Upconversion luminescence in Er-doped tellurite-phosphate glass during crystallization with femtosecond laser pulses

Wojciech Talik[1,2*], Magdalena Leśniak[3], Dominik Dorosz[3], Witold Zawadzki[1] and Krzysztof Dzierżęga[1]

[1] Marian Smoluchowski Institute of Physics, Jagiellonian University in Cracow, ul. Łojasiewicza 11, 30-348 Kraków, Poland
[2] Doctoral School of Exact and Natural Sciences, Jagiellonian University in Cracow, ul. Łojasiewicza 11, 30-348 Kraków, Poland
[3] AGH University of Science and Technology, al. A. Mickiewicza 30, 30-059 Kraków, Poland
*Corresponding author email: wojciech.talik@doctoral.uj.edu.pl

Crystallization through femtosecond direct laser writing (DLW) is a promising technique for inducing oriented nanocrystals and nanostructures in glass materials, including those with photoluminescent properties. Glasses doped with rare earth ions such as Er3+, Eu3+, or Yb3+ exhibit efficient luminescence, including upconversion luminescence (UCL). Furthermore, their spectra are highly sensitive to the ion host, making them valuable for monitoring the effects of the DLW process. While research in this field has been ongoing for several years, the UCL properties related to the irradiation of such luminescent materials with laser pulses are not yet fully understood.

In this study, we investigate the UCL properties of Er-doped TeO_2-P_2O_5-BaF_2-ZnF_2-Na_2O (TeP) glass during its crystallization induced by irradiation with 230 fs laser pulses at a wavelength of 1030 nm, with varying repetition rates and energies. A femtosecond laser beam was focused within the glass at a depth of 50 µm in air, using an achromatic lens (NA=0.25), resulting in a spot diameter of 3.9 µm ($1/e^2$). The induced crystalline phase was confirmed each time by Raman spectra and scanning electron microscopy (SEM) and is attributed to barium fluoride (BaF2) crystals.

The recorded UCL spectra consist of several broad luminescence bands at 525 nm, 550 nm, and 660 nm, excited by two-photon processes corresponding to electronic transitions between Stark manifolds of the excited lower-lying Er3+ energy levels. These spectra exhibit significant variations depending on the laser parameters and exposure time. The intensity of these bands carries information about the concentration of Erbium ions, thus providing insights into the final outcome of the DLW process.

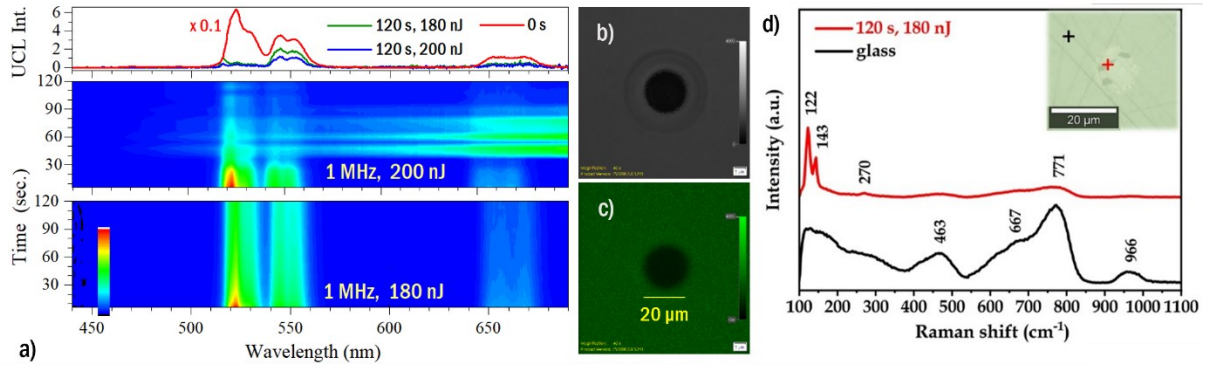

Figure1: Evolution of UCL spectra during DLW in TeP glass with 230 fs laser pulses (a). Widefield (b) and fluorescence (c) microscopic images of irradiated areas of glass sample. (d) Raman spectra of un- (black) and irradiated (red) TeP glass. The inset reveals a photo of polished TeP glass.

Acknowledgements: The research activity was granted by the National Science Centre, Poland No. 2020/39/D/ST5/02287, as well as in part by the "Excellence Initiative—Research University" for the AGH University of Science and Technology grant no. 501.696.7996 D2 L34 ID 4844.