS-22 filter. Figure 2 shows a sample of the resulting pattern.

To the best of our knowledge, this is the first instance of image conversion in a system of this sort. There have been reports in several places, e.g., Ref. 3, of image conversion by the up-conversion method in metal vapor. The approach proposed here has the advantage over up conversion that the number of converted photons may exceed the number of IR photons introduced into the converter. An image intensification at the frequency of the seed light has been achieved in several active media of gas-discharge metal-vapor lasers.[4] The approach proposed here thus combines a frequency conversion of light and an image intensification in the transmission of an image.

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