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First demonstration of *Type A* femtosecond-written Volume Bragg Gratings using a Gaussian-Bessel laser beam

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In the past decades, Volume Bragg gratings (VBGs) have been extensively used in many applications. So far, they have been commonly inscribed in photo-thermo-refractive glasses using UV light [1]. Moreover, femtosecond (fs) direct laser writing (DLW) has been employed to obtain VBGs in other materials supported mainly by type-1 refractive-index modifications (Δn) [2]. Thanks to this approach, there is therefore an ever-growing interest for writing VBGs in new types of glasses capable of generating stronger refractive-index modifications like silver-containing phosphate glasses. These glasses have a distinct modification type referred to as *Type A* (*A* for Argentum), related to the spatial distribution of the generated silver clusters around the interaction voxel showing two positive Δn peaks for every laser pass [3,4], allowing to reach Δn values of up to 2×10^{-2} [5].

An ytterbium laser (Yuja, Amplitude system) emitting pulses of 417 fs and at a repetition rate of 1 MHz was used to realize the fs-DLW of VBGs. The sample is a commercial silver-containing zinc-phosphate glass (AG01®, Argolight) with a measured composition of $39.0\text{P}_2\text{O}_5\text{-}53.8\text{ZnO}\text{-}5.8\text{Ag}_2\text{O}\text{-}1\text{Al}_2\text{O}_3$ (nominal cationic composition in mol%). To accelerate the recording time, a Gaussian-Bessel laser beam is used to produce a greater modification length. Lines of 200 μm in length were inscribed along the *y*-axis for a series of writing velocities (20 $\mu\text{m}/\text{s}$ – 60 $\mu\text{m}/\text{s}$ – 80 $\mu\text{m}/\text{s}$) and writing irradiances (5.05 TW/cm^2 – 5.35 TW/cm^2). Figure 1(a) shows the side view fluorescence image (along the *z*-axis) of the axial modification tracks produced by the Gaussian-Bessel beam of one single inscribed line (DLW parameters: 20 $\mu\text{m}/\text{s}$ - 5.30 TW/cm^2) representing the traces of fluorescence composed of silver clusters. The associated axial length of fluorescence tracks appeared to be up to 300 μm . VBGs were produced with their top position located at 160 μm below the surface for the same laser parameters of the inscribed lines. Diffraction efficiencies up to $\sim 95\%$ at 632.8 nm are reached for single-plane gratings with a period of 2 μm and a 150 μm effective thickness, which thus indicates a strong refractive index modulation Δn_{AC} of 1.78×10^{-3} (Fig. 1(b)). In addition, experimental measurements showed the presence of second-order diffraction exhibiting a significant diffraction efficiency of $\sim 65\%$, resulting in a modulated effective thickness of 165 μm and a slightly lower refractive index modulation $\Delta n_{\text{AC}} = 1.12 \times 10^{-3}$. The spectral characteristics also exhibited good agreement with the numerical simulation. Moreover, the VBG's diffraction efficiency is analyzed at 1.55 μm showing a high refractive index modulation of 1.37×10^{-3} .

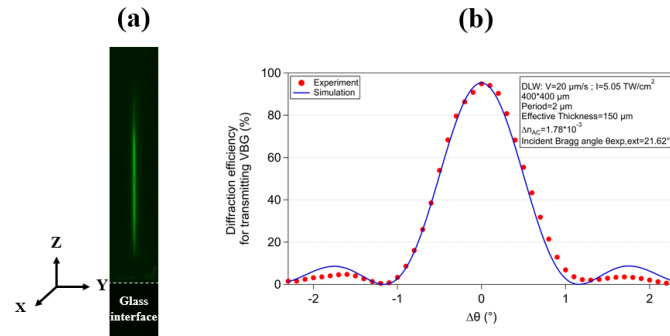


Fig. 1. (a) Side view fluorescence image (excitation at 365nm) of modifications induced with the Gaussian-Bessel beam (DLW parameters: 20 $\mu\text{m}/\text{s}$; 5.05 TW/cm^2) (b) Experimental and simulated dependence of the first order diffraction efficiency of the deviation from the Bragg angle of the transmitting Bragg grating for $\lambda=632.8$ nm

In summary, we have demonstrated for the first time to our knowledge the femtosecond writing of *Type-A* VBG using Gaussian-Bessel laser pulses in silver-containing phosphate glasses, resulting in a refractive-index modification zone induced by the creation of silver clusters. It reached a first-order diffraction efficiency of $\sim 95\%$ in transmission at 632.8 nm. Meanwhile, a high refractive-index modulation was also observed at a wavelength of 1.55 μm . Thus, this work opens the avenue for highly effective femtosecond-written VBGs suitable for industrial applications.

[1] L.A.Siiman *et al.*; Optics Letters **34**,17 (2009).

[2] C.Voigtländer *et al.*; Applied Physics A,**102** (2010).

[3] Y.Petit *et al.*, Advanced Optical Technologies,**7**,5 (2018).

[4] A.Abou Khalil *et al.*, Scientific reports,**7**,1 (2017).

[5] L.Loï *et al.*, Optical Materials Express,**12**, 6 (2022).

Abstract 35 words:

To our knowledge, we report the first *Type-A* Volume Bragg grating inscribed in silver-containing phosphate glasses using Gaussian-Bessel beam. Diffraction efficiency of 95% at 632.8 nm was achieved indicating a strong refractive-index modulation of 1.78×10^{-3} .