A long-distance monitor lidar should feature high radiation intensity (of the order of hundreds of millijoules), because a scattered light intensity falls with distance more rapidly than $R_0$. The laser radiation spectral width should be sufficiently small (of the order of hundreds small or the order of one tenth of an angstrom).

In the present summary of the paper we report the experimental design of a laser system of $5\,\text{ps}$ for the linewidth of hundreds of millijoules at wavelengths allowing one to detect atmospheric impurities of $\text{SO}_2$ and $\text{NO}_2$ without making essential changes in the configuration of the optical scheme. The system includes two laser channels, each consisting of the following system: XeCl-laser oscillator-amplifier and dye laser oscillator-two amplifiers. The wavelength in the first channel is $\lambda_{\text{m}} = 3084.5\,\text{Å}$ and in the second one it is $\lambda_{\text{m}} = 3077.0\,\text{Å}$. The radiation energy is up to $250\,\text{mJ}$ per pulse and the linewidth is $0.1-0.3\,\text{Å}$. In NO$_2$ monitoring mode, the XeCl-laser amplifier operating in a free lasing regime pumps the dye laser oscillator-two amplifier system. The first channel is tuned to the wavelength of $\lambda_{\text{m}} = 4469\,\text{Å}$ and the other, $\lambda_{\text{m}} = 4482\,\text{Å}$. The radiation energy is about $150\,\text{mJ}$ and the linewidth is $0.1\,\text{Å}$ in each channel.

The lasers operate at a repetition rate of 5 Hz and are synchronized to provide a time delay of 10 ms for each channel.

Because manufacturing of lasers with characteristics described above is a significant problem, we will discuss the laser optical scheme in more detail. The difficulty of obtaining intense narrow-band radiation at the specified wavelengths in the XeCl laser is caused by the following: these wavelengths correspond to the peaks of electronic-vibrational transitions $0-0$ and $0-3$ with the Frank-Condon factors and hence cross sections and weak signal gains are two times smaller than for $0-1$ and $0-2$ transitions for these molecules. The use of an original resonator and thereby cross sections and weak signal gains are two times smaller than for $0-1$ and $0-2$ transitions for these molecules.

The use of an original resonator allowed one to obtain the output oscillator energy of 13 mJ for the linewidth of 0.25 Å, and 30 mJ for the linewidth of 0.4 Å at the wavelengths of 3077 and 3084.5 Å. An LIDA-T laser was also used as an amplifier.

A problem of intense UV radiation (with energy $\gtrsim 1\,\text{J}$ per pulse) conversion in dye lasers was solved by the original design of dye-cells, such as a cell-prism of total internal reflection. A cell-prism is made of quartz with a cavity for dye solution oriented in a special way. Due to the phenomenon of total internal reflection, pump radiation fills the dye volume uniformly by four light beams. This allows one to produce a uniform laser output beam with a sufficiently small divergence ($\lesssim 3\,\text{mrad}$). A high conversion efficiency (of about 25%) is possible for flow power fluency $\gtrsim 2\,\text{MW/cm}^2$. An optical setup required to obtain high energy parameters of narrow-band radiation (linewidth of about 0.1 Å) involves a high-power MHzIL-03 dye laser. The design also includes a master generator and two amplifiers.

One of the interests in solid-state laser physics has focused on diode-pumped blue and green upconversion lasers. At 531 nm upconversion-pumped laser operation in Er$^{3+}$:LiYF$_4$ at cryogenic temperatures has been reported, see e.g., Ref. 1. Recently room-temperature lasing under different excitation schemes has been achieved. However, the population and deexcitation processes of the upper laser level as well as the influence of reabsorption on the laser wavelength have not yet been quantitatively understood. In this paper the results of a computer simulation of the Er$^{3+}$:LiYF$_4$ laser are reported. The rate-equation scheme considers all excited levels up to $4\,\text{H}_{2}^\text{2}$, ground-state depletion, excited-state absorption (ESA) on the pump and laser wavelength, three upconversion processes, stimulated emission, and a realistic resonator design. From the computer simulation the population mechanisms of the laser system are analyzed.
In conclusion we have shown that the strong cross relaxation from the upper laser level is responsible for the quenching of the laser output with dopant concentration. The corresponding parameter has been estimated. Crystals with a smaller cross-relaxation parameter would allow higher dopant concentrations and absorption coefficients. An avalanche effect appears to be an important excitation mechanism for the green erbium laser. This effect can be optimized by using other pump wavelengths with higher ESA cross sections.

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New data on induced-emission cross section in solid-state laser materials

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The values for induced-emission cross section of laser glasses and crystals determined from standard absorption and emission measurements and Judd-Offelt calculations are not sufficient to describe the generation properties of laser materials. A more successful way to determine effective values for laser material cross section is based on mathematical approximation of output to input energy characteristics realized in lasers with known resonator parameters. The measurements were made by using pulse lasers. Active rods from materials to be measured were located in the pumping cavity of the laser. It was necessary to make some tricks to avoid the influence on the results of the measurements by such phenomena as pumping system nonlinearity, uncertainty in irradiation losses in the resonator, and non-homogeneity of pumping light in active rod. After realizing these tricks measuring values for effective cross section became independent on the parameters of the laser and on laser construction.

An essential difference was found between the values for effective cross section received in our experiments and values determined with standard spectroscopic calculations. It turned out that the effective cross sections in similar laser materials were dependent on the concentration of the activator. Effective cross section in neodymium-doped phosphate glasses changes from 3.6 × 10^{-16} cm^2 for concentration 1.4 × 10^{-5} cm^3 to 1.9 × 10^{-16} cm^2 for 12.2 × 10^{-5} cm^3. Moreover the values for effective cross section in neodymium silicate glasses were found to be 3.1 × 10^{-16} cm^2 for concentration 1.9 × 10^{-5} cm^3 and 2 × 10^{-16} cm^2 for 4.6 × 10^{-5} cm^3 while the spectroscopic value for these glasses is only 1.7 × 10^{-16} cm^2.

The measurements were made also for some neodymium-doped crystals. The efficient cross section in YAG:Nd at 1.06 micron was 1.7 × 10^{-15} cm^2 for concentration of Nd 1.1 wt. percent and about 3 × 10^{-16} cm^2 for 0.5 wt. percent. The Judd-Offelt cross section of neodymium in KGd(WO_4)_2:Nd (4.3 × 10^{-16} cm^2) is more than in YAG:Nd (3.6 × 10^{-16} cm^2) but its effective cross section is 1.25 × 10^{-16} cm^2 for concentration 7 wt. percent and 1.9 × 10^{-16} cm^2 for 3 wt. percent. The greatest difference between effective and spectroscopic cross sections in KGd(WO_4)_2 than in YAG can be explained by the greater concentration of neodymium in KGd(WO_4)_2. The method for measuring the effective cross section can be used not only for neodymium-doped laser materials. We began to investigate laser solid-state materials for other generation wavelengths. The results of the investigations show that our method for measuring effective cross section has given new opportunity to evaluate laser properties of active solid state materials.