Electro–optic Q-switched Cr:LiSAF laser

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Abstract. We demonstrate electro-optic Q-switched solid state laser with Cr:LiSAF active medium. A single 50 ns pulse with 14 mJ of output energy is demonstrated. Simultaneous generation of several peaks with a step of 1.4 nm within the spectrum envelope with a full width at half maximum of 10.3 nm is demonstrated. For an electro-optic Q-switched mode a Pockels cell is used. Demonstrated laser can be used in differential absorption lidar systems.

1. Introduction
Laser radiation sources operating in the mode of generation of several wavelengths are used to solve various scientific and technical problems. For example, different types of microscopy [1,2], including two-photon scanning microscopy [3,4], atmospheric spectroscopy [5-7], spectroscopy, various medical applications, including angioplasty, photodynamic therapy, treatment of ulcerative haemangioma [8]. Both tunable lasers [5] and lasers operating simultaneously at several wavelengths [6] can be used as radiation sources in such problems.

We have previously demonstrated a tunable laser based on a Cr:LiSAF active medium [9] using a transmission volume Bragg grating. The active medium of Cr:LiSAF has a wide gain band from 700 nm to 1100 nm [10], a long lifetime of the upper laser level – 67 μs [11], and an absorption band in the visible region with a peak at a wavelength of 650 nm [11,12]. The properties of this medium make it possible to use it in diode and lamp pumped lasers.

The mode of electro-optical Q-switching, described in detail in [13], is used in various laser systems and makes it possible to obtain short pulse durations of the order of 10 ns - 100 ns [14-16]. We noticed that the topic of electro-optical Q-switching for a Cr: LiSAF active medium is not fully disclosed in the literature and decided to consider this issue in more detail.

2. Methods
Figure 1 shows an experimental setup. Cavity used in set up – Fabry – Perot. Cavity length is 45 cm. The high reflection (HR) mirror (1) is broadband and has reflectivity >99.9%. Pockels cell (BBO-crystal) (2) is used for electro-optical Q-switching. The active medium (3) is 75 mm long, with a diameter of 6.3 mm, the alloying percentage is 1.5%, manufactured by Kazan Federal University, Russia. Output coupler (OC) (4) is a broadband mirror with reflectivity 85%. Active medium is pumped by lamp with energy of 45 J, and pulse duration 250 μs.
We used Tektronix oscilloscope – TDS5054B, and Ophir fast photo diode – VIS-300, to measure pulse duration. Spectrum was measured with Aurora spectrometer. Pulse Energy was measures by Ophir power meter – PE50BF-DIF. Q-switching was performed by controlling the refractive index of the Pockels cell, with high voltage. Pockels cell aperture was only 3 mm, so this made a negative effect on lasing efficiency.

3. Results

In this work, we obtained lasing on a Cr: LiSAF laser operating in the Q-switched mode, and compared it with the free running mode with the same cavity.

3.1. Free running mode

The cavity in this mode is the same as shown in figure 1, but without Pockels cell. We measured lasing spectrum, duration of pulse train and its energy. All measurements were performed on a series of 100 pulses. The results are shown in figures 2, 3 and table 1.

Pulse train duration was 160 μs ± 5 μs. Large standard deviation can be explained by instability in power and control circuit.
Bandwidth of lasing spectrum is 2.5 nm. Central peak has a wavelength 830 nm.

Table 1. Lasing properties.

| Property                  | Value | St. dev |
|---------------------------|-------|---------|
| Pulse train energy, J     | 0.9   | 0.02    |
| Pulse train duration, ns  | 160   | 5       |
| Central wavelength, nm    | 830   | 0.1     |
| Spectrum width, nm        | 2.5   | 0.2     |

Energy in pulse is 0.9 J±0.02 J. Instability of pulse energy is caused by instability of lamp pumping energy.

3.2. Electro-optic Q-switched mode

The cavity for this mode is shown on figure 1. Installing Pockels cell, without applying high voltage decreased energy of pulse train to 40 mJ. Applying high voltage and tuning the Pockels cell resulted 14 mJ single pulse energy with duration 50 ns. The pulse duration, pulse energy, and generation spectrum were measured. All measurements were performed on a series of 100 pulses. The results are shown in figures 4, 5 and table 2.

Pulse duration was 50 ns ±7 ns. Laser pulse has a Gaussian form. Large standard deviation can be explained by instability in power and control circuit combined with uncertainty caused by longitude mode competition.
Figure 5. Lasing spectrum (normalised).

Bandwidth of lasing spectrum is 10.3 nm. On spectrum clearly observed peaks with an interval of 1.4 nm – 1.5 nm. Central peak has a wavelength 894.7 nm.

Table 2. Lasing properties.

| Property                | Value | St. dev |
|-------------------------|-------|---------|
| Pulse energy, mJ        | 14    | 0.2     |
| Pulse duration, ns      | 50    | 7       |
| Central wavelength, nm  | 894.7 | 0.1     |
| Spectrum width, nm      | 10.3  | 0.2     |

Energy in pulse is 14 mJ±0.2 mJ. Instability of pulse energy is caused by instability of lamp pumping energy.

4. Discussion
A solid-state Cr:LiSAF laser operating in electro-optical Q-switched mode is demonstrated. Pulse energy is 14 mJ, pulse duration is 50 ns. Spectrum width is 10.3 nm. Instability in lasing properties can be explained by instability in pumping lamp pulse energy. With a pump energy of 45 J efficiency is only 0.03% which is extremely low due to decrease in a volume of intracavity mode because of Pockels cell aperture is 2 times less than aperture of active medium, inserted into cavity Pockels cell without voltage applied decreases energy in free running mode from 0.9 J to 40 mJ (decrease in efficiency – 22.5 times).

Spectrum generated has a wide bandwidth of 10.3 nm, and several peaks with an interval 1.4 nm – 1.5 nm. Central wavelength is 894.7 nm. In free running mode central wavelength on a same cavity is 830 nm. Such change can be explained not only by spectral properties of Pockels cell under high voltage and change in its refractive index.

Efficiency of lasing can be improved by using Pockels cell with larger aperture, and using laser diodes as a pumping source. The wideband lasing spectrum is much of interest for a further research. We are planning to conduct an experiment of tuning it by several spectral selectors and also narrowing it up to one longitude mode.

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