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New trends in tunable lasers based on color center and radiationally pertubed doped crystals

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Abstract

Four trends in tunable lasers based on color center and radiationally pertubed doped crystals are reported. The first trend takes advantage of optimizing the processes of radiational coloration of the crystals and color center stabilization. The second new trend is connected with the development of highly concentrated LiF color center crystals with a wave guide thin film geometry. The third new trend is composed of a novel color center laser optical cavity, providing superbroadband generation across the whole emission region of the LiF : F_2^- active medium. The fourth trend relates to new promising laser media based on radiationally pertubed Sc-doped crystals.

Keywords: Color center lasers; Scandium doped crystals

1. Stabilization of color centers

The first trend in color center (CC) tunable lasers takes advantage of optimizing the processes of coloration of the crystals and CC stabilization. It is demonstrated by the alexandrite laser pumped LiF : F_2^{+}** room temperature (RT) stable CC laser with an output power of about 1.4 W and a real efficiency of about 30% [1].

LiF crystals doped with LiOH, Li_2O and MgF_2 were subjected to a special multistep ionizing irradiation treatment. It results in a high concentration of RT stable active F_2^{+}** centers ($4–8 \times 10^{16}$ cm^{-3}) at a low level of losses (contrast is about 40). F_2^{+}** CCs feature homogeneously broadened absorption ($\lambda_{max} \sim 620$ nm, $\Delta\nu \sim 3550$ cm^{-1}) and luminescence ($\lambda_{max} \sim 890$ nm, $\Delta\nu \sim 2300$ cm^{-1}) bands, short luminescence lifetime (20 ns at 300 K and 37.5 ns at 77 K), high emission cross section ($\sigma_e = 5.7 \times 10^{-17}$ cm^2 at 885 nm), and a high-quantum efficiency of fluorescence ~50% at 300 K.

The slope efficiency of LiF : F_2^+ laser for the non-selective resonator with 50% output coupler was measured to be 30.6%. Spectral output of the laser in a diffraction grating dispersive cavity was tunable in 820–1200 nm range. Hence, the use of alexandrite laser pumping and a new technology of LiF : F_2^{+}** formation allowed to solve the problem of photodestruction of F_2^+ CCs and achieve a stable room temperature operation with record output energy parameters.

2. Optically dense thin film CC crystals

The key advantages of an optically dense media are the high efficiency of the pump energy conver-

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sion into the output generation and miniaturization of the laser devices on their basis. The aforesaid advantageous are undeniably true for the CC crystals as well. For example, in Ref. [2] a highly-concentrated ($k = 400\ cm^{-1}$) $LiF:F_2$ crystal with a 90 μm thickness of coloration was developed under low-energy electron irradiation. A similar result was obtained in Ref. [3], using LiF coloring with quanta of soft X-ray radiation, generated with the use of a laser (1.06 μm) plasma source. The absorption coefficient in the F_2 band was about $1500\ cm^{-1}$.

Another principal peculiarity of the highly concentrated CC crystals is the fact, that due to their large cross sections of the stimulated transitions ($\sigma \approx 10^{-16}$–$10^{-17}\ cm^2$) it is possible to reach a laser threshold conditions and high gain coefficients on the colored layers with a thickness of about 0.1–1 μm. Such a thin colored films of dielectric exhibit some features of semiconductor crystals. This fact provides a theoretical reason enough to develop principally new lasers based on the dielectric crystals with an electrical pumping.

To this end, it was of interest to use surface microwave discharges for LiF crystals coloration. The details of the experiment are described in Ref. [4]. After several thousands of microwave radiation pulses a change in the crystal's color is observed: they changed from colorless to yellow. At the same time, in the absorption spectra of specimens two bands of a Gaussian profile appeared, having their maxima at 250 and 445 nm that is typical for F and F_2 centers. The estimates show that the concentrations of both F and F_2 centers reach the values 10^{20}–$10^{21}\ cm^{-3}$ that is by 1 or 2 order higher than in the case when high-energy irradiation is used for coloration. Hence, our studies demonstrated the potentialities of the surface microwave discharges for production of a high concentrations of CCs in alkali halides.

3. Novel CCL optical cavities

The third new trend is composed of a novel CCL optical cavity, providing two unique regimes of generation: (a) a superbroadband generation across the whole emission region of the $LiF:F_2^-$ active medium (1.1–1.24 μm) with efficiency of 15% and a simultaneous frequency doubling in the visible green–red spectral region (0.55–0.62 μm) and (b) a regime of multi frequency lasing with a special pre-assigned spectral distribution or spectral coding [5].

4. Radiationally pertubed doped crystals

By combining the advantages of the well-developed fluoride crystals with the ability of fluoride crystals' dopants to change their electronic state under subsequent ionizing treatment, a new promising active media can be designed. It is demonstrated on the example of the Sc^{2+} ions in CaF_2 crystals ($3d^1$ configuration). Scandium enters CaF_2 host as a Sc^{3+} ion which substitutes for the divalent cation (e.g. Ca^{2+}). The excess positive charge is compensated by a defect or impurity. Our EPR studies have shown that the additional treatment of $1\%ScF_3:CaF_2$ crystals by γ-irradiation results in $Sc^{3+} \Rightarrow Sc^{2+}$ conversion with efficiency of about 0.1%. An identification of absorption bands was performed in Ref. [6]. The 310 nm absorption band (V_k center absorption [7]) masks another weaker band centered at 280 nm (Sc^{2+} absorption) that gives rise to the observed luminescence. The major absorption band responsible for the 380 nm luminescence is at about 190 nm and is due to F center pertubed by scandium [8].

A broad emission band at 380 nm in γ-irradiated $Sc:CaF_2$ crystals was observed and attributed to Sc^{2+} ions [6]. The actual band width was about 100 nm (FWHM). The luminescence decay time of this band at 380 nm was equal to 17 μs at 300 K.

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