Form Birefringence in UV-exposed photosensitive fibers computed using a higher order finite element methode

N. Belhadj, S. LaRochelle and K. Dossou

Canadian Institute for Photonic Innovations (CIPI)
Centre d'optique, photonique et laser (COPL), Université Laval

Abstract: *The effective index change and form birefringence are calculated in UV-exposed fibers using a high-order vectorial finite element method. The birefringence is compared in optical fibers with and without photosensitive inner cladding.*

Introduction:

- Writing of photo-induced gratings is usually performed by side exposure of germanosilicate fibers to UV-laser radiation. Due to the strong absorption of the UV-light across the photosensitive core, the index change occurs in an asymmetric way [1] which results in a form birefringence.
- The form birefringence has been calculated using different numerical methods [2,3], vectorial and scalar numerical methods were compared [4]. All calculations were performed considering standard single-mode fiber.
- We consider three fiber types: step-index fiber (SF), cladding-mode-suppression fiber (CMSF) [5] and photosensitive cladding only fiber (PCOF) [6].
- A full vectorial formulation with high order interpolation polynomials of the vectorial finite element method (VFEM) is used. The impact of the presence of photosensitive cladding on the form birefringence was numerically examined.

The UV-induced refractive index profile:

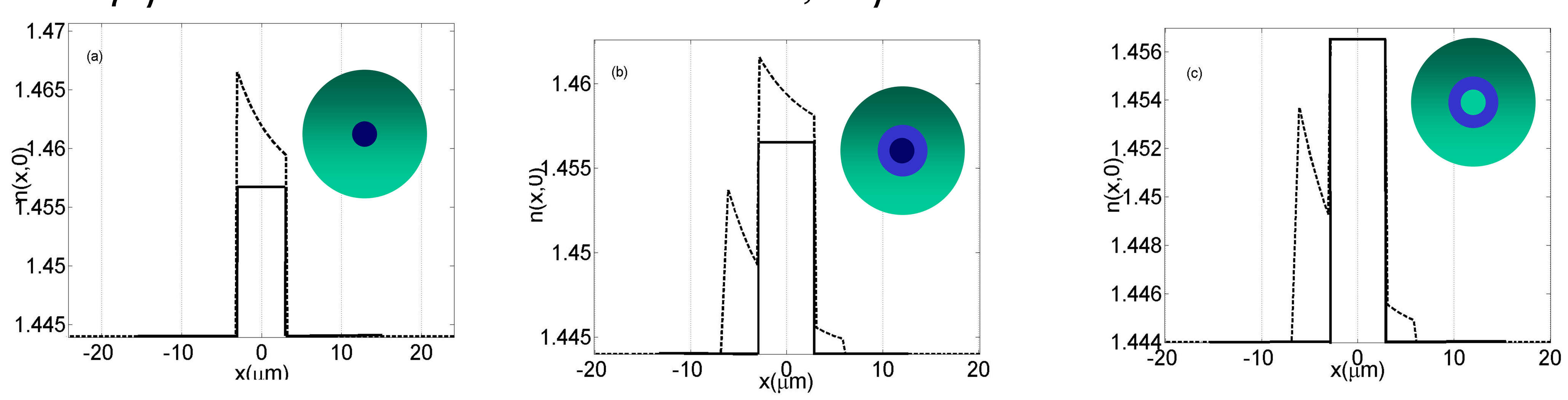
The UV-induced refractive index change is assumed to have an exponential decay across the fiber core [2,3] :

$$\begin{cases} \delta n(x,y) = \delta n_p \exp\left[-2\alpha\left(x+\sqrt{\eta^2-y^2}\right)\right] & \text{for } \theta \le r \le \eta \\ \delta n(x,y) = 0 & \text{elsewhere} \end{cases}$$

When : δn_p : the peak refractive index change on the exposed side.

2α : the asymmetry coefficient.

The limits of the photosensitive region are: $\eta=\sigma$ for CMSF and PCOF and, $\eta=\rho$ for SF. for CMSF and SF $\theta=0$ and, $\theta=\rho$ for PCOF.



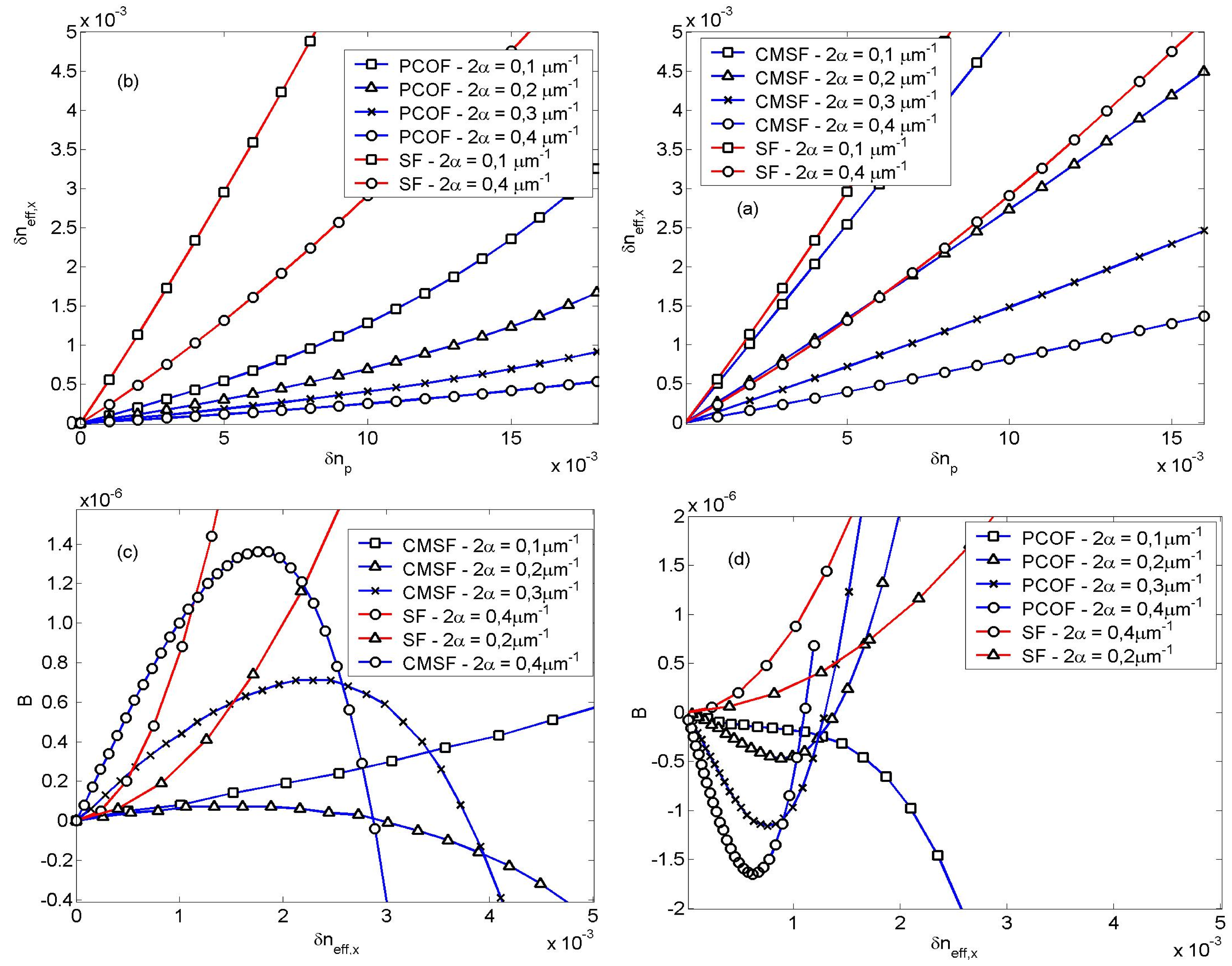
The transverse refractive index profile for (a) ST, (b) CMSF and (c) PCOF

Fiber Parameters : Core radius : ρ =3,05 µm, photosensitive-cladding radius: σ = 6,25 µm, free space wavelength : λ = 1550 nm, core index : n_{co} = 1,4565 and cladding index n_{cl} =1,444.

The effective index in a non-illuminated fiber computed by VFEM and HO-VFEM and compared to the analytical result :

	n_{eff}	*erreur*
Analytic	1.450469714	0
VFEM	1.450463617	0.6×10^{-5}
HO-VFEM	1.450469727	0.13×10^{-7}

Results:



The effective index change (a-b) and the form birefringence (B= $n_{eff,x}$-$n_{eff,y}$) (c-d) as a function of the peak refractive index change for CMSF and SF (a-c) and PCOF and SF (b-d) .

Comments :

- δn_{eff} varies almost linearly with δn_p, with weak quadratic contribution.
- A higher δn_p is required in the CMSF and PCOF to reach the same $\delta n_{eff,x}$ than in the SF. (In CMSF and PCOF the δn_p first occurs in the photosensitive cladding where the overlap with the guided mode is smaller.)
- In CMSF and in PCOF, the birefringence has a quasi-quadratic form for small asymmetry coefficients and a parabolic shape for higher values.
- In CMSF and PCOF cases, form birefringence reaches an extremum. Then, *B* decreases quickly and goes through zero when the mode polarized along the y-axis becomes associated to the slow axis and the mode polarized along the x-axis becomes associated to the fast axis. This cross-over occurs when the refractive index in the cladding reaches a value close to that of the core, a situation not likely to occur in experiments because of the saturation of the photosensitive response.
- For more usual values of effective index change, $\delta n_{eff}<1.\times10^{-3}$, the form birefringence can be significantly higher in the PCOF than in other fiber types.
- Further information about photo-induced birefringence could be obtained by developing a more complete physical model of the refractive index change that would consider saturation and anisotropy. Both these effects could be taken into account in the calculations performed using the high-order VFEM.

References :

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