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The influence of Nb_2O_5 in the linear and nonlinear properties of fluorophosphates glasses

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In nonlinear optics, glasses play an important role in applications, such as telecommunication and integrated optics [1]. The fluorophosphate glasses have stood out, within this group, presenting excellent properties of both phosphate and fluorites, such as chemical stability, lower hygroscopicity, and high transmittance between UV and infrared [2]. Modifiers, such as $\mathbf{Nb_2O_5}$, proved an interesting way to enhance some desirable characteristics in glasses, including improvements in both linear and nonlinear optical properties [3]. Adding higher concentrations of $\mathbf{Nb_2O_5}$ can also promote higher polarizability, attributed to forming non-bridging oxygens (NBOs), crucial in enhancing nonlinear responses. This work studies the linear and nonlinear optical response of fluorophosphate glasses with different concentrations of $\mathbf{Nb_2O_5}$, presenting higher n_2 than conventional glass systems, such as silicate, pyrophosphate, or borogermanate glasses [4,5], with the potential for even greater optical applications.

FPNMgy glasses with nominal composition (80-y) %$NaPO_3$ - 20%MgF_2 - y%Nb_2O_5 (y =0.05-0.2 mol%) were investigated. Density was measured using the Archimedes method with Shimadzu AUY 220 balance. Structural features were examined by a confocal Raman microscope. The nonlinear refractive index (n_2) in the visible-NIR range was determined via Nonlinear Elliptic Rotation (NER) method [6], employing a femtosecond laser system.

The UV-Vis spectra (Figure 1a) show a broad transparency window between 500 and 800 nm for all samples, which is important for nonlinear optical applications. As the niobium oxide concentration increases, the band gap decreases, causing a redshift in the absorption edge compared to FPNMg5%. This shift arises from structural changes in the glass network, notably increased NBO, which modify the electronic structure and lower the band gap. The Raman spectra (Figure 1b) confirm these findings, showing increased intensity near 910 cm^{-1}, attributed to Nb-O bonds in the NbO_6 octahedra, as the $\mathbf{Nb_2O_5}$ concentration increases from 5 mol% to 20 mol%. These structural modifications boost the network polarizability and enhance the nonlinear optical response, highlighting the critical role of $\mathbf{Nb_2O_5}$.

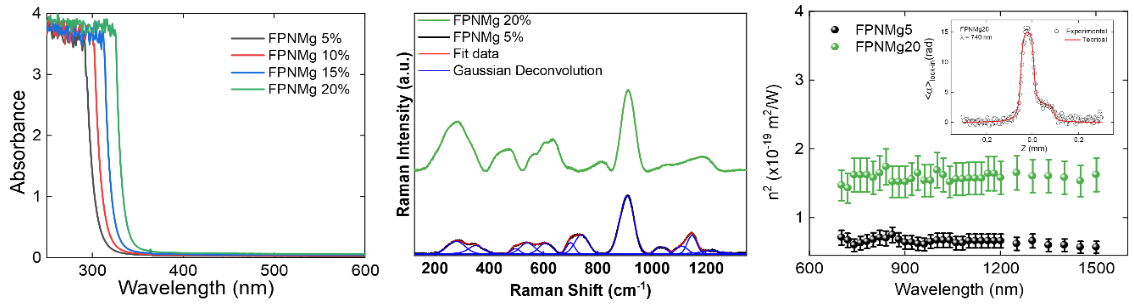

Fig. 1 (a) UV-Vis spectra from 200-800 nm for all glasses, (b) The Raman spectra of FPNMg5% and FPNMg20%, (c) Nonlinear refractive index dispersion of FPNMg5% and FPNMg20% from 700 to 1500 nm, and experimental result of the NER measurement.

The nonlinear refractive index (n_2) of the bismuth phosphate glasses, shown in Figure 1c, reveals consistent values across the measured wavelength range (700-1500 nm), with negligible dispersion within experimental error. The sample with 5% of Nb_2O_5 exhibits a n_2 approximately 0.6 x 10^{-19} m^2/W, about twice the value of fused silica. Increasing the Nb_2O_5 concentration enhances n_2, reaching 1.6 x 10^{-19} m^2/W in FPNMg20%, five times higher than silica. This increase is attributed to the higher Nb_2O_5 content, which promotes the formation of NBOs and enhances the network polarizability.

In conclusion, their high n_2, stability, and broad transparency make these glasses excellent candidates for various photonic technologies, including ultrafast optical switching and other nonlinear applications.

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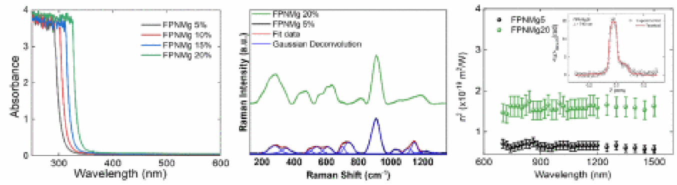

Fig. 1

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