Summary of doctoral dissertation of mgr. M. Chaika

Investigation of the laser-stimulated white emission phenomenon in $Y_3Al_5O_{12}$ materials doped with chromium and rare earth ions

In the recent decades, much attention was paid to anti-Stokes photoluminescence phenomenon known as Laser Induced White Emission (LIWE) under focused near-infrared laser excitation. LIWE has been studied in various optical materials doped with rare-earth and transition metal ions, etc. The number of scientific publications relating to LIWE since its discovery in 2010 is growing steadily.

The objective of the PhD thesis is the mechanism responsible for the generation of laser induced white emission for development of highly efficient sun-like sources of artificial lighting. For this purpose, two groups of materials were studied: Yb:YAG nanopowders and Cr^{3+},Cr^{4+}-doped YAG transparent ceramics. The photophysical properties of LIWE including optical spectra, temperature evolution and kinetics of the phenomenon are investigated for Cr/Yb-doped YAG materials. We have found that Cr/Yb-doped YAG materials is able to generate bright LIWE at excitation power above a certain threshold. LIWE covers whole visible and near infrared region. LIWE process in Yb:YAG materials is accompanied by appearance of Yb^{2+} ions. The temperature dependence of the LIWE intensity in Cr:YAG transparent ceramic has been investigated. Temporal evolution of LIWE in Cr:YAG ceramics exhibits an increase in intensity up to the critical point, with a further decrease above it. The reason for this behavior is the increase in the host temperature over time. It was found that LIWE can occur at relatively low temperatures below ~50 °C. Intense LIWE was detected at a sample temperature of ~50 °C with the maximum emission intensity at ~300 °C. A further increase in the temperature leads to decrease in the LIWE emission intensity. It was shown that LIWE occurs on the surface of the Cr:YAG transparent ceramics and does not penetrate inside the volume. White light emission occurs at the input and the output points of the laser beam with no emission in the bulk of the sample.

The most important result of this thesis is related to the surface nature of LIWE, which does not occur in the volume of the sample and proposing a model of this phenomenon. In our case LIWE occurs through ejection an electron originating form a mixed valence pair with subsequent recombination, accompanied by photon emission. It was suggested that multiphoton ionization process is involved in LIWE, as ionization can occur only outside the sample. Moreover, the applicability of this model is based also on the similarities in LIWE and multiphoton ionization phenomena, as the saturation, threshold, and exponential power dependence are common for both cases. Ionization occurs when electrons receive enough energy to remove an electron to vacuum. Most of their trajectories return to the surface and can lead to radiative recombination back to the valence band, thus creating the photon λ_{em} plus the kinetic energy of electron.

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